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Respectfully,

Alexandru TĂBUȘCĂ, PhD

JISOM Editor-in-Chief

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INTELLIGENCE CYCLE IN THE FIGHT AGAINST TERRORISM WITH USAGE OF OSINT DATA

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Abstract

Today, intelligence work is unequivocally connected with national security and political stability. Therefore, governments and political leaders rely heavily on the work of intelligence services. The main task of these services is to collect information and data that are important for conducting the country's policy and undertaking various actions in war and peace in order to achieve political and state goals. Terrorism is the greatest threat to the security of the 21st century, but also a challenge in the economic, moral and cultural sense. Although the world has set itself the task of unconditionally dealing with terrorism, it has been shown that the set goal is not so easily achieved. There is no dispute about is that terrorism is a global problem and as such requires international cooperation and exchange of information. Information is a key resource that can help make the fight against terrorism easier. When it comes to information in the security sense, it is clear that intelligence work with the advancement of modern technologies has become extremely important for countering terrorism. For these purposes, there are several databases that record data related to terrorist attacks and terrorist organizations themselves. Publicly available, so-called OSINT data that can be used in the analysis of terrorism are also important. Considering that, the focus of this paper will be the intelligence cycle with reference to modern databases and modern technologies that can be significant in the fight against terrorism, such as the TANGELS platform.

Keywords: Terrorism, intelligence cycle, information, threat, database, OSINT, TANGELS.

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1. Introduction

Ever since there have been relations between states, there has been intelligence work in some form. Hiding one's own confidential data and finding out someone else's - has always

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been an imperative of security prevention, but also of proactive action. Today, intelligence work is unequivocally linked to national security and political stability. Therefore, governments and the political leadership of countries rely heavily on the work of intelligence services. The main task of these services is the collection of information and data that are important for the conduct of the country's policy and undertaking various actions in war and peace in order to achieve political and state goals.

Intelligence activity, as one of the three key channels of information and an essential element of the national power of every modern state and its security system, in the most general sense implies purposeful, timely, planned, secret and organized collection and processing of intelligence information, which through the process of analysis, processing and integration turn into final intelligence knowledge about a given problem, phenomenon or event and, in the form of final intelligence documents, give it to end users.[3]

Therefore, everything that can be significant for the security of a country can also be the subject of interest of intelligence or security services. Thus, in the conditions of globalization, which has led to the expansion of the sphere of security both horizontally and vertically, the spectrum of intelligence work is also expanding. In modern conditions, there is a lot of data that is publicly available, and which may also have intelligence significance, the so-called OSINT data.

Terrorism is the greatest security threat of the 21st century, but at the same time a challenge in the economic, moral and cultural sense.[4] It is a complex phenomenon that has many forms and is characterized by dynamism and variability. Due to its actuality, terrorism has actually become the focus of interest of many intelligence services, and in this sense, it is assumed that in the fight against terrorism, the established intelligence cycle can be applied with certain specifics.

Given that terrorism is an extremely secret activity that relies on the surprise factor, there is no doubt about the importance of intelligence work in order to prevent it. In this sense, modern publicly available databases and OSINT data can also be used in the fight against terrorism.

2. Intelligence work

In theory, one often comes across views that intelligence activity is as old as human history. Those authors who want to determine more closely the beginnings of intelligence usually link it to the emergence of states and interstate relations. The attachment to the state as a creation that dictates and makes the most use of intelligence extends to modern states that

[3]Bajagić, M. Criminal Intelligence Activities, Review of Criminology and Criminal Law, Institute for Criminological and Sociological Research, 3/210:193-212 (2010), p. 194.
[4]Andrić, J., Kovač, M. Contemporary terrorism as a threat to security, Bezbednost, MUP (2/2021:107-118)(2021). P.110.

strive to obtain information about the secret plans, intentions and activities of other states, while at the same time hiding their own information. Intelligence services and the analytical sector play a significant role in that process. Thus, Stajić states that "the intelligence service creates the conditions for the country's leadership (political, military, etc.) to direct its activity only towards reliable, credible and accurate data."[5]

2.1. Theoretical definition of intelligence activity

As Joseph Nye states: power is the ability to accomplish our purpose or reach our goals. More precisely, it is the ability to influence others and achieve desired results. There are many factors that affect our ability to get what we want, and they vary depending on the context of the relationship.[6]In terms of these allegations, if one party has more information about the other party, it will be easier to induce it to do what the first party wants. In this way, intelligence activity can really be linked to the concept of power. Given that intelligence activity is an often-researched area in the theory of international relations, it is understood as a building block of the state's national power, but also as a means of directing the use of that power in the form of offensive force, or understanding one's environment and capabilities, and how to apply force or power and against whom. Therefore, intelligence activity must be understood as an indispensable category in the study of contemporary international reality, especially in the context of the new security environment of the XXI century.[7]

Although there is no generally accepted definition of intelligence activity, it can be said that in the most general sense it implies the purposeful, timely, planned, secret and organized collection and processing of intelligence information which, through the process of analysis, processing and integration, is transformed into final intelligence knowledge about a given problem, phenomenon or occur and, in the form of final intelligence documents, are given to end users.[8]

The above shows the importance of operability and practice when talking about intelligence activities, and therefore it is difficult to theoretically determine this term without a close connection with practical application. We can say that the theoretical framework of intelligence activity is based on practice. That is, based on the experiences of the intelligence services of modern countries. Different approaches in practice are, among others, one of the reasons why there is no generally accepted definition of this term.

[5]Stajić, Lj. Basics of the security system, Faculty of Law Novi Sad. (2008). P.224.
[6]Joseph S. Nye Soft power: the evolution of a concept, Journal of Political Power, DOI: 10.1080/2158379X.2021.1879572. (2021). p.2.
[7]Bajagić, M. Criminal Intelligence Activities, Review of Criminology and Criminal Law, Institute for Criminological and Sociological Research, 3/210:193-212. (2010). p.194.
[8]Bajagić, M. Criminal Intelligence Activities, Review of Criminology and Criminal Law, Institute for Criminological and Sociological Research, 3/210:193-212. (2010). p.195.

In the theoretical sense, intelligence activity means "discovering and successfully and fully presenting the real truth, that is, "noticing reality in its beginning". In the operational sense, intelligence activity serves to understand other entities or exert influence on them. The purpose of intelligence activity is primarily to inform the political leadership, but also to support the work of the army and the police and to contribute to the success of their operations. It is realized through several stages, and the ultimate goal is an intelligence product.

The theoretical framework of intelligence activity can be understood as multidisciplinary considering that it relies heavily on theoretical knowledge related to politics, international relations and security. The relationship between power and intelligence work has a special place in the theoretical framework of intelligence activity. In the modern context of technological and informational progress, the development of which has also created new types of warfare (cyber warfare), the relationship between intelligence, information and power is gaining importance.

2.2 Intelligence cycle

The intelligence cycle represents a type of model by which intelligence requirements are managed and the process of collecting and processing data and delivering the intelligence product to end users. The intelligence cycle consists of several dynamic phases and has a cyclical character because intelligence work requires continuity and permanent up-to-date activities. Therefore, the intelligence cycle is a process that is constantly repeated in the work of intelligence subjects.

The intelligence cycle consists of several phases that are separate but often overlap in practice. Different classifications of the stages of the intelligence cycle can be found in various documents, so five, six or more stages are mentioned somewhere. However, most authors agree that there are four key stages of the intelligence cycle: 1) Issuing tasks (orders), 2) Data collection, 3) Intelligence production - analytics, and 4) Delivering intelligence to users.[9]

[9]Forca, B., Anočić, B.Security Analytics, Union University "Nikola Tesla" - Faculty of Business Studies and Law.(2018).p.143.

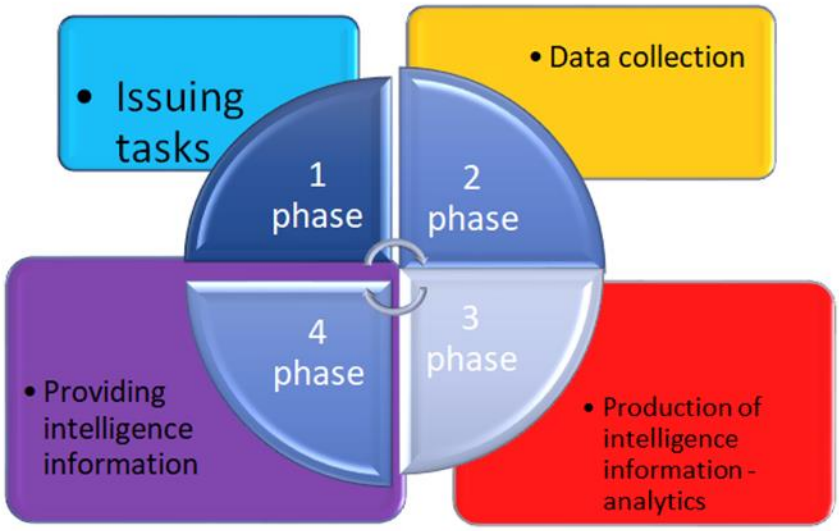


Figure 1.Graphic representation of the intelligence cycle

Finally, the so-called "feedback" should be mentioned. It is a notification from our superior, be he a political leader, a military commander, or a director of a manufacturing or financial corporation, about the impact of our information on a decision he has made or will make. The knowledge that our information was useful (in the broadest sense of the term) or that, on the other hand, we "completely missed the point", is very important for our further work and direction, both in terms of collection and capacity for the production of intelligence products, states Forca[10].

3. Key aspects of the intelligence cycle in the fight against terrorism

Intelligence work is one of the pillars of national security. Covering a wide range of security challenges, risks and threats and responding to the demands of superiors, intelligence services play a major role in guiding the decisions of political, military and security leadership. One of the key threats to the national security of many countries as a form of political violence is terrorism. The fight against terrorism can be fought on two fronts, the first is preventive action, and the second is post-active. Both ways of dealing with terrorism as a threatening phenomenon are based on the possession of information.

3.1. Obstacles in confronting modern terrorism

[10]Forca, B., Anočić, B.Security Analytics, Union University "Nikola Tesla" - Faculty of Business Studies and Law.(2018).p.154.

Terrorism, as the biggest threat to security today, which has a transnational character, requires serious international cooperation in the matter of opposing it. No single country can tackle this global phenomenon alone. The characteristics of terrorism have forced both small and large states to join forces, exchange data and organize joint responses to terrorism. However, this type of cooperation is not ideal and is marked by various types of obstacles.

The first and basic obstacle is the lack of a generally accepted definition of terrorism. In order to be able to adequately fight against a phenomenon, we must first know what it is. Likewise, when it comes to terrorism, we must know how to recognize it, then determine what type of terrorism it is and what are the goals and motives of terrorists in different parts of the world. Given that there is no internationally recognized definition of terrorism, states respond differently to the question of whether a specific case is terrorism.[11]

A significant obstacle to international cooperation is legal and normative inconsistency. Laws and procedures regarding terrorism differ from country to country, which makes cooperation in this field difficult. Then non-compliance in practice. While police cooperation, official and covert, takes place through INTERPOL, it still depends on the individual will of states. Which means that the fight against terrorism can be conditioned by cooperation between two or more countries, and their interest in that fight is not the same.

The fight against terrorism requires a special exchange of data between the intelligence systems of different countries, but also the exchange of such data with international organizations and other similar actors. The problem is that intelligence agencies are not always interested in sharing such data. There are also often irregularities in the work of intelligence structures at the national level.

A characteristic of contemporary terrorism, in addition to extremist foundations, are new methods of both recruitment and combat. The battlefield is increasingly moving from the real world to the virtual world. Technologies used by terrorists are often more advanced than those used by those fighting terrorism. Thus, due to the lack of trained staff or the lack of compliance of the security system with new technologies, it is often difficult for fighters against terrorism to obtain significant information about potential terrorist attacks in a timely manner.

Timely information about potential terrorists and planned attacks is the first wall of defense, and when we talk about information, in addition to security-intelligence structures and the population, the media and various scientific research centers must be involved in this battle. The media and the Internet are the filter through which the messages that terrorists want to send to the primary and secondary victims of their activities pass.

[11]Forca, B., Anočić, B.Security Analytics, Union University "Nikola Tesla" - Faculty of Business Studies and Law.(2018).p.116.

3.2 Collection of information and data

An important stage of planning is the decision of the intelligence service which methods, that is, intelligence collection disciplines/procedures will be chosen (one or more of them), which will guarantee the successful collection of timely intelligence information with a high degree of accuracy, comprehensiveness and verification.[12]

All data collection methods, in principle, can be divided into the following categories:

• intelligence-operational work

• using technical means

• using open sources[13]

Intelligence-operational work in the field can be extremely demanding but also significant when it comes to terrorism. Given that terrorist organizations often act as intelligence services themselves. Although it does not have the attributes of institutionalization, the intelligence and security component of terrorist organizations applies similar methods to the intelligence and security services. The reasons for its existence and operation are the provision of maximum "information and action logistics" to specialized perpetrators of terrorist acts, that is, the security protection of a terrorist organization from "breaking in", cutting off terrorist activities and from arresting its members.[14]

In this sense, operational contact or infiltration into the ranks of terrorist organizations can be valuable. Terrorist organizations rely heavily on secrecy and anonymity to carry out their religious and politically driven agendas, and intelligence gathering and exploitation is best suited to stripping away this critical layer of protection, making them more vulnerable to infiltration, investigation and arrest.[15]

When it comes to the application of technical means, it should be emphasized that a large number of terrorists possess extensive and professional knowledge when it comes to communication through technical means. In addition, they have the necessary technical means and are extremely resourceful when they need to communicate, convey a message or make a money transaction. There are well-known examples where terrorists communicated with each other through draft messages via e-mail, but also that they used video games in a much more complex way than one might think they are capable of. The

[12]Bajagić, M.Methodology of intelligence work, Criminal and Police Academy.(2015).p.169.
[13]Forca, B., Anočić, B.Security Analytics, Union University "Nikola Tesla" - Faculty of Business Studies and Law.(2018).p.149.
[14]Mijalković, S. Intelligence structures of terrorist and criminal organizations, Journal of Criminalistics and Law, Criminal and Police Academy, 2/2010:101-114. (2010).p.105.
[15]Hughbank, R., Githens, D. Intelligence and Its Role in Protecting Against Terrorism. Journal of Strategic Security 3, no. 1/2010:31-38 (2010). p35.

fact that they often turn to hacking and cyberwarfare, which requires serious skill, tells us how much the terrorists have kept up with technological progress.

However, data collection using technical means is a broad field of action, especially for large and rich countries that have highly developed, sophisticated technical means, i.e. sensors that record data (satellites, drones, photo and thermal imaging cameras, eavesdropping devices, hacking the Internet traffic, etc.).[16]

Using open sources is the way for intelligence services to obtain data in most cases. This method is also applicable when it comes to terrorism. Thus, a lot can be learned about potential terrorists or terrorism suspects through social networks. Open sources can also be various religious and propaganda websites that are used for the purpose of radicalizing the population. Also, banking systems may contain suspicious transactions related to the financing of terrorism. There are also several scientific databases that systematize knowledge about terrorism. They can also be a significant resource.

EXAMPLES OF DATA COLLECTION METHODS IN THE FIGHT AGAINST TERRORISM	
Intelligence-operational work	-monitoring -direct conversation - checking and searching the terrain -infiltration into terrorist organizations
Using technical means	- eavesdropping -recording -satellite tracking -application of technologies for monitoring internet communications
By using open sources	-visiting religious websites that are used to recruit new members -the media - open scientific databases on terrorism

Table 1. Examples of data collection methods in the fight against terrorism

[16] Forca, B., Anočić, B.Security Analytics, Union University "Nikola Tesla" - Faculty of Business Studies and Law.(2018).p.150.

In practice, the methods of data collection are most often combined and the data is obtained from several sources, which is often the case when it comes to terrorism.

4. Use of OSINT data in the fight against terrorism

Publicly available information that has potential intelligence value is also called OSINT data. Information that is publicly available is that which is found in the media, on the Internet and other similar sources that are intended for the general public and that are not difficult to access. Thus, "google" today is not only one of the ways in which people get information, but it has also become indispensable in the modern context.

However, the question arises, how is this data used for intelligence purposes? The first assumption is that social networks as platforms that contain a lot of data and are used for different types of communication are the starting point. In practice, it doesn't work that simple because you can't easily find potential terrorists among millions of social media users. If we exclude the specialized software used by the police to monitor such types of communication, how can we use open data to learn something about terrorists.

One way could be open scientific databases that already contain data on terrorist attacks and that have tools to sort through such data. Another way can be specially designed platforms that deal with the processing of publicly available data, such as the TANGELS platform.

4.1 Scientific bases on terrorists

We often seek to determine the spatial distribution of terrorist attacks, their consequences, lethality, origin, and financing of terrorist organizations, whether the reactions to those attacks were adequate and most importantly to predict where, when and how the next attack might occur. The predictive function of such analyzes is the reason why they are often performed under the assumption of urgency, curtly and incompletely. Such an analysis requires a significant amount of verified data, which is not easy to obtain, and that is the reason why it is necessary to wait for such data to be collected. For this purpose, there are several databases that record data related to terrorist attacks.

One of the bases that is often used for various reports is the Global Terrorism Index of the Institute for Economics and Peace in New York. The Global Terrorism Index (GTI) is a comprehensive study analyzing the impact of terrorism for 163 countries covering 99.7 per cent of the world's population. The GTI report is produced by the Institute for Economics & Peace (IEP) using data from the Terrorism Tracker and other sources. The GTI produces a composite score so as to provide an ordinal ranking of countries on the impact of

terrorism. The GTI scores each country on a scale from 0 to 10; where 0 represents no impact from terrorism and 10 represents the highest measurable impact of terrorism."[17]

RANK	COUNTRY	SCORE	RANK CHANGE
1	Afghanistan	8.822	↔
2	Burkina Faso	8.564	↑ 2
3	Somalia	8.463	↔
4	Mali	8.412	↑ 3
5	Syria	8.161	↑ 1
6	Pakistan	8.160	↑ 3
7	Iraq	8.139	↓ 5
8	Nigeria	8.065	↓ 3
9	Myanmar (Burma)	7.977	↑ 1
10	Niger	7.616	↓ 2
11	Cameroon	7.347	↑ 1
12	Mozambique	7.330	↓ 1
13	India	7.175	↔
14	Democratic Republic of the Congo	6.872	↑ 2
15	Colombia	6.697	↓ 1
16	Egypt	6.632	↓ 1
17	Chile	6.619	↑ 1
18	Philippines	6.328	↓ 1
19	Chad	6.168	↔
20	Kenya	6.163	↔
21	Iran	5.688	↑ 5
22	Yemen	5.616	↓ 1
23	Türkiye	5.600	↔
24	Indonesia	5.502	↔
25	Israel	5.489	↑ 5
26	Thailand	5.430	↓ 4
27	Togo	4.915	↑ 49

RANK	COUNTRY	SCORE	RANK CHANGE
29	Sri Lanka	4.839	↓ 4
30	United States of America	4.799	↓ 2
31	Greece	4.793	↓ 2
32	Libya	4.730	↓ 5
33	Palestine	4.611	↓ 1
34	France	4.419	↑ 2
35	Germany	4.242	↓ 4
36	Nepal	4.134	↓ 2
37	Algeria	4.083	↑ 3
38	Tanzania	4.065	↓ 3
39	Burundi	4.051	↓ 6
40	Tunisia	3.989	↓ 1
41	Peru	3.856	↓ 3
42	United Kingdom	3.840	↓ 5
43	Bangladesh	3.827	↓ 2
44	Djibouti	3.800	↑ 52
45	Russia	3.799	↓ 1
46	New Zealand	3.776	↓ 4
47	Côte d'Ivoire	3.747	↓ 4
48	Uganda	3.599	↓ 3
49	Norway	3.514	↑ 31
50	Tajikistan	3.438	↓ 3
51	Venezuela	3.409	↓ 5
52	Lebanon	3.400	↔
53	Italy	3.290	↓ 3
54	Canada	3.275	↓ 6
55	Central African Republic	3.194	↑ 12

RANK	COUNTRY	SCORE	RANK CHANGE
56	Ethiopia	3.044	↓ 7
57	Argentina	2.875	↔
58	Slovakia	2.784	↑ 38
59	Belgium	2.763	↑ 11
60	Spain	2.712	↓ 5
61	Austria	2.677	↓ 8
62	Japan	2.398	↑ 12
63	South Arabia	2.387	↓ 9
64	Sweden	2.307	↑ 7
65	Switzerland	2.205	↓ 9
66	Ecuador	2.198	↓ 8
67	Netherlands	2.120	↓ 8
68	Jordan	2.033	↓ 8
69	Australia	1.830	↓ 8
70	Uzbekistan	1.731	↑ 26
71	Paraguay	1.605	↓ 7
72	Mexico	1.578	↓ 10
73	Ukraine	1.535	↓ 10
74	Cyprus	1.392	↓ 8
75	Malaysia	1.357	↓ 7
76	United Arab Emirates	1.241	↑ 20
77	Senegal	1.108	↓ 5
78	Eswatini	1.058	↓ 5
=79	Bahrain	0.826	↓ 14
=79	Rwanda	0.826	↓ 3
=79	South Africa	0.826	↓ 3
=79	Uruguay	0.826	↓ 4

Figure 2.GTI list (taken from GTI report for 2023)

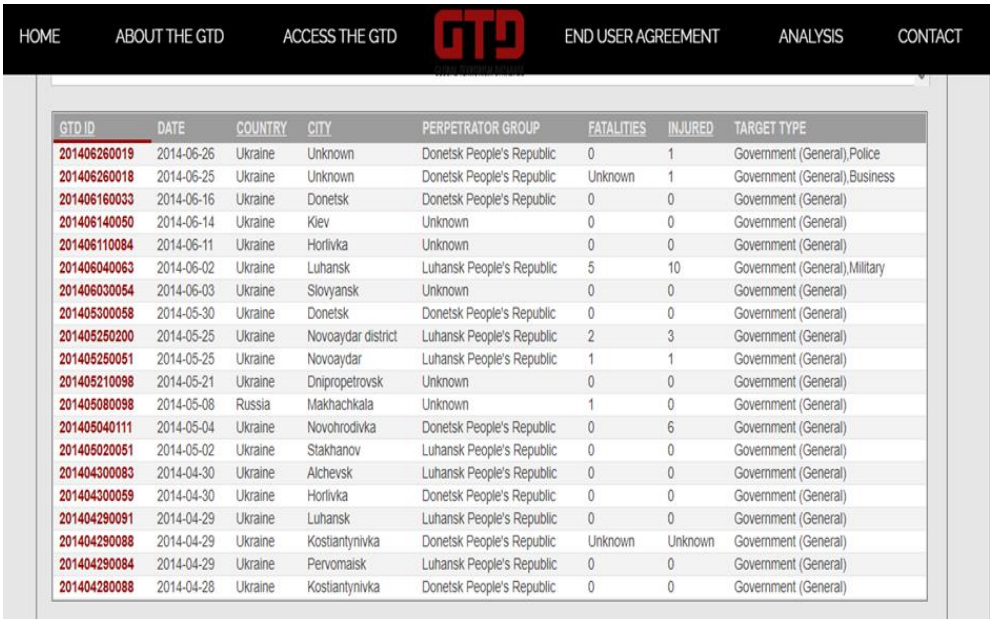
Also, on this site you can find special reports that professionally process data related to terrorism. "The GTI report is produced by the Institute for Economics & Peace (IEP) using data from TerrorismTracker and other sources. TerrorismTracker provides event records on terrorist attacks since 1 January 2007. The dataset contains almost The GTI report is produced by the Institute for Economics66,000 terrorist incidents for the period 2007 to 2022."[18]

Another important database is the database of terrorist events in Europe. This is an academic-scientific base belonging to the University of Bergen in Norway. „The Global Terrorism Database™ (GTD) is an open-source database including information on terrorist events around the world from 1970 through 2020 (with annual updates planned for the future). Unlike many other event databases, the GTD includes systematic data on domestic as well as international terrorist incidents that have occurred during this time period and now includes more than 200,000 cases."[19]

The database of terrorist activities should also be taken for analysis. The academic database belonging to the University of Maryland, College Park, is specific in that, among other things, it contains data on how and why terrorist groups are formed and covers the period

[17] https://www.visionofhumanity.org/maps/global-terrorism-index/#/-The GTI score. 25.03.2023.
[18] https://www.visionofhumanity.org/wp-content/uploads/2023/03/GTI-2023-web-270323.pdf - THE GTI report. 26.03.2023
[19] https://www.start.umd.edu/gtd/-Global Terrorism Database. 26.03.2023.

from 1970 to 2018. Searching for terrorist attacks directed against governments in the period 2013-2018. 122 terrorist attacks took place in Western Europe, most of which took place in Greece. Applying the same search criteria in this database for Eastern Europe yields data on 145 attacks, most of which took place in Ukraine.



GTD ID	DATE	COUNTRY	CITY	PERPETRATOR GROUP	FATALITIES	INJURED	TARGET TYPE
201406260019	2014-06-26	Ukraine	Unknown	Donetsk People's Republic	0	1	Government (General),Police
201406260018	2014-06-25	Ukraine	Unknown	Donetsk People's Republic	Unknown	1	Government (General),Business
201406160033	2014-06-16	Ukraine	Donetsk	Donetsk People's Republic	0	0	Government (General)
201406140050	2014-06-14	Ukraine	Kiev	Unknown	0	0	Government (General)
201406110084	2014-06-11	Ukraine	Horlivka	Unknown	0	0	Government (General)
201406040063	2014-06-02	Ukraine	Luhansk	Luhansk People's Republic	5	10	Government (General),Military
201406030054	2014-06-03	Ukraine	Slovyansk	Unknown	0	0	Government (General)
201405300058	2014-05-30	Ukraine	Donetsk	Donetsk People's Republic	0	0	Government (General)
201405250200	2014-05-25	Ukraine	Novoaydar district	Luhansk People's Republic	2	3	Government (General)
201405250051	2014-05-25	Ukraine	Novoaydar	Luhansk People's Republic	1	1	Government (General)
201405210098	2014-05-21	Ukraine	Dnipropetrovsk	Unknown	0	0	Government (General)
201405080098	2014-05-08	Russia	Makhachkala	Unknown	1	0	Government (General)
201405040111	2014-05-04	Ukraine	Novohrodivka	Donetsk People's Republic	0	6	Government (General)
201405020051	2014-05-02	Ukraine	Stakhanov	Luhansk People's Republic	0	0	Government (General)
201404300083	2014-04-30	Ukraine	Alchevsk	Luhansk People's Republic	0	0	Government (General)
201404300059	2014-04-30	Ukraine	Horlivka	Donetsk People's Republic	0	0	Government (General)
201404290091	2014-04-29	Ukraine	Luhansk	Luhansk People's Republic	0	0	Government (General)
201404290088	2014-04-29	Ukraine	Kostiantynivka	Donetsk People's Republic	Unknown	Unknown	Government (General)
201404290084	2014-04-29	Ukraine	Pervomaisk	Luhansk People's Republic	0	0	Government (General)
201404280088	2014-04-28	Ukraine	Kostiantynivka	Donetsk People's Republic	0	0	Government (General)

Figure 3. Global terrorism database search for terrorist attacks against governments in Eastern Europe for the period 2013-2018. Source: https://www.start.umd.edu/gtd/

World databases of criminal information are a pillar of the fight against international terrorism. INTERPOL is a multi-use platform for such databases, as it contains databases of names, and special databases on international fugitives and suspected terrorists. Then data on fingerprints, weapons, stolen or missing travel documents and many others, all databases are constantly available through Interpol's secure global communication system. Finally, it should be noted that Serbia also participated in the creation of a similar base. It is the TOK database[20] whose purpose is to search for terrorists and terrorist organizations.

4.2 Web Investigation Platform

A characteristic of contemporary terrorism, in addition to extremist foundations, is that it is also characterized by new methods of both recruitment and combat. The battlefield is increasingly moving from the real world to the virtual world. Technologies used by

[20]http://www.tocsearch.com- TOC database. 30.03.2023.

terrorists are often more advanced than those used by those fighting terrorism. The asymmetry of terrorism as a threat is also complicated by the increasing inclusion of women, minors and children as fighters. The methods of recruitment and radicalization are both complex and follow modern aspects of life, so young people are increasingly recruited through social networks and the use of the Internet.

Considering that there is a lot of data that is on the Internet and that is publicly available in the modern context, it is not easy to sort, correlate and finally use such data in order to obtain intelligence. Especially the data that can be linked to terrorism. That is why there are special platforms or software solutions that process such data for us.

For example, extremism and hate speech are something that is easily spread via the Internet, which can consequently lead to terrorist acts. Thus, through social networks, religious websites and even through the official media, such ideas can be marketed and attract and radicalize new people. However, in order to group such data and put it in a common context, we need web investigation platforms. Such platforms allow us to monitor, for example, how often the word "terrorism" is mentioned on social networks. What is important to point out is that such platforms can only track those posts on social networks that are public. So, if someone has made his post available only to those he is connected to on social networks, he will not be included in that statistic. Also, such platforms can monitor how much that word is mentioned in a certain geographical area or in a certain period of time.

One such platform is TANGELS[21]. „ The leading AI-powered, user-friendly search engine for deep, automated web investigations. Extract critical, intelligent insights with ease and efficiency from social media, surface & deep web data sources. Gain unmatched situational awareness with real-time intelligent insights generated via online content monitoring. Cobwebs' platform assists analysts in identifying new threats, while uncovering potential profiles and groups across the web using automated, advanced search capabilities. Users gain deep insights and substantial intelligence, including locations, context, internal relations, group structures, hierarchies, and more."[22]

[21]Access to Tangles has been given to the Research Centre for Defence and Security by AGENFOR INTERNATIONAL for research purposes. Reports using OSINT can be found at their website https://www.agenformedia.com/publication/antisemitism-in-italy/

[22]https://www.g2.com/products/tangles-web-investigation-platform/reviews–review of tangels platform. 26.03.2023.

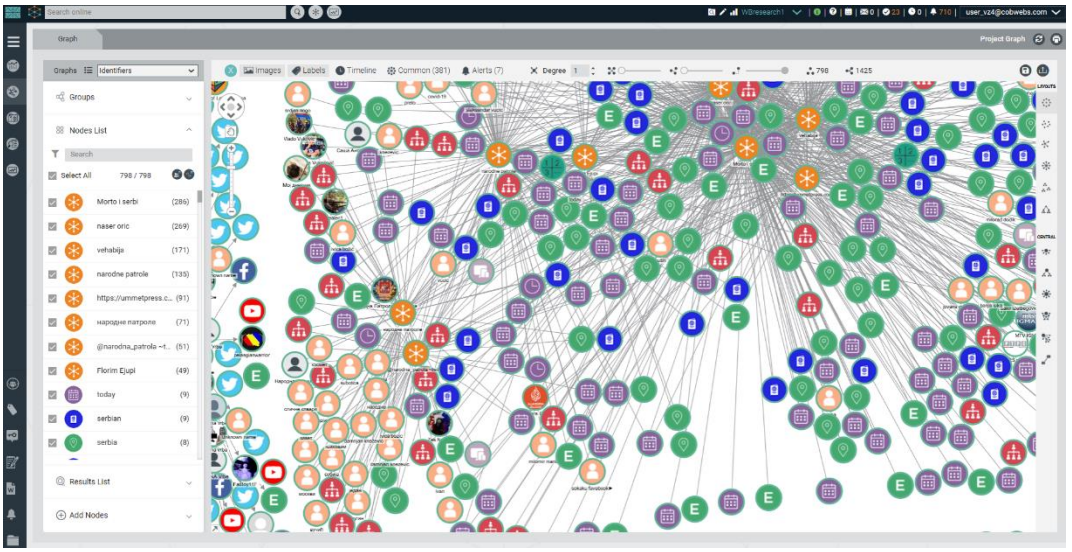


Figure 4. Tangels screenshot

Tangles is a powerful OSINT tool that uses Big Data technologies that are collecting open-source data in both surface web and deep web, while having ability to analyze and monitor specific data in the ocean of information. It can search, analyze, monitor, and even track geodetic with Web Location. When searching for a term that can be put in a dictionary for example “Kill” or a specific person “Petar Peric” it will give a broad search and analyst that is using this platform will need to pursue its aim by analyzing search results. The second step would be to find either target persons, term, organization, or other info that would then be sent to advanced analysis which will thoroughly search for those specific results. Monitoring options gives you the ability to track specific targets in a specific region in a specific timeframe, which will immediately give you results on the terms you want to follow on up. Analysis results are built in minor reports that contain everything in open-source data that can be found and ready to analyze. While the analyst/operator is searching and filling dictionaries, monitors, target persons etc. Tangles create network charts (seen in picture above), that makes it easier to, “connect the dots” and find a specific target. This solution is also not limited to a surface net, it can also go deep inside servers underneath and find any open data, on the deep web forums, communication platforms using specific software for data gathering.

This makes Tangles very convenient to find sources of extremism, intelligence activity, crime, and similar security threats as it can easily find the patterns, trace of GPSs, hate speech focal points etc. This powerful tool is also in line with law, and data protection laws in Europe and wider.

Therefore, such platforms can be an excellent tool for exploiting all the potential of publicly available data. They can find their application in the scientific community but also in

operational intelligence work that can improve the prevention of terrorist threats. For example, with the help of these platforms, it is possible to observe increased activities of certain extremist organizations in a certain space and time, which can be an indication that a terrorist attack is being prepared in a certain area. This may be of particular importance to those engaged in operational counter-terrorism.

5. Conclusion

Terrorism as a dynamic and complex phenomenon, and at the same time unevenly defined, requires extraordinary efforts from all those who participate in its suppression. Although the world has given itself the task of dealing with terrorism without reserve, it has turned out that the set goal is not so easily achievable. Many obstacles stand in his way, from the lack of a generally accepted definition to different legislation and double standards in international relations. However, what is not disputed is that terrorism is a global problem and as such requires international cooperation and information exchange.

It is information that is a key resource that can contribute to making the fight against terrorism easier. When we talk about information in terms of security, it is clear that intelligence work is extremely important for countering terrorism. Intelligence work has existed for a long time throughout history, but it seems that with the emergence of complex challenges, risks and threats today, which includes terrorism in particular, it is gaining more and more importance.

In intelligence work, the central concept is the intelligence cycle as a process that is repeated continuously in order to protect national security. Depending on the author, the intelligence cycle has more or less phases, but by looking at the literature from this domain, four phases can be distinguished: 1) Issuing tasks (orders), 2) Data collection, 3) Production of intelligence information - analytics, and 4) Delivery of intelligence information to users.

When we look at these stages, we can conclude that terrorism as a threat to national security can be treated through the same process. The intelligence cycle in countering terrorism is not only applicable but also extremely important. Where there is room for further progress is the additional development of analytical methods specialized for working with terrorism-related data. In particular, it is necessary to improve the phase of data collection about terrorists, their organizations and planned activities. For this purpose, in the intelligence cycle in the data collection phase, it is necessary to include publicly available data that can help not only the scientific community, but also those who deal with the fight against terrorism in an operational way.

Less exploited but extremely important tools that can be used to collect data on terrorist organizations, actors and trends are publicly available scientific databases related to theorizing and platforms for researching publicly available data on the Internet. The

assumption is that the full potential of such tools will still be expressed and that their application will be the subject of new research.

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EXPECTED INNOVATIONS IN THE ACCOUNTING EDUCATION CURRICULA – CASE OF THE UNIVERSITY OF TIRANA.

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Abstract

After the recent pandemic, rapid adjustments were undertaken in all areas, education included, and professors and students began aligning to new requirements, learning environments, and perspectives. Like other universities in the world, Albanian Universities, like those all over the world have been working under unprecedented conditions for the past year, and as students and professors try to do their best under the pressure of unknown circumstances, it is imperative to study and observe the first results that the reality is offering us to be able to draw conclusions and learn lessons from them. Having identified this need, the focus of this article is to study the factors that are likely to impact the expected changes in the accounting curricula reflecting the increased digitalization of education, industry, and business processes. The analysis is based on empirical data collected through questionnaires with accounting students at the University of Tirana. We process the data by employing simple statistical univariate analysis. Our findings reveal the students' perspectives and what they think would help improve the process. Despite the mutual efforts we recognize the fact that online learning and teaching remain challenging and complex processes and because of this, students and teachers alike should be open to learning more and to be flexible and evolve to adapt to new environments.

Keywords: Accounting Education, Innovation, Curricula modernization

JEL Classification: O33, I23, I21

1. Introduction

Online teaching and Internet courses at universities across the world were introduced many years before the pandemic and especially after that when they became the only way of teaching and learning for higher education and all levels of education. Coupled with better access to the Internet and increased use of information technology in teaching, online

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learning can soon become a prominent way of learning at higher education levels and beyond. Online learning alone or offered as part of a blended teaching approach, presents its challenges especially if introduced and becoming mandatory within a short time such as happened last year. Many were caught unprepared but tried to quickly adjust to the changing environment. The course materials, delivery methods, and evaluation tools were adjusted to allow distance learners to achieve the best under the given conditions. Like all other disciplines, the accounting curricula courses were deeply impacted by the online teaching period and are expected to reflect many changes as we are emerging from this era.

The challenges and difficulties were part of the experience of online learning across Universities in Albania and one year into the process it is interesting to survey the landscape of the problem and to draw conclusions, and if possible, hints to improve the process in the future. With this purpose, this paper focuses on the study of empirical evidence gathered during the academic year of 2021 – 2022 at the master's in accounting, Faculty of Economics, University of Tirana. We conducted an anonymous survey with the master students at this Faculty and received a good response rate from them allowing us to draw reliable conclusions on their perceptions, challenges, motivational traits, and suggestions for improvement. We analyzed these data with simple statistical univariate analysis using the Excel ad inn feature in Microsoft Office. Microsoft Office survey tools were also used to collect data from students.

We found that, despite the difficulties, the students were highly motivated to actively engage in online learning, they preferred the synchronous teaching method during which they could interact with professors and their peers. They appreciated those professors who demonstrated flexibility in office hours and access and that adjusted the academic workload and the course evaluation matrix to reflect the new conditions. They brought several suggestions as to changes in the accounting topics to adjust to the recent changes. We were able to draw several important and valuable conclusions and pose some recommendations based on these findings, but we emphasize and recognize the limitations of the paper. A larger sample, a wider time horizon, a more sophisticated statistical analysis, as well as a more unbiased analysis, can provide more valuable conclusions in the long run.

The rest of the paper is organized as follows. In the following section, we present a review of similar studies performed with a focus on online learning and teaching and especially those covering the expectations and reflections of the students. Through analysis of previous studies, we want to form some expectations as to what the challenges and sources of motivation are for students in the conditions of online learning, and what could be changed after the wholly online teaching period is completed. In the next section, we present the methodology of the study followed by a thorough analysis and discussion of the main findings from our primary empirical data. In the last section, we conclude by giving some recommendations for further improvements in the coverage of accounting topics for master in accounting students.

2. Literature Review

The advancement of the Internet, and the developments of Information and Communication Technology, especially in the twenty-first century have played an important role in changing the level of access to instruction and education from basically everywhere (*Means, et.al, 2013*) [1]. Resistance to change and fear of different things is not something new to human beings. Considering online learning is still relatively new, only a little over 20 years, the success and growth are amazing, especially in the face of an educational format (in person) that has existed since the beginning of the modern human era. In his study in *2016, Vivolo* [2] based on a study performed by the New York University in 2012, reports that the most common reasons for faculty resistance to online learning vary from: Online learning is a fad that will go away; There is no engagement with other learners; Fear that online learning will replace onsite learning; Particular courses cannot be taught online; The content or experience is not as 'good' as onsite classes; and, online is not for me.

In 2015 *O'Byrne and Pytash* [3] reported in their study that professors and teachers are increasingly trying to identify opportunities to embed learning experiences for their students that blend traditional face-to-face with the newest online environments. As technology is modifying every aspect of time, quality, and place in our lives, it also is affecting teaching and learning environments and conditions. To be prepared to face the challenges of new technologies emerging in learning environments they report that many teachers are enrolling in hybrid learning programs. Online learning is preferred by students within each study area as *Smith* (*2005*) [4] reported in his study on a sample consisting of 314 university students from Australia. Another survey with alumni and students at one US university (*Nollenberger, 2015*) [5], aiming to assess the preferences of adult learners for the different modes of instruction, their perceptions of the process, and their perceptions of the learning outcomes indicated that most of the adult learners value the flexibility and other aspects of online classes while still desiring on-campus classes for the interaction with other students and the professor for the learning outcomes. The growing interest in the academic communities for disruptive technologies adoption highlights the need for higher education institutions to become more agile and plan for the post-pandemic future as demonstrated by Purcarea I, [6] in his study in 2021. According to his research, with a relevant digital strategy, the University can drive efficiency, create a superior digital offer, enable curriculum improvements, and meet students' digital expectations.

(*Bhagat, et.al, 2016*) [7] demonstrated that the connectivity of online learning with social networks has evolved to form a popular means to connect, collaborate and engage users in the learning process. Based on empirical data from 208 Taiwan university students they develop a scale for determining students' perceptions of online learning. They name this tool *POSTOL* and organize it into four dimensions: instructor characteristics, social presence, instructional design, and trust. Their study emphasizes the importance of the

above dimensions/features to increase the motivation and engagement of the students during online learning. Another large-scale study involved more than 900 students across universities in Canada and the United States. (*Oguz et al., 2015*) [8] testes students that had completed at least one online course and were asked about the motivational factors during their studies. Three areas of motivation emerged from this survey namely: the accommodation options, the predisposition towards an online learning environment, and selectivity. But these students also reported experiencing isolation from peers and instructors, and a general lack of professional development and networking opportunities with peers.

Studies focused on patterns of learning from students were also carried out. One of them, the research of Maduta (2022) [9] focused on learning foreign languages online. He indicated that the majority of those interviewed have both the resources and the knowledge and skills necessary to learn English online, perceive a high self-efficacy following online courses, and have a favorable attitude towards the idea of continuing to learn English exclusively online. Previously in 2018, Knewtson, [10] had experimented with different testing techniques with his students at a university in the USA and found that providing quicker, electronic feedback was a factor that improved the student learning experience. Hence, online homework and the course quiz average were associated with stronger final examination performance. The impact of more focused and frequent quizzes online, compared to in-class quizzes, on final examination performance was also significantly positive. The study found that factors such as student absences, gender, status as a quantitative major, or as an upper-division student did not have any impact on final examination performance.

Engagement and motivation are not the same, but motivation can be transformed into engagement with the proper design of support. In their study in 2015 ChanMin et al., [11] focus on the examination of how the changes in the motivation level, regulation, and engagement throughout the semester make any difference or not between high performers and low performers in the course. They included in their survey, 100 students enrolled in online asynchronous courses offered at a virtual school in the USA and administered to this sample three different questionnaires during the semester They found that overall, high performers and low performers differed about their changes in motivation and regulation throughout the course, self-efficacy and effort regulation being the most important distinctive features. The important and rather expected finding was that high performers started the semester with a higher level of effort regulation than low performers and they maintained their superior level of effort regulation over low performers throughout the semester. The higher the level of effort regulation that students had, the higher their achievement was.

Another study in *2018 by Butchey et.al.,* [12] analyzes the characteristics of success of students enrolled in an online program aiming at providing insight and guidelines for excellence in an online learning environment. They compare the performance of the

students from two the same program but delivered in different ways, one through a face-to-face traditional teaching mode and the other through an online platform. As their study reveals that the overall performance of students in the two programs is similar in statistical terms, they continue by trying to identify the factors that influence the student choice between a face-to-face program and one that is offered online. They found that students that prefer face-to-face MBA are generally individuals with higher work experience, younger students, students who pay in-state tuition, and students who are not U.S. citizens. They further investigated the determinants of effective teaching performance in online courses finding that the most important factor in instructor evaluation is the percentage of the class expecting lower grades, indicating that students tend to blame their instructors for their poor performance in the course.

Sung-Hee 2017 [13] studied the effects of visualization to motivate students to participate in online learning environments. They argued to find evidence that the visualization tool can enhance the online participation of students; especially the visualization of individual participation was found to have greater effects on online participation than the visualization of group participation despite the collaborative learning community. Their findings may be important for teachers and professors to help guide them design better collaborative online learning tools for their students. Previous studies by Osgerby et. al. [14] have shown that students perceive the technique of visual metaphor as a stimulating exploration of their personal goals that enhanced their engagement in the reflective PDP process. On the other side, the professors are found to have included more visual effects, and in general, more technology in their classrooms. Blankley et.al [15] indicate that, in general, today's accounting students are obtaining valuable experience with a wide array of IT tools – both hardware and software – in their accounting courses.

The innovation of the accounting education curricula is crucially important, especially in the view of the digital natives' generation. Al-Htaybat, et al [16] focused their study in 2018 on expected changes and how the accounting profession, practice, and, consequently, education will be affected and adjusted to the new emerging technologies. They report that supportive changes include amending respective courses to emphasize classic skills, such as problem-solving, and contemporary skills, such as new technologies, to illustrate developments practically. Incorporating innovative teaching tools, one of them being Problem-Based Learning is another suggestion from empirical research (Wyness, Dalton, 2018) [17]. Overall, despite many arguments and opinions, all may agree that given recent changes in reporting requirements and technological advances, the accounting curricula should adapt to deliver more content in a more effective way like other studies done previously, Madsen [18] in his study focusing on 1970 to 2000, showed that the quality of accounting education has been steady or increasing over time.

As Carstea [19] summarizes in his study in 2021, online teaching also revealed a series of shortcomings, that was unheard of in the offline teaching system and they had to be overcome, as fast as possible, to reduce the interruption in the student's learning. The tech-

aided learning, although it has its challenges, will prevail even after the pandemic, as all its benefits will be widely spread in the educational system throughout the world.

After that, we are witnessing even bigger challenges for teaching and learning (AI such as Chat GPT in but one of them), and therefore professors need to readjust their approaches to what works for the students and how to deliver content more acceptably. Gathering impressions and suggestions from students is one way to derive conclusions related to the adjustment of curricula content and delivery regarding the accounting courses.

3. Methodology of the study

The study is based on gathering data from the perception of the students of accounting master's study programs at the Faculty of Economics at the University of Tirana. The primary data was generated by the authors based on a survey performed with these students. The dataset remains at our disposal to further analyze the intrinsic information it contains.

The population of the study is represented by all the students of professional and scientific master's in accounting study programs of the Faculty of Economics at the University of Tirana. We approached them through a questionnaire delivered to all the students through the same platform they used to engage in online learning, MS Teams. The questionnaire consisted of nineteen diverse questions, some of them multiple choice, some of them with open questions, and the others were questions with Likert scale. The survey was administered in an anonymous way to encourage the participation of all the students.

The questionaries were administered by the end of the first semester after the students had completed their studies, but before they were subjected to the exams, or received any evaluation, thus avoiding any unconscious bias that could have hindered the survey from achieving its purpose. The interest of the students was considerable and for almost a week we were able to gather about 214 completed questionaries and all of them were considered to be appropriate for further analysis of data. Against a total population of roughly 1000 masters' students that were sent the questionaries, this represents a 21% response rate. According to Visser, et al, (1996) [15] online surveys with lower rates of return responses (at about 20%) yielded more accurate measurements than those with higher return rates (at about 60-70%). Therefore, we consider a response rate of 21% to be an acceptable and reliable rate to perform the analysis of the gathered data.

After the responses were received, they were processed with Statistical Analysis Tools available for the Excel package applying the simple univariate analysis. Given the constraints of the sample, we could not apply further analysis, but the available dataset could be further processed for other studies as deemed necessary.

4. Results and Discussions

The demographics of the sample of this study including gender, age, and educational background are summarized in table 1. As shown in Table 1, about 85% were female students and 15% were male students, which in general corresponds to the profile of gender distribution of students at the Faculty of Economics, University of Tirana. 90% of the respondents were at a young age (younger than 25 years old), and for more than 90% of them, the current program was the first master's studies program they were attending. We also notice that around 73 % of the students come from a Professional master's program, whereas the rest are from a Master of Sciences Program. Only 37% of the students are unemployed, the rest being either part-time or full-time employed. There was also a minority of 2% of the students that were currently employed in two different jobs.

Measure	Category	Number	Percentage (%)
Age	20 - 25	191	89.3%
	26 - 30	13	6.1%
	Mbi 30	10	4.7%
	Total	214	100.0%
Gender	Female	183	85.5%
	Male	31	14.5%
	Total	214	100.0%
Master Experience	First master program	200	93.5%
	Further Master studies	14	6.5%
	Total	214	100.0%
Current Master Program	Professional Master	157	73.4%
	Master of Sciences	57	26.6%
	Total	214	100.0%
Employment status	Unemployed	81	37.9%

Part-time	31	14.5%
Full time	98	45.8%
Double employment	4	1.9%
Total	214	100.0%

Table 1: Demographic Statistics[4]

The second set of questions in the questionnaire aimed to reveal the quality of access of students during the online learning process and their experiences with an Internet connection and with teaching methods (synchronous or asynchronous teaching). Most of these questions had multiple choices allowing us to capture more information about the variety of reality.

136 students (64% of the sample) declared to have used a PC or a laptop during their learning process, whereas 170 students (almost 80%[5]) stated they had used a smartphone device to access their classes. This insight goes in line with the answers received in the next question of the survey regarding the Internet connection type they have used. 128 students (60% of the sample) state to have used a cellular connection to the Internet and the others declare to have used WIFI connections in their homes. This finding confirms one of the main problems experienced during online learning. The devices used by the students were not, in most cases, appropriate to allow them to experience the most from the online learning process, and sometimes became a hindrance in acquiring new knowledge and information.

We next asked the respondents about the most widely used teaching method they had been exposed to. 135 students (64% of the sample) stated that they had participated in synchronous teaching, and 75 students (35%) stated they have been exposed to both methods. Only 4 respondents (less than 2% of the sample) say that their teachers have mainly used the asynchronous method. The synchronous teaching method was considered more successful and desirable by 189 respondents (88% of the sample) whereas the asynchronous method was preferred by only 12% of the students. This finding was particularly interesting and contradictory because similar studies performed in other countries revealed asynchronous teaching as the preferred method for those students who were working and attending graduate studies. Maybe this can confirm the high level of dependency of the Albanian students on the teaching process itself and from the close interaction with peers and professors.

[4] Source: Authors' primary data
[5] Respondents could select more than one option for this question.

We also asked the students several questions aiming to discover the extent of Internet usage for online learning. 146 students (68% of the sample) say that they have used the internet more than 4 hours a day for online lectures and the overall learning process; 45 students (21%) for 3-4 hours per day whereas only 23 students (10%) say they have used the internet for 1-2 hours per day. Asked how successful they had been to access the internet during the semester, 132 students (62% of the sample) stated they have successfully participated in almost all 15 weeks of the semester; 67 students (31%) say they could access during more than 10 weeks whereas only 15 students (7%) could access the lectures in less than 5 weeks. We witness a high interest on behalf of the students.

Asked if they considered that the examination period was adequately organized by the university, in terms of information delivered before the exams and help offered by IT staff, only 40 students (19% of the sample) stated they were very satisfied with the organization measures undertaken that far; 139 students (65%) were moderately satisfied, whereas 16% (35 students) were very dissatisfied by the management of the process. We reveal the neutrality of the students in their expectations and perceptions regarding the easiness of organizing the first online examination period.

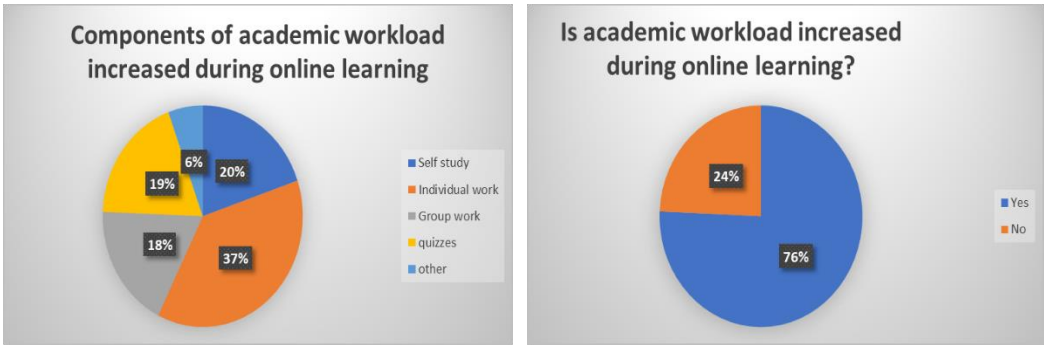

Figure 2: Academic workload during online learning[6]

Academic requirements are an important part of the learning process and most of the students (76% of them) have experienced an increase in their academic workload due to the specific characteristics of online learning. When asked which of the components increased more, they indicated the individual work and self-study which demonstrates that this kind of learning requires more involvement and engagement of the student.

[6] Source: Authors' primary data

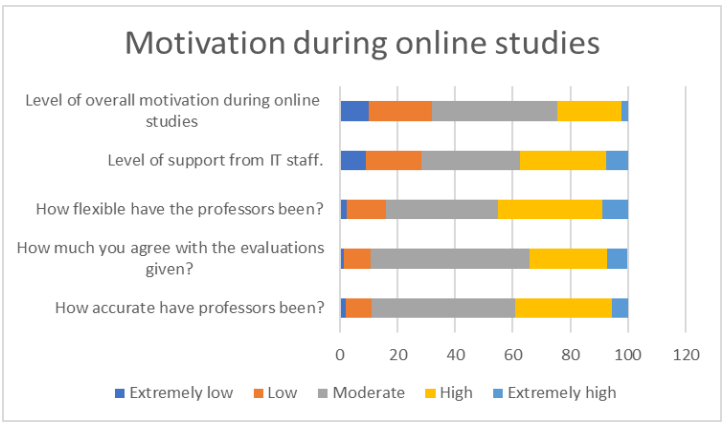

Figure 3: Motivation and its factors during online studies[7]

The next set of questions in the survey aimed to reveal the overall level of motivation of the students during their studies, and which factor had any impact on the motivation (figure 4). Overall, the students seem to be moderately or very motivated (65% of the respondents), and while the level of support from the IT staff has not been very high on one hand, the level of professors' flexibility, the accuracy of their evaluation during the semester and the acceptance of their evaluation from the students seem to be a factor that has contributed to the moderate and somehow high level of motivation.

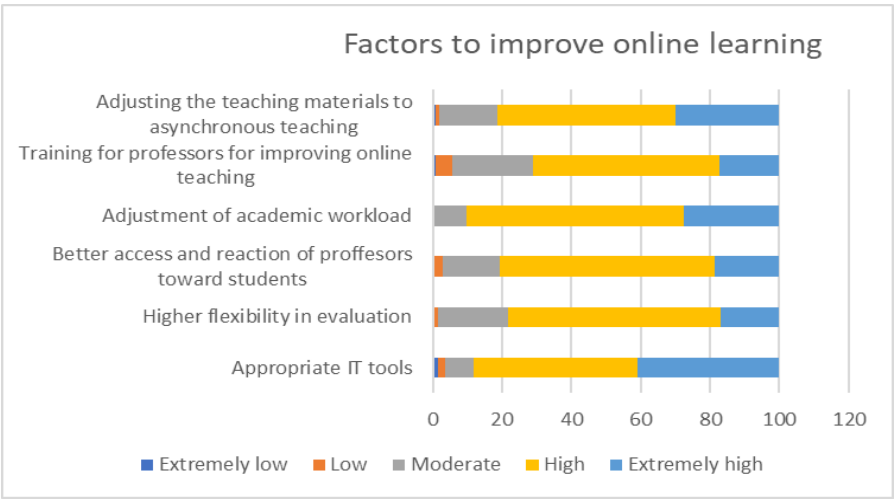

Figure 4: Impact of various factors on online learning[8]

[7] Source: Authors' primary data

[8] Source: Authors' primary data

The next section of the questionnaire consisted of several open questions through which we wanted to collect suggestions from students on how to improve their experience of online learning. As seen in figure 4, the students regard that the most important factors that could improve the online learning environment vary from the adjustment of academic workload; better access to professors' reaction and support during the online learning process; providing adequate training for professors so they can deliver better the contents of the lectures; professing higher flexibility in evaluation; and finally having appropriate IT tools to facilitate the online learning process.

The questionnaire was concluded with a section devoted to suggestions from the students on how to improve the contents and delivery of the accounting courses. As many of the students are already employed (figure 1), in related job positions we regard that they can give suggestions related to the curricula contents. In this section, we list various new and emerging topics in accounting and ask whether the students consider it important to learn about these topics during their studies at the University. We list there: (1) sustainability accounting and reporting; (2) climate impact on financial reporting; (3) sustainability auditing; (4) digital innovation; (5) blockchain and distributed ledger technology in accounting; (6) artificial intelligence in accounting and auditing; (7) others. The last option is entitled "others" and was designed as an open question to collect opinions that varied from the above. We find that the most sought-after topic is climate-related accounting matters, maybe related to regulations and requirements already in place in Albania. Sustainability reporting was also regarded as important, sorted as second by the respondents. Issues related to advanced digital innovation were only moderately considered important, maybe due to a more relaxed approach on behalf of Albanian businesses on the implementation of digital innovations.

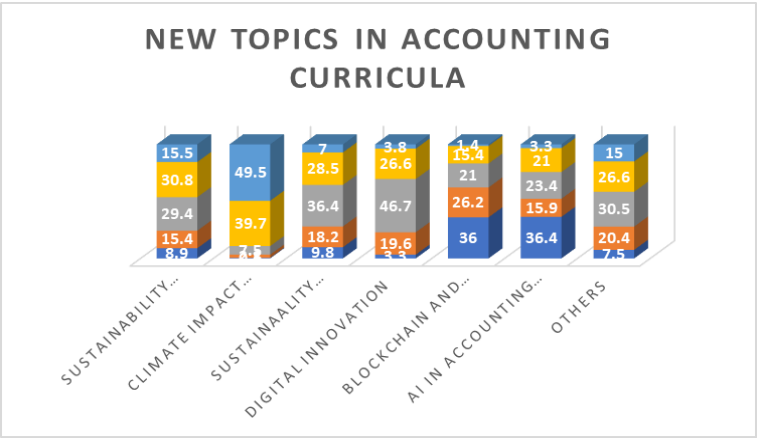

Figure 5: New topics suggested to be included in the Accounting Curricula[9]

[9] Source: Authors' primary data

5. Conclusions and Recommendations

The purpose of this paper was to provide empirical observation on the perception of accounting students about online learning and new topics that could likely be introduced in the curricula in Universities. We gathered first-hand observations through a survey distributed to the students from the 2021 – 2022 academic year at the University of Tirana, Faculty of Economics. This Faculty has more than 1000 students at the graduate level, thus providing a good representation for drawing a picture of the current situation regarding the challenges of online teaching and learning.

In the period March 2022, a survey was electronically sent to the master's students at the Faculty of Economics at the University of Tirana, receiving back more than 200 questionaries which represents a 21% response rate. The interest in participating in the survey was considerable and the feedback of the students is invaluable to evaluate the situation.

The findings of this study confirm that one of the main problems experienced during online learning was the lack of adequate IT devices because most of the students were studying through a mobile phone and over WIFI connections. The synchronous teaching method was considered more successful and desirable by 189 respondents (88% of the sample) which may confirm the high level of dependency of the Albanian students on the teaching process itself and from the close interaction with peers and professors. We witness a high interest on behalf of the students because more than 60% of them access the online learning process for almost all 15 weeks of the semester.

The respondents report having experienced family issues during the pandemic associated with increased academic workload, especially in the form of individual work and self-study. Overall, the students seem to be moderately or very motivated (65% of the respondents), and while the level of support from the IT staff has not been very high on one hand, the level of professors' flexibility, the accuracy of their evaluation during the semester and the acceptance of their evaluation from the students seem to be a factor that has contributed to the moderate and somehow high level of motivation.

The students regard that the most important factors that could improve the online learning environment vary from an adjustment of academic workload; better access to professors' reaction and support during the online learning process; providing adequate training for professors so they can deliver better content of the lectures; professing higher flexibility in evaluation; and finally having appropriate IT tools to facilitate the online learning process.

Based on suggestions given by the students we recommend that topics such as climate-related accounting and sustainability reporting could be soon integrated into the curricula of the Accounting study programs in Albania, recognizing at the same time their prime

international importance. Whereas digital and IT topics such as AI, DLT, and Blockchain could be implemented for a second time in the accounting curricula.

Based on our findings, we also recommend that a very important step to take is to start the process of adjustment of teaching materials to the new online environment. Learning objectives, quizzes, materials, and interaction with students should all be reconsidered in the face of this new reality. The universities also should try to provide more facilities for the students and the academic staff to enable them to perform better.

This study serves as a good starting point to start observing the effects of online learning n the students, but it has its limitations like the restrictions in the time frame (only the first semester of the studies), focus on only one university in Albania, and simple methodology and analysis. We consider that a study administered for a larger sample, over an extended period, and from an independent observer (rather than their professor), would yield more reliable results.

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A COMPARATIVE ANALYSIS OF 'S' AND 'V' TYPE TRANSFER FUNCTIONS FOR BINARY PARTICLE SWARM OPTIMIZATION ALGORITHM-BASED WIND FARM DESIGN SELECTION PROBLEM

Prasun BHATTACHARJEE[1]

Somenath BHATTACHARYA[2]

Abstract

To check the upsurge of universal average temperature well below 2oC as projected by the Paris Agreement of 2016, renewable energy technologies like wind power must remain commercially feasible for enabling the green energy transition. The current study emphasizes the relevance of the Binary Particle Swarm Optimization method for solving wind farm layout selection problems. The relative efficiency of different transfer functions for attaining the minimum cost of energy has been examined. The research outcomes demonstrate the better competence of 'S' type transfer functions over the 'V' type ones for five terrain situations and wind-flow settings.

Keywords: Wind Power, Wind Farm Design, Binary Particle Swarm Optimization, Transfer Function, Power Generation Cost

JEL Classification: -

1. Introduction

Since universal power generation grew rapidly with the consolidation of industrial pursuits, the fossil fuel stashes are depleting at an exceptional rapidity [1]. Renewable power resources offer thriving substitutes when there is an expanding global trepidation for the insufficient reserve of fossil fuels and their drawbacks on the bionetwork [2]. Global renewable energy utilization and Wind Power Generation (WPG) segment have advanced exponentially since the introductory years of the twenty-first era [3]. Universal collective WPG capacity has grown from 20 GW in 2000 to 650 GW in 2019, estimated to reach 4042 GW by 2050.

Along with lower emission advantage, WPG farms are entailed to function economically [5]. Due to the relatively low capacity of the Wind Turbine (WT), a vast count of WTs is to be instated within a wind farm to accomplish the capability of traditional power plants.

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Wind farm design should be prudently evaluated for selecting the most acceptable option that delivers the best possible profit for definite capital spending [6]. Several research works have been executed to resolve the concerns allied to Wind Farm Layout Optimization (WFLO).

Initially, in 1994, WFLO was explored with a Genetic Algorithm (GA) [7]. Since the mid-2000s, GA has been extensively applied to WFLO problems for grid-like discrete as well as coordinate-based continuous representations of wind farms [8]. Grady et al. (2005) [8] employed GA to find the optimum location of WTs for maximizing the power generation capacity whereas reducing the number of WTs and the land usage. Huang (2007) [9] proposed a distributed GA methodology to amplify the yearly profit for bigger wind farms. Elkinton et al. (2008) [10] discussed the application of five diverse kinds of optimization techniques for offshore WFLO. An innovative coding tactic was employed for GA-based WFLO [11].

Chen et al. (2015) [12] employed multi-objective GA for enhancing the power yield while reducing the overall cost of wind power generation farms. Yin et al. (2017) [13] suggested an enhanced GA methodology to reduce the cost of power generation subjected to the uncertainty of wind flow. Particle Swarm Optimization (PSO) algorithm with the Gaussian mutation has been applied for WFLO [14]. Chowdhury et al. (2012) [15] attempted unrestricted WFLO employing constrained PSO.

The BPSO technique with time-varying acceleration coefficients was employed to maximize the generation capacity for a minimum investment [16]. Hou et al. (2016) [17] proposed PSO with multiple adaptive approaches to maximize the generated power. Pillai et al. (2017) [18] engaged both GA and PSO for reducing the Levelized Cost of power generation at the Middelgrunden wind farm in Denmark. PSO is an AI-enabled optimization technique that searches for the most optimal solution by communicating knowledge about universal or local best solutions [19].

Apart from GA and PSO, Monte Carlo simulation has been applied to increase the power output while minimizing the total cost [20]. A Simulated Annealing algorithm has been utilized by Rivas et al. (2009) [21] for offshore WFLO. DuPont et al. (2016) [22] engaged the Pattern Search algorithm to WFLO with steady and inconsistent wind patterns. The heuristic methodology is preferred over mathematical programming because of the multifaceted nature of WPG farm design problems [23, 24]. Although the BPSO technique has been used in WFLO, the relative effect of different transfer functions applied in BPSO has not yet been explored for wind farm design purposes.

The current study has focused on the BPSO technique for the WFLO problem. A grid-like structure of wind farms has been taken into consideration for utilizing the binary coding capability of BPSO. Four ‘S’ and four ‘V’-type transfer functions have been employed simultaneously to evaluate their relative effectivity in finding the least possible power generation cost for five arbitrarily selected terrain and wind flow conditions. This paper has

been coordinated as follows. The problem presentation, accessible in segment 2, furnishes a comprehensive depiction of the objective function. The optimization algorithm, 'S', and 'V' type transfer function-related details are obtainable in segment 3. Results and related discussions are accessible in segment 4. Conclusion and future prospect-related discussions are available in segment 5.

2. Problem Presentation

Objective Function Formulation

The rationale of the current research is to optimize the positioning of WTs by minimizing the Cost of Energy (C_E). This WFLO problem is framed through wind flow patterns, wake effect, WT parameters, and allied power generation factors. The present study has engaged the cost function, five arbitrarily chosen terrain conditions, and wind flow models as the benchmarking evaluation setup for assessing the comparative effectiveness of eight different transfer functions of BPSO following [25][26]. The objective function is formulated as:

$$C_E = \frac{\{\gamma * \delta\} + (C_o X)}{(1-(1+k)^{-p})/k} * \frac{1}{8760 * E} + \frac{0.1}{X} \quad (1)$$

$$\gamma = C_A X + C_B floor\left(\frac{X}{Y}\right) \quad (2)$$

$$\delta = \frac{2}{3} + \frac{1}{3} e^{-0.00174X^2} \quad (3)$$

Where C_A symbolizes the outlay of a WT. C_B represents the expense of a sub-station. X signifies the tally of WTs in a WPG farm, and Y stands for WT per sub-station i.e., 30. Co indicates the operational and maintenance cost per annum. E denotes the power yield of the WPG farm. k symbolizes the percentage of interest. p signifies the lifespan of the wind farm.

The latter term (0.1/X) recompenses the layouts with a higher WT count to make the most of the wind farm's power output. The intent of the current work is to curtail the C_E. The goal function is constrained within the defined limits of the terrain dimensions, and the gap between two adjacent WTs must be at least eight times the WT radius to minimize the wake loss.

If you use subsections, please follow the draft regulations: if you start right after the section declaration, just place the subsection on the next paragraph, if you have a content for the section and then insert a subsection leave 1 (one) empty paragraph above and below the subsection (see below).

3. Optimization Algorithm

Binary Particle Optimization Algorithm (BPSOA)

Due to the complex nature of wind flow scenarios, a heuristic methodology is essential to be adapted for WFLO. In the current research work, BPSOA has been considered for minimizing the C_E in the current study. The optimization algorithm has been discussed in the subsequent sub-sections.

PSO imitates the societal activities of birds, bees, or a shoal of fishes. Every member of the swarm is signified by a vector in the search domain. The algorithm regulates the updating strategy of the swiftness of a swarm member known as a 'particle' correspondingly. The PSO procedure repeats up to a preset number of counts or till an acceptable level of error is attained [27].

A 'particle' can be categorized as a bit sequence in BPSO. The spot of a 'particle' can be revised by swapping between 0 and 1 according to the velocity [28].

For the n^{th} bit of m^{th} particle, the velocity v_{mn} is computed as per Eq. (4) and (5),

$$v_{mn} = wv_{mn} + \tau \tag{4}$$

$$\tau = c_1 r_{1n}(p_{mn} - x_{mn}) + c_2 r_{2n}(g_n - x_{mn}) \tag{5}$$

where w signifies the inertia weight with a value ranging between 0 and 1. w can be computed according to a linearly declining technique as per Eq. (6).

$$w = w_{max} - (w_{max} - w_{min})\frac{k}{L} \tag{6}$$

where w_{max} and w_{min} are the supreme and least confines of inertia weight respectively. k stands for the current counts of repetition and L denotes the maximum count of repetitions. c_1 and c_2 are non-negative acceleration parameters. r_{1n} and r_{2n} are arbitrary variables following uniform distribution with values ranging between 0 and 1.

P_{mn} indicates the nth bit of the individual preeminent location of the m^{th} particle. g_n represents the n^{th} bit of the universal paramount location.

The transfer function which is used to update the value of the bit has been defined in Eq. (7).

$$v_{mn} = \frac{1}{1+e^{-v_{mn}}} \tag{7}$$

The value of the bit is updated as per Eq. (8).

$$x_{mn} = \begin{cases} 1, & if\ rand() \leq s(v_{mn}) \\ 0, & otherwise \end{cases} \tag{8}$$

Where rand() arbitrarily generates a number ranging between 0 and 1 with uniform distribution [28].

The algorithm of the proposed BPSO has been presented in Table 1, where present locations, individual best locations, and universal best locations have been signified as $x_m = (x_{m1}, \ldots\ldots, x_{mn})$, $pm = (p_{m1}, \ldots\ldots, p_{mn})$ and $g = (g_1, \ldots\ldots, g_n)$ respectively.

Arbitrarily create a preliminary population
Arbitrarily create the primary velocities in the interior of the velocity limits
repeat
for m = 1 to Populace Limit **do**
if f ($\mathbf{x_m}$) < f ($\mathbf{p_m}$) **then** $\mathbf{p_m} = \mathbf{x_m}$;
if f ($\mathbf{p_m}$) < f (**g**) **then** $\mathbf{g} = \mathbf{p_m}$;
end
for m = 1 to Populace Limit **do**
for n = 1 to Particle Bit Limit **do**
Compute **w** with Eq. (6)
Revise velocity using Eq. (4) and (5)
Revise location with Eq. (7) and Eq. (8)
end
end
until the Ending criteria are attained

Table 1. Algorithm for BPSO [28]

The transfer function depicts the possibility of altering location vector particles between 0 and 1.

The transfer function must be capable enough to offer a superior possibility of altering the location for a sizeable amount of particle velocity. It must also tender a minor possibility of shifting the location for a lesser quantity of particle velocity [29] [30].

Serial No.	Transfer Function
S_1	$S(x) = \frac{1}{1+e^{-2x}}$
S_2	$S(x) = \frac{1}{1+e^{-x}}$
S_3	$S(x) = \frac{1}{1+e^{-\frac{x}{2}}}$
S_4	$S(x) = \frac{1}{1+e^{-\frac{x}{3}}}$

Table 2. 'S' Type Transfer Functions [29]

Serial No.	Transfer Function
V_1	$S(x) = \left\lvert \text{erf}\left(\frac{\sqrt{\pi}}{2}x\right)\right\rvert = \left\lvert \frac{\sqrt{2}}{\pi}\int_0^{\frac{\sqrt{\pi}}{2}x} e^{-t^2}\,dt \right\rvert$
V_2	$S(x) = \lvert\tanh(x)\rvert$
V_3	$S(x) = \left\lvert \frac{x}{\sqrt{1+x^2}} \right\rvert$
V_4	$S(x) = \left\lvert \frac{2}{\pi} arc\tan\left(\frac{\pi}{2}x\right) \right\rvert$

Table 3. 'V' Type Transfer Functions [29]

These transfer functions can be classified as 'S'-shaped and 'V'-shaped according to their graphical plots [31].

Four 'S' and four 'V' type transfer functions used for BPSO have been mentioned in Tables 2 and 3, respectively. Their graphical plots have been shown in Figs. 1 and 2 correspondingly.

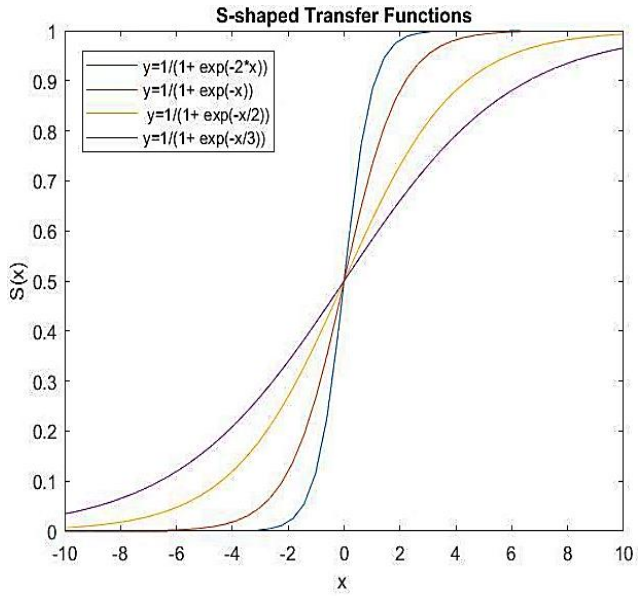

Figure 1. Plots of 'S' Type Transfer Functions [31]

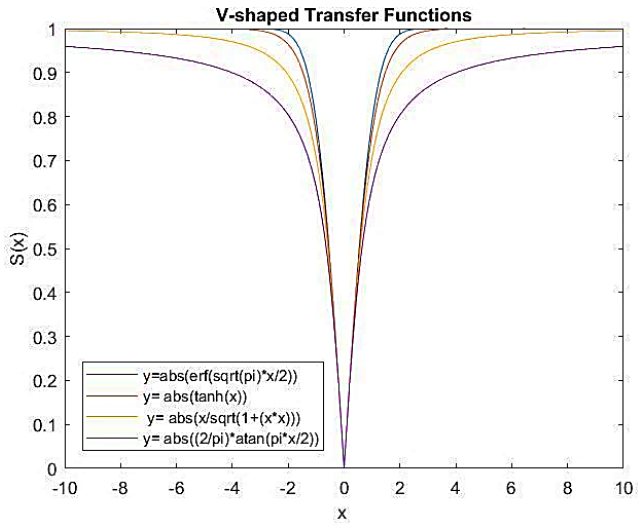

Figure 2. Plots of 'V' Type Transfer Functions [31]

The transfer functions engaged for BPSO are influential in providing the appropriate probability according to the absolute velocity of a particle [30]. The choice of the competent transfer function can facilitate the decision-makers to explore the search domain (terrain) most efficiently and locate the best possible emplacement of the WTs in a WPG farm for achieving the least possible C_E [32]-[35].

4. Results and Discussion

For appraising the proportional performance of 'S' and 'V' type transfer functions for the WFLO problem, a similar CE function, described in section 2, has been employed. CE has been measured in USD/kWh. A terrain condition considered by Wilson et al. (2018) is put into operation as a benchmark terrain situation in contemporary research and it is shown in Fig. 3.

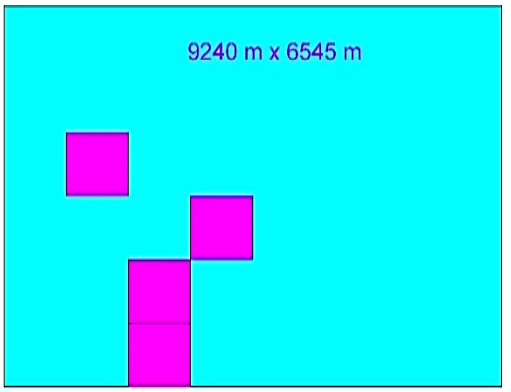

Figure 3. Considered Terrain Setting

The rectangular terrain of length and breadth of 9240 m and 6545 m respectively has been deemed in the existing study. The area shown in blue is available for positioning WTs whereas the area shown in pink indicates the obstructions inside the terrain. WTs cannot be placed within the obstruction area. The airflow scenario spread across directional angles (shown as 0 to 345) held in the present work is graphically represented in Fig. 4 [36]-[40].

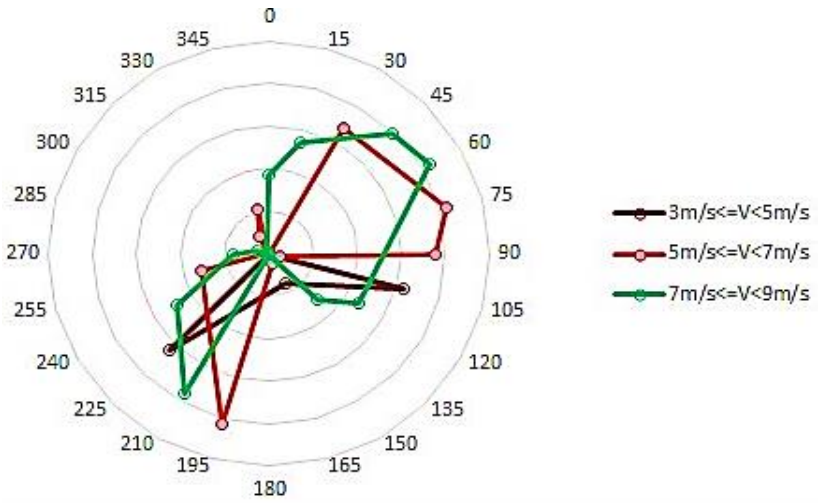

Figure 4. Considered Airflow Condition

The parameter setting for the WFLO problem has been presented in Table 4, and experimentation outcomes have been displayed in Fig. 5. The minimum CE has been specified in bold form.

Parameter	**Considered Value**
Operational Charge	USD 20,000
c_1	2
c_2	2
Diameter of WT	77m
Number of Iterations	50
Operative Period	20 Years
Population Size	20
Rate of Interest	3%
Rated Power	1500 kW
Sub-Station Outlay	USD 8,000,000
v_{max}	6
w	2
w_{max}	0.9
w_{min}	0.4
WT Outlay	USD 750,000

Table 4. Parameter Settings

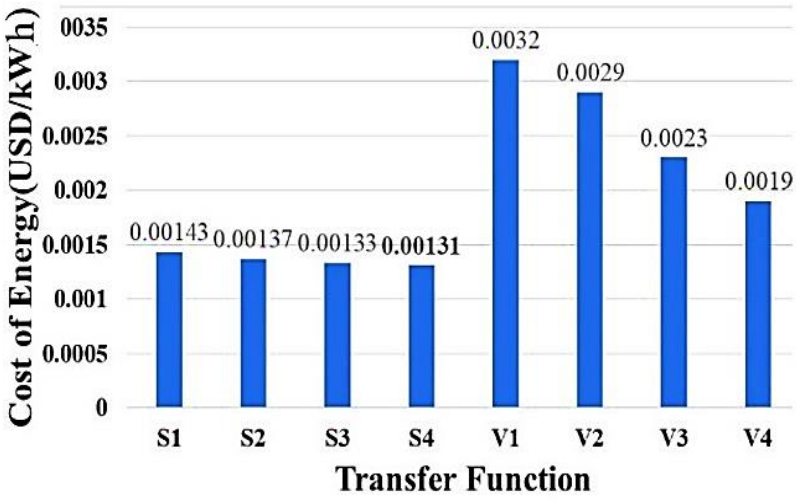

Figure 5. Comparison of Optimized Costs of Energy

Transfer Function	Cost of Energy (USD/kWh)
S_1	0.00143
S_2	0.00137
S_3	0.00133
S_4	0.00131
V_1	0.00320
V_2	0.00290
V_3	0.00230
V_4	0.00190

Table 5. Optimized Costs of Energy

Each optimization run has been iterated 50 times for every chosen scenario and transfer function. The plots shown in Fig.5 depict that 'S' type transfer functions offer more optimal wind power generation cost when compared to corresponding 'V' type transfer functions. Moreover, the 'S4' type transfer function, among all the mentioned transfer functions, has presented the minimal CE for every wind flow scenario. The most optimal CE that has been attained in the current WFLO problem is 0.00131 USD/kWh. The accepted error for estimating the CE is less than 0.00001 USD/kWh for the present work [41]-[45].

5. Conclusions

The BPSO-based WFLO methodology presented in the current work has offered an economical and prompt technique to assess the optimum generation cost for a given cost function and five arbitrarily chosen wind flow scenarios taken into account in the 22nd Genetic and Evolutionary Computation Conference [25]. Both types of transfer functions have been considered for changing the particle velocity for BPSO. The research outcomes demonstrate the suitability of S-type transfer functions over V-type ones in finding the optimal wind power generation cost. The 'S4' function, mentioned in Table 2, is the most efficient transfer function for exploring the randomly generated layouts to search for the best possible positioning of the WTs inside the wind farm with the most optimal WPG cost per kWh. This study will initiate innovative possibilities for enhancing the plan of the WPG farms to find the least probable CE for several terrains and wind flow conditions using AI methods like the PSO algorithm.

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CIRCULAR ECONOMY AND INTERNET OF THINGS, HAND IN HAND FOR A SMOOTH TRANSITION TOWARDS A SUSTAINABLE BUSINESS MODEL. QUALITATIVE RESEARCH ON HOW ROMANIAN COMPANIES PERCEIVED THIS TRANSITION AND NEXT STEPS

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Abstract

The paper aims to assess the contributions of Circular Economy (CE) and Internet of Things (IoT) into a world of a continuous transition, highlighting especially those that help companies towards a sustainable business model. Hand in hand towards the same main purpose to integrate sustainability in all the organizational activities, 7 Romanian organizations from various industries have responded to a qualitative interview, assessing the concept of digitalization as a key component in the developing process for a green future. Used as a starting point, the United Nations' 17 Sustainable Development Goals contribute to a clear vision in creating an efficient marketing strategy, by noticing the effects of a relationship between Circular Economy and Internet of Things through sustainability. As for sustainability, a question might be posed on how it is viewed today and what it represents in the nowadays context. In order to find out an assumed response that could be correlated with various field of activities, some analytical questions have been asked, based on the way of developing a sustainable strategy through digitalization, the main role of the digital instruments, the types of the resources used and the consumer and public perception onto the business model, directing the research towards the creation of hypotheses based on a thought process of sustainability. The transition towards a sustainable business model is reflected in this research through the perception of Romanian companies from different fields, identifying their green practices, and use of digital solutions, by highlighting the importance of circular economy and the IoT component.

Keywords: sustainability, marketing strategy, Internet of Things, circular economy, digitalization

JEL Classification: Q01, M00, M30, L10, L86, O30

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1. Introduction

The intersection between the Internet of Things and Circular Economy represents at this moment state-of-the-art research, correlated to the modern technologies which generate benefits to the economic environmental and the social pillars. Nowadays, more and more companies ask themselves how they can insert digitization into their sustainability strategy or how they could further promote the technological practices that they have already adopted, in order to be considered green organizations, but, at the same time maximizing their profits. The premise that stood at the forefront of the present research includes the concept of a smooth transition towards a sustainable business model, achievable through and with the help of technology. By becoming progressively modern, digital, and innovative, many companies channel their efforts towards the adoption of a sustainable system, supporting and promoting the relationship between the CE and IoT.

In one of our previous research projects, we studied how digital instruments and, especially, the Internet of Things (IoT) help companies to adopt a Circular Economy and transition towards a sustainable business model. A case study through desk research has been conducted upon one of the biggest groups of companies, Schwarz Group, involved mainly in the retail industry, but supporting its circular needs through other companies of the group. Overall, the conclusion was that IoT was one of the most useful instruments during the journey of becoming sustainable but posing its challenges mainly in its inclusion in the companies' business strategy. Another important point was the experience gained during this journey and the lessons learned that should help the companies to improve their strategies, but also to help other companies not to go blindly on these avenues.

The case study on Schwarz Group proved the efforts brought in by big companies, using instruments not only for their own business models, but also supporting their partners and the supply chain and, more important, trying to educate their customers to become smart, sustainable, and green. But what about smaller companies? Did they start their journey towards sustainability? And if the answer is yes, how did or does it go? Do they have any recommendations for those that are still thinking on how to do it?

Romania, as a European Union Member State since 2007, applies the *acquis communautaire* including that on sustainability, and with the new proposed Directive on corporate sustainability reporting companies will be obliged to adopt a sustainable business model [01]. Also, in May 2022 Romania ranked 1st place among Central and Eastern Europe's countries in terms of fixed broadband speed (*CEE: fixed broadband internet speed 2022*, no date). We have the context, the instruments, and the precedents, to be able to ask the questions: *Are Romanian companies on their way to sustainability? Are the IoT and digitalization part of the tools used to support their journey?*

In order to find out the level of preparedness and the tools used by the Romanian companies in their efforts to turn their linear business model into a circular one through digital

instruments, especially IoT, we got in touch with a series of Romanian companies and asked their representatives to fill in a short and focused questionnaire.

2. Designing the interview

The concept of circularity includes a series of characteristics, starting from the principles of sustainability and ending with the life cycle of products. This concept is intensively promoted by the European Commission in its attempt to adopt global well-being through a sustainable development seen as an approach of economic, environmental, and social pillars.

So, what does sustainability represent and how is it viewed today? In a historical approach, the concept of sustainability was strongly influenced by psychological, behavioral, and institutional factors through which people understood and implemented the need to trade, live and consume in a sustainable way [02].

Nowadays, the importance of Circular Economy concept is given by many international polices, academic research and innovations, such as green strategies for climate change, by encouraging bio-based products and developing sustainable activities for all sectors. Regarding the actual European context, promotion of the Circular Economy has become a key element for many companies (M. Åkerman, et al., 2020), with the business ecosystem becoming greener and smarter and the impact of sustainability on this system representing a strategy for the future (World Commission on Environment and Development, 1987).

Industrial revolutions have helped humanity to evolve and the 4th one, also known as Industry 4.0 or "smart factory", has introduced the Internet of Things (Erboz, 2017). Introduced by Kevin Ashton in 1999, only 10 years later he realized that IoT is not only a system to track things with the help of the internet, but also a way to sum up, take inventory and assess which would support sustainability and a circular business model (Ashton, no date).

In the modern world, the association of the three concepts: Circular Economy, IoT and sustainability is given by the technological influence, combined with the effects of global challenges. Over time, technological innovations brought considerable improvements in human life and in the activities of companies, transforming classic industries into fast ones, emphasizing a behavior harmful to the environment, namely: excessive consumerism. To stop this type of excess, sustainability was emphasized by promoting economic, social, and environmental integrity, complemented by the new technologies that could bring added value by reducing the carbon footprint.

Through this qualitative research using a targeted questionnaire we wanted to see how the Romanian companies adapted or try to adapt their business models to a circular one considering: 1. The 17 Sustainable Development Goals (SDGs) established by the United Nations (UN); 2. Motives that brought them to the decision to adopt a sustainable business

strategy; 3. Tools used in their works, identifying also the digital ones; 4. The part played by the digitalization in their endeavors; 5. Resources used to become sustainable; 6. Ways and means used to make their new business model known to their customers and the general public, how it was perceived and forecasts on attracting new customers. Given that we have targeted companies that were already involved in such a transition towards the Circular Economy, we also asked the representatives to include recommendations for those companies that find themselves during the thinking process on how to do it and with the emphasis on digitalization and IoT.

Out of the 7 answers received we noticed that a wide range of business areas have been covered. Representatives of companies involved in consultancy, packaging, including production of, fashion, and digital platforms have offered their views on sustainability, digitalization and IoT, and circular business models.

3. Interpretation of the interview – a state of the art of mixing Circular Economy and Internet of Things aiming the transition towards a sustainable business model

3.1. The UN 17 Sustainable Development Goals (SDGs)

Since September 2015, when all the UN countries decided to adopt the 17 SDGs, more and more entities and people started to work towards peace and prosperity, tackling poverty and deprivations in general, calling on health and systems' improvements, economic growth, all of them fighting climate change and saving nature [03].

Our analysis discovered that Romanian companies are aware of the UN 17 goals with an average of 6 goals being addressed in their business models. All respondents have adopted at least 2 goals in the business model with one of them adopting all 17 Goals (Figure 1, below)

The one Goal adopted by all our respondents was *Goal 12 - Responsible Consumption and Production,* showing that companies are aware that consumption and production are those operations that should be addressed first when adopting a sustainable business model, referring not only to an internal adoption, but also in their relations with various stakeholders, partner companies and clients. According to the UN stats, Europe is one of the three regions that together account for 70% of the global domestic material consumption (DMC), food waste taking the lead and also electronic waste. The term "domestic material consumption" (DMC) refers to the entire quantity of raw materials required by a country's economy to produce products and provide services for domestic and foreign consumers (— *SDG Indicators*, no date).

Not surprisingly, *Goal 13 - Climate Action* was the next one in adoption, with a couple of exceptions, all our respondents confirming this goal as being adopted by the company. Climate change is one of the reasons for these efforts on sustainability and circularity and more is needed in order to achieve net zero by 2050 as per Intergovernmental Panel on

Climate Change (IPCC) plans. In 2021 carbon emissions registered a record high, whipping out the reductions of 2020 because of the pandemic. IPCC considers climate change a *code red* for humanity with disastrous consequences if not taken seriously: extreme weather, increasing oceans' levels, biodiversity loss and less agriculture and food production (— *SDG Indicators*, no date).

Quality Education, Goal 4, is recognized as another important aspect that should be adopted by the business environment. Heavily hit during and after the pandemic, education is considered one of the top priorities also by the Romanian companies, 50% of the respondents adopting this goal and it is not only about children being in schools and learning, but also about what they learn and the overall education of population about recycling, reuse, and sustainability in general.

It is recognized that without help, support, and cooperation a sustainable model cannot be adopted and applied. That is why 50% of the respondents confirmed the adoption of *Goal 17 - Partnerships for the Goals*. At global level, foreign direct investments (FDI), Official Development Assistance (ODA) and access to the internet are recognized as the most important instruments, especially for developing economies, in tackling sustainability (SDG Indicators). At the company level, this goal is translated in their partnerships with their stakeholders. Clients and partners, downstream and upstream, define the capability of the company to adopt a circular business model in a sustainable way.

33% of the respondents had included in their business models *Goal 6 - Clean Water and Sanitation, Goal 9 - Industry, Innovation and Infrastructure and Goal 11 - Sustainable Cities and Communitie*s.

Goal 5 - Gender Equality, Goal 7 - Affordable and Clean Energy, Goal 8 - Decent Work and Economic Growth, *Goal 15 - Life on Land and Goal 16 - Peace and Justice Strong Institutions* have been adopted by 25% of the respondents, while *Goal 2 - Zero Hunger, Goal 3 - Good Health and Well-being, Goal 10 - Reduced Inequality and Goal 14 - Life Below Water* have been adopted by 10% of them.

Consultancy companies are focusing mainly on Goal 12 and Goal 17, while those involved also in production and consumption focus also on Goals 6 and 13.

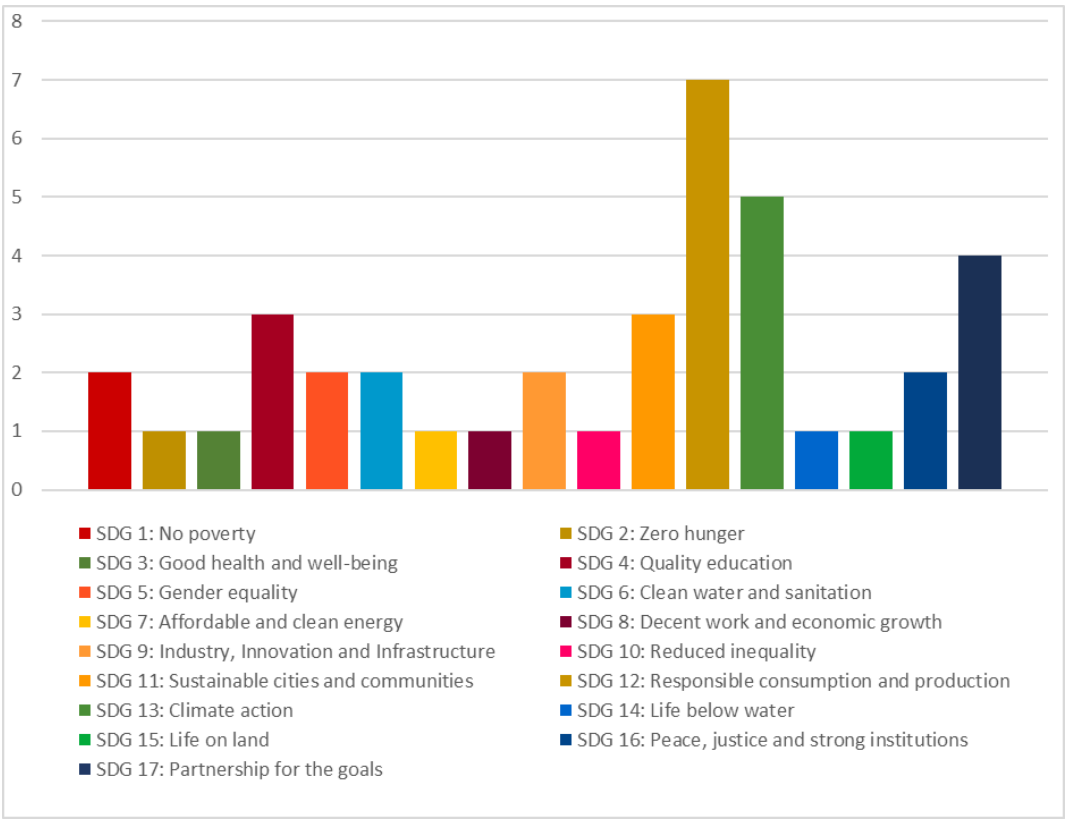

Figure 1. Sustainable Development Goals assumed by companies.

3.2. Motives that brought them to the decision to adopt a sustainable business strategy.

During our research we also wanted to find out what were the reasons behind their decision to take the turn towards a sustainable business model. The one answer across the board was responsibility towards society, economy, and environment, accompanied also by social pressure. We have also noticed the desire to become an example and influence others, either companies or the public itself. Research and science have also been mentioned from the point of view that nowadays it is much easier and cheaper to adhere to sustainable practices and technologies.

Both the environmental factors, as well as the social or governmental ones (ESG), are pillars that would influence the activity of a company towards a sustainable development, making also a profit in a responsible way with the help of environment, society, and employees. The legal factors that put pressure on non-financial reporting, as well as the climate emergency we face, definitely determine the managerial decisions to take a step towards a sustainable business.

3.3. Tools used in their activities, also identifying the digital ones

Many tools have been mentioned, but also practices adopted in order to become more sustainable. Various platforms are used according to the specific nature of the business, either for operations like CRMs, accounting, management of documents or meetings, or the business itself is represented by a platform or interlinked platforms. As for practices, by using online meetings in order to avoid transport, outsourcing various services or basically reducing the consumption and when not possible recycling, reusing and repairing, the companies switch steadily to a sustainable business model.

Social media and blog features are an integral part of the companies' ways to communicate to their clients and potential customers and to make their business model known to the public, but also to educate the consumer and their partners towards a sustainable way of living or doing business.

3.4. The part played by the digitalization in their endeavors

There was no big surprise when all of them answered that digitalization helped them to become more sustainable and by using data collected, including through IoT, it offered them the support to design and adopt swift business decisions. Predictability was also mentioned in the overall context of using data, an advantage that should not be neglected and it is quite encouraging that it was already noticed and used in the nowadays sustainable business models.

Also, more and more companies are starting to make the transition towards a sustainable business with the help of the IoT component, found in the digitization segment, allocating time and resources to future better models. Thus, building a green strategy becomes a priority for any organization in any industry, as a need in the mission of many companies involved in combating the climate challenges.

3.5. Resources used to become sustainable

The impact and the need for resources in the transition process of a company towards sustainability are important factors in all stages of an activity, starting with the product, and continuing with the price, placement, and promotion. Among the three types of resources: material, financial and human, the interviewed companies had to choose and argue about the resource or resources with the highest involvement as an effort in the company's process to become sustainable.

Human resources have the highest percentage in the selection with 50%, compared to 30% financial resources and 20% material resources. The reasons of the interviewees who chose human resources relate to the need and awareness of the staff to specialize and have expertise in a field of the future, such as sustainability. Also, in this sense, the support

offered by companies by presenting specialized training, implementing retraining programs, and adapting today's employees to the jobs of tomorrow's market, has been highlighted as an element that should be on the agenda of any business with a solid strategy in the medium and long term.

3.6. Ways and means used to make their new business model known to their customers and the general public, how it was perceived and forecasts on attracting new customers

According to specialists, being green is not easy [4]. Starting from the concept of Corporate Social Responsibility (CSR), communication can be seen as a key element in thinking, implementing, executing, and re-evaluating a strategy on sustainability. Depending on the industry, the type of activity and the sustainable development objectives assumed, the way a company communicates and the tools it chooses to use can substantially be different.

Most of the respondents expressed their choice to use the Internet, as the main means of communication to make their business model known to clients, but also to the general public. Types of communication such as internal and external, using Social Media channels and online press, are the most common nowadays, in accordance with their popularity among the audience. One of the companies, known for taking responsibility for the fulfilment of the annual objectives of valorization and recycling of packaging, mentioned the fact that in the field in which it operates, in Romania there are currently only 16 such organizations, and these are published on the website of the Ministry of the Environment. For this reason, being a niche activity, communication is done in specialized magazines.

3.7. Perception of the business model by customers and the general public

Considering that the 7 companies, that we have analyzed, are companies that have already started the transition towards a sustainable business model or started their business from this concept, we evaluated the perception of customers and the general public on this model, from the point of view of the company's reaction. Thus, the answers found were based on the green marketing mix, through the 4Ps (product, price, promotion, and placement), interpreted from the point of view of the degree of notoriety of the activity.

Low level of awareness, lack of education in this regard and relatively reduced responsibility in terms of purchasing behavior are some of the main reactions and types of response to sustainable practices faced by companies inclined to make these changes in society, for a better, cleaner, and healthier world. For example, as stated also by one of the companies in our research, the competition brought by the fast fashion industry to those companies that produce responsibly, from organic materials, without artificial dyes and encourages recycling and reuse, is seen as an effect of overproduction and non-compliance with the principles of circularity. In this sense, the importance of adopting responsible

behavior, both by companies and by consumers, becomes a decisive factor in determining future trends.

3.8. Attracting new customers by adopting a sustainable business model

Depending on the sustainable business model defined by experts through the lens of several categories, such as: social entrepreneurship, corporate intrapreneurship, creativity, innovation, and other approaches to sustainability challenges (Nikolay Dentchev, et al., 2016), we can appreciate qualitative answers in accordance with the companies' industry.

Thus, the 7 answers directed us towards the opinion according to which the level of awareness of the concept of sustainability in Romania is increasing, this being supported by the massive digitization present in many sectors of activity, including by adoption of IoT technologies, and above all, complemented more and more by the human behavior in their daily activities. The fact that people understand that resources are becoming limited due to the climate events experienced in the last decades, the level of responsibility gains a larger scope by supporting innovative solutions. That is why we can appreciate that the result of this particular question could be summed up in the following conclusion: the future belongs to the circular economy with an important touch coming from digitalization and its IoT resources.

3.9. Recommendations for those companies that find themselves during the thinking process on how to do it and with the emphasis on digitalization and IoT

The transition to a sustainable business model through digitalization represents a state of the art of the contemporary period, in relation to the social, environmental, and economic challenges of this world. From a broad perspective, we could note that the goal is only one: to contribute together to combating the negative effects we face at global level, without affecting economic efficiency. Joint efforts, governmental support and clear directions represent the premises for a company that would like to remain on the business map of the future.

The related answers of the 7 companies outline the concept of the importance of digitization, as well as its implementation in a responsible way. Calculating the carbon footprint, as well as finding and adopting solutions to help with this, it is another factor that should be taken into account. Also, innovation, hand in hand with research, reflects the future trajectory of any business that wants to be in the market trend, bringing, through its activity, value to society. Investments in human capital, development, and motivation towards sustainability practices, as well as those in innovative equipment or software, all these represent an increase in efficiency, alignment to the new business models and, even if they imply costs, an opportunity that they are not allowed to miss.

4. Methodology

During our research we have used a structured approach of a qualitative interview run through internet/ Google forms, on a number of 7 companies directly involved or already applying concepts of circular economy, but also with a digital component - IoT. We have used the structured approach because even if it gave us limited flexibility, our goal was to collect similar and realistic facts without any external intervention.

The interview consisted in 11 questions starting from those to identify the person and its role in the company and the company and its area of activity to the specific in which we tried to find out in which they have adopted concepts of the Circular Economy, how did they use digitalization and IoT in they endeavor towards sustainability, highlighting also the resources that they used. We have focused also on their marketing strategy through which they have promoted the new business circular model applied, but also to talk about the future, lessons learnt and next steps towards sustainability.

The questionnaire started from identifying the area of activity of the said companies and went through: 1. The United Nations' 17 Sustainable Development Goals (SDGs), highlighting those that were undertaken; 2. Reasons for adopting a sustainable business strategy; 3. Digital tools used on their way to sustainability and if these tools helped them; 4. Resources needed and used for this new approach; 5. Ways of communicating their business model and how it was perceived by the public; 6. Sharing their experience and best practices for other companies who are on their way towards sustainability through digital tools.

The answers for our qualitative questionnaire have been received over a period of 6 weeks from 7 companies that came back with extensive answers.

It is quite clear that society as a whole had and has a big influence in running various businesses. Highlighting the tools that emphasize the responsibility of a company, we find the relationship between the circular economy and IoT to be essential, as an element of awareness, development, and regulation of a green future. Even if there is still room of improvement, the methods adopted being quite basic at this moment in Romania, the rate of implementation of innovations is increasing. Following this idea, we can see more and more businesses that promote sustainability among consumers or partners, contributing to combating the challenges we face at global level: from pollution to waste or overproduction, we are dealing with a series of effects of activity generated by large industries as a response to consumer behavior.

The main findings of this work, according to the answers generated after the qualitative interview, direct us to the following facts:

- More and more companies are starting to make the transition towards a sustainable business model with the help of the IoT component, understanding the effects of a reasonable activity supported by digitization.
- Sustainable Development object number 12: sustainable consumption and production, is the most assumed by the majority of companies that support sustainability both inside the company and outside it.
- The adoption of digital solutions for business, although it represents a must have of this modern period, is part of the future strategy of a green company.

Starting from the principle, “the more you reuse, the more you reduce”, we should also consider the value chain of the companies. This principle of circularity is applied to the area of raw materials and re-use resources and highlights a series of measures one should adopt to reduce the carbon footprint, such as circularity. Thus, the ultimate goal is the reduction of carbon footprint, circularity being a measure that companies take in this regard.

The most interviewed companies responded that they use a digital management system in their activities, setting meetings on digitals platform and trying to reduce the use of paper. Also, using rental services instead of buying various products and materials is a big contribution to the achievement of a sustainable behavior, regardless the industry. One of the answers stated that the calculation of the carbon footprint is an essential aspect for their organization, but it should be for any other organization that wants to become responsible now and in the future. The level of emissions generated by the activities started may be different depending on the field, but the hypothesis of trying to protect the natural, social, and economic environment should not be excluded and even more, to be of utmost importance for their future. This must also be supported by the application of the main principles of circularity, which through repair, reuse, and recycling, contribute to the image of a company that wants to be seen as sustainable.

5. Conclusions

Nowadays, sustainable development is seen as a trend among companies willing to become responsible, while maximizing their profit through environmentally friendly methods, but also emphasizing future directions in the entrepreneurial field. The transition towards sustainability brings both opportunities and challenges on a domestic or global level, also representing an innovative concept that highlights the interconnected system between the Circular Economy and the Internet of Things. Starting from the concept of "common journey" [5], we appreciate the fact that transition comes hand in hand with trends.

Exploring the future by adopting sustainable business models among companies that aim to be present on the market through innovations, technology, and artificial intelligence, is

one of the options, but also the opportunity of this era. The role of technology within a circular economy is becoming more and more critical, the in-depth of this transition from linearity to circularity being given by the complexity of recycle, reuse, and reduce processes. Boosting a company's potential could be activated by implementing technology-based solutions. Increasing the degree of responsibility could be achieved by adopting activities that respect the principles of circularity in relation to the environment, society, and governance pillars.

In this paper, in order to find out the perception of companies about the status of the transition towards a sustainable business model, a contemporary approach was highlighted through the launch of this qualitative endeavour. The use of different industries, such as sustainability consulting, fashion, technology, packaging, and non-financial reporting, have helped the design of this research in an academic and professional way, reflecting the status quo of the Romanian market. Understanding the motivations of the 7 companies that appeared in the interview, we have been able to highlight the emerging role of the IoT component in the activities they are already undertaking, as well as in the future strategy present in the mission, vision and values designed in a responsible way. Circular economy is increasingly attracting the attention of companies, being part of the strategy of rethinking their image in the market, from the point of view of the assumed sustainable development objectives.

Considering what it was mentioned during this paper, as well as the results drawn with the help of the interview, the combination of some premises found in the specialized literature with the main findings highlighted on the basis of a qualitative research, we could state the fact that today's businesses undertake lots of efforts towards a responsible activity model, having in mind the environmental, societal and economic aspects, realizing the importance of digitization in all the sectors of the activity that they carry out. Investing in the resources of the company, such as financial, human, or material, also represents a defining point of an ecosystem of exploitation, production and sale and implicitly clearing, reusing, and reducing resources, with medium and long-term effects.

In conclusion, the relationship between the circular economy and the Internet of Things, seen as an interdependent relationship encompassed in the activity of companies with sustainable perspectives, underlines the important perception of the concept of sustainability in Romania, both from the point of view of companies that channel their efforts towards the reconfiguration of an ecological model, as well as of consumer, which dictates the demand in the market at a certain moment, for a certain industry. In this sense, niche industries, such as those presented in this qualitative research, are the central element of a future economy, a circular economy characterized by innovation, digitization, and technological interconnectivity.

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DESIGNING AN ICT TOOL FOR ENTREPRENEURSHIP AS AN ONLINE PLATFORM FOR THE GREENBE ERASMUS PLUS PROJECT

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Abstract

When designing an online ICT tool for entrepreneurship, several factors need to be considered. The tool needs to be user-friendly and intuitive. Entrepreneurs are busy individuals who don't have the time to learn complex software systems. Therefore, the online tool should be easy to use, with clear and concise instructions, to enable entrepreneurs to focus on their core business activities. Designing an online ICT tool for entrepreneurship is an exciting and challenging endeavor. It requires a deep understanding of the needs of entrepreneurs and a passion for using technology to drive innovation in the field of entrepreneurship. With the right design principles, an online ICT tool for entrepreneurship can provide entrepreneurs with the tools they need to succeed in today's competitive business landscape.

Keywords: ICT, Entrepreneurship, e-Learning, social media

JEL Classification: L26; M15

1. Introduction

The GreenBE ICT Tool for entrepreneurship has to be designed and used by the Biotech students is part of the GreenBE project supported by the Erasmus+ Strategic Partnerships project 2021-1-RO01-KA220-HED-000032162 which has as general objective develop an innovative educational framework for Biotech & Economics HE graduates from Romanian, Spanish, Italian and Greek partners toward a Biotech Green Entrepreneurial pathway, able to support the Biotech sector to solve environmental and climate change problems.

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It requires a deep understanding of the needs of entrepreneurs and a passion for using technology to drive innovation in the field of entrepreneurship. With the right design principles, an online ICT tool for entrepreneurship can provide entrepreneurs with the tools they need to succeed in today's competitive business landscape.

2. The need of an ICT tool for entrepreneurship

The tool should be tailored to the specific needs of entrepreneurs. Different entrepreneurs have different requirements depending on their business type and size. Therefore, the tool should be customizable to meet the unique needs of each entrepreneur. This customization should include features such as templates, analytics, and customization options to enable entrepreneurs to create business plans, analyze their financial data, and track their progress.

The tool should be cloud-based. Entrepreneurs are always on the move, and they need to access their business data from anywhere, at any time. A cloud-based tool will enable entrepreneurs to access their business data from any device with an internet connection, allowing them to manage their business on the go.

The tool should be secure and Entrepreneurship [4] involves sensitive business data that needs to be protected from unauthorized access. Therefore, the online tool should have robust security features, such as encryption and secure authentication, to protect against data breaches and cyber-attacks.

The tool should have a reliable customer support system. Entrepreneurs may encounter technical difficulties when using the tool, and they need a responsive and reliable customer support system to resolve any issues they may encounter promptly.

3. Components and Structure

The structure of an ICT (Information and Communication Technology) tool for entrepreneurship will depend on the specific needs and objectives of the tool. The key elements and strategies for developing web platforms [3] that are relevant and effective for today's entrepreneurs are presented in the next paragraphs.

Defining the Target Audience

The first step in creating a modern ICT software web platform for entrepreneurship is to identify the target audience. Entrepreneurs come from different backgrounds and have different needs, which means it is crucial to conduct thorough research to understand the audience. The research should include the target audience's age, income, education level, location, and other relevant factors that will help in developing a web platform that meets their needs.

User Experience

A key aspect of modern ICT software web platforms for entrepreneurship is user experience. Entrepreneurs need an intuitive and user-friendly platform that they can navigate easily. The web platform should be designed with the user in mind, taking into consideration their needs, preferences, and level of technical proficiency.

Mobile Responsiveness

In today's digital world, mobile responsiveness is essential. Modern ICT software web platforms for entrepreneurship should be optimized for mobile devices, ensuring that entrepreneurs can access the platform on-the-go. This means developing a web platform that is responsive to different screen sizes and devices.

Scalability and Integration with Key Business Tools

Entrepreneurs need a web platform that integrates seamlessly with key business tools such as payment processing, customer relationship management (CRM) software, and marketing automation tools. This integration allows entrepreneurs to manage their business operations more efficiently and effectively.

Security

Security is crucial for modern ICT software web platforms for entrepreneurship. Entrepreneurs need a platform that is secure and protects their sensitive business data from cyber threats. The web platform should be designed with robust security features that protect against hacking, data breaches, and other security threats.

Customization

Entrepreneurs have unique business needs, and a modern ICT software web platform for entrepreneurship should allow for customization. The platform should be flexible enough to allow entrepreneurs to customize it to their specific business needs. This customization should include branding, user interface, and functionality.

Data Analytics

Data analytics is an essential aspect of modern ICT software web platforms for entrepreneurship. Entrepreneurs need a web platform that provides them with valuable data that they can use to make informed business decisions. The platform should be designed with robust data analytics tools that help entrepreneurs track key metrics such as customer engagement, sales, and revenue.

Cloud-Based Technology

Modern ICT software web platforms for entrepreneurship should be built on cloud-based technology that provides entrepreneurs with flexibility and scalability. Cloud-based platforms allow entrepreneurs to access their business data from anywhere, anytime, and on any device. Additionally, cloud-based technology provides scalability, which means that the platform can grow with the business needs of entrepreneurs.

Artificial Intelligence (AI)

AI is transforming the business landscape, and a modern ICT software web platform for entrepreneurship should leverage AI

Customer Support

Entrepreneurs need a web platform that provides them with efficient and effective customer support. The platform should be designed with features that enable entrepreneurs to reach out to customer support via different channels such as phone, email, and chat. Additionally, the platform should have a knowledge base that provides entrepreneurs with answers to frequently asked questions. Figure 1 encompasses the main drive functions for the GreenBE ICT tool for entrepreneurship.

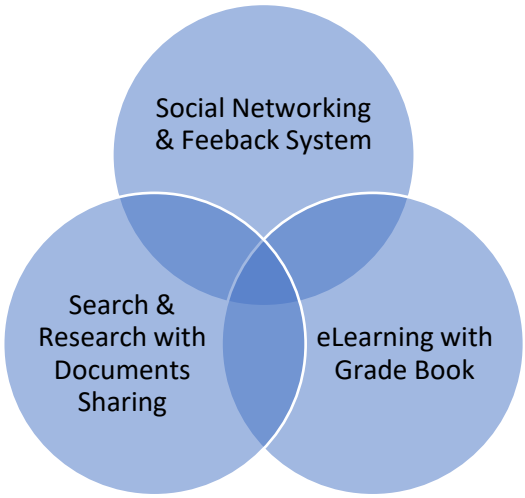

Figure 1 - Main functions for the GreenBE platform

Social media is a powerful marketing tool used in the GreenBE ICT, and a modern ICT software web platform for entrepreneurship should allow for social media integration. The platform is designed with features that enable the researchers to share their content on the integrated social media module. This integration helps entrepreneurs to reach their colleagues and community for a broader audience and increase their research visibility and feedback.

Entrepreneurship is a team effort, and the GreenBE ICT software web platform for entrepreneurship allows collaboration. The platform is designed with features that enable entrepreneurs to collaborate with team members, partners, and colleagues. Collaboration features include real-time collaboration tools such as chat, and document sharing.

A modern ICT software web platform for entrepreneurship should be designed with a robust content management system. The CMS feature inside GreenBE ICT allows users to create, edit, and publish content on their web space without the need for technical skills.

Additionally, the CMS is designed with modules that enable entrepreneurs to optimize their content for search engines.

The eLearning module of the GreenBE ICT platform has the implementation of Microlearning which is a function that breaks down course materials into smaller, bite-sized pieces. This approach is particularly useful for students in green entrepreneurship who have limited time and need to learn on the go. With microlearning, students can quickly access the information they need and learn at their own pace.

The platform is developed on a MySQL database with PHP web programming. The open-source programming languages have been used to accompany the idea of the GreenBE project to offer the platform for public use for both the trainers and the students in the field of Green Entrepreneurship through the use of the worldwide cloud services.

The descriptive screen capture from the GreenBE in figure 2 shows the main menu presenting the main functions and the actual page of the Social Networking Module with the active working account of one of the authors of this book chapter.

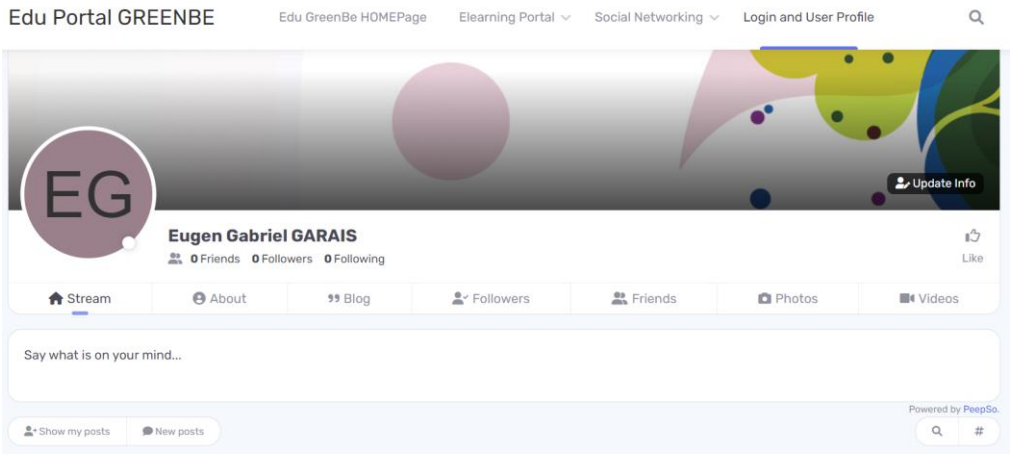

Figure 2 - Main functions for the GreenBE platform [5]

3.1 e-learning module for the ICT tool for entrepreneurship

The e-learning modules are designed to be interactive and engaging, with quizzes, assessments, and other activities that help entrepreneurs reinforce their learning.

In addition to e-learning, an ICT tool for entrepreneurship with social media modules provides entrepreneurs with a platform to connect and collaborate with other entrepreneurs and industry experts. The social media module allows entrepreneurs to share ideas, ask questions, and get feedback from their peers. They can also network and build relationships that can be valuable for their businesses.

In today's fast-paced business environment, entrepreneurs need to stay up-to-date with the latest knowledge and skills to succeed. eLearning [1] is a powerful tool that can be used to provide entrepreneurs with the resources and training they need to start, run, and grow their businesses. By using an eLearning plugin or module with courses and quizzes on an online platform for entrepreneurship, entrepreneurs can learn at their own pace and on their own schedule.

An eLearning plugin or module with courses and quizzes on an online platform for entrepreneurship can be a valuable addition to any entrepreneur's toolkit. Here are some benefits of using an eLearning plugin or module with courses and quizzes on an online platform for entrepreneurship:

Self-paced learning: eLearning allows entrepreneurs to learn at their own pace and on their own schedule. This is particularly important for entrepreneurs who are busy running their businesses and may not have time for traditional classroom-based training.

Flexibility: eLearning can be accessed from anywhere with an internet connection, which means entrepreneurs can learn from anywhere in the world. This can be particularly useful for entrepreneurs who live in remote areas or who travel frequently.

Interactive learning: eLearning can be designed to be interactive and engaging, with courses and quizzes that test knowledge and skills. This can help to reinforce learning and improve retention.

Cost-effective: eLearning can be more cost-effective than traditional classroom-based training, as it eliminates the need for travel, accommodation, and other expenses associated with traditional training.

When choosing an eLearning plugin or module for an online platform for entrepreneurship, it's important to choose one that is user-friendly and easy to use. The plugin or module should offer a wide range of courses and quizzes that cover topics relevant to entrepreneurship, such as business planning, marketing, finance, and management.

Using an eLearning plugin or module with courses and quizzes on an online platform for entrepreneurship can be a valuable tool for entrepreneurs. By providing access to high-quality training and resources, eLearning can help entrepreneurs to stay competitive and grow their businesses.

3.2 Social-Media and Networking module for the ICT tool for entrepreneurship

Social media has become an essential part of our daily lives, and it has also become a crucial tool for entrepreneurs to promote their businesses and connect with customers. Social media can be used to build brand awareness, generate leads, and drive traffic to a website. When social media modules are added to an online platform for entrepreneurship e-learning, it

provides entrepreneurs with additional resources and tools to learn and collaborate with others in their field.

Social media plugins or modules on an online platform for entrepreneurship e-learning can be used to create a more engaging and interactive learning experience. Here are some benefits of using social media plugins or modules on an online platform for entrepreneurship e-learning:

Increased engagement: Social media modules can be used to encourage learners to interact with each other and with the course material. For example, learners can share their thoughts on a discussion board, collaborate on a project, or provide feedback on their peers' work. This can help to increase engagement and retention.

Real-world examples: Social media modules can be used to showcase real-world examples of entrepreneurship in action. For example, learners can follow successful entrepreneurs on social media and learn from their experiences.

Networking opportunities: Social media modules can be used to facilitate networking opportunities between learners and industry experts. For example, learners can connect with entrepreneurs, investors, and other professionals on social media platforms like LinkedIn.

Brand awareness: Social media modules can be used to promote the online platform for entrepreneurship e-learning and increase its visibility. For example, learners can share their progress on social media and encourage their followers to sign up for the course.

When choosing a social media plugin or module for an online platform for entrepreneurship e-learning, it's important to choose one that is user-friendly and easy to use. The plugin or module should integrate seamlessly with the platform, and it should be easy to set up and configure.

Social media plugins or modules can be a valuable addition to an online platform for entrepreneurship e-learning. By using social media, entrepreneurs can learn from each other, connect with industry experts, and promote their businesses.

3.3 Search & Research with Documents Sharing module for the ICT tool for entrepreneurship.

As biotech [2] entrepreneurship continues to grow, there is an increasing need for students to have access to tools that can help them search and research the latest developments in the field. An online platform for entrepreneurship biotech students that includes document sharing capabilities can be a powerful tool to meet this need.

With document sharing, students can access research papers, scientific journals, and other industry publications in real-time. They can also collaborate on projects and share their own research with peers and mentors, enabling them to work more effectively as a team.

One of the key benefits of document sharing is that it can save time and reduce duplication of effort. Rather than spending hours searching for relevant research, students can access a centralized repository of documents that have already been curated and organized for them. This can be especially helpful for students who may be working on multiple projects simultaneously, as they can easily find and access the information they need.

In addition to saving time, document sharing can also facilitate collaboration among students and mentors. By allowing multiple users to access and edit documents simultaneously, document sharing tools enable students to work together on projects and share their ideas and insights with each other. This can help to foster a sense of community and encourage students to learn from each other.

Moreover, document sharing can enable students to stay up-to-date with the latest developments in the biotech industry. By accessing and sharing research papers and scientific journals, students can learn about new discoveries and developments in the field, and stay ahead of the curve.

Finally, document sharing can be an invaluable resource for biotech entrepreneurs who are seeking funding or looking to commercialize their research. By sharing their work with potential investors and business partners, entrepreneurs can gain valuable feedback and insights that can help them refine their ideas and take their businesses to the next level.

In conclusion, document sharing is a valuable tool for biotech entrepreneurial students who are seeking to stay up-to-date with the latest developments in the field. By providing access to research papers, scientific journals, and other industry publications, document sharing tools can save time, facilitate collaboration, and enable students to learn from each other. As biotech entrepreneurship continues to grow, document sharing is likely to become an increasingly important tool for students and entrepreneurs alike.

4. Benefits of combining e-Learning with Social-Media in an ICT platform for entrepreneurship

In today's digital age, entrepreneurs need to stay ahead of the curve when it comes to technology and business practices. An online ICT platform for entrepreneurship that combines e-Learning, social media, and document sharing modules can provide a powerful suite of tools that can help entrepreneurs achieve their business goals. In this article, we'll explore the benefits of combining these modules in an online platform for entrepreneurship.

Increased engagement: The combination of e-Learning, social media, and document sharing modules can help entrepreneurs to engage with each other and with the course material in new and innovative ways. For example, learners can share their thoughts and ideas on a discussion board, collaborate on a project, and provide feedback on their peers' work.

Real-world examples: The integration of social media and document sharing modules can be used to showcase real-world examples of entrepreneurship in action. Learners can follow successful entrepreneurs on social media and learn from their experiences, or access case studies and other resources through the document sharing module.

Networking opportunities: Social media modules can be used to facilitate networking opportunities between learners and industry experts. For example, learners can connect with entrepreneurs, investors, and other professionals on social media platforms like LinkedIn.

Flexibility: The combination of e-Learning and document sharing modules allows entrepreneurs to learn at their own pace and on their own schedule. They can access course materials and other resources anytime, anywhere, as long as they have an internet connection.

Customization: An online platform for entrepreneurship that combines e-Learning, social media, and document sharing modules can be customized to meet the specific needs of learners. For example, learners can choose to follow specific topics or experts on social media, or access only the course materials that are relevant to their particular business.

Cost-effective: The integration of e-Learning, social media, and document sharing modules can be more cost-effective than traditional classroom-based training. It eliminates the need for travel, accommodation, and other expenses associated with traditional training.

Combining e-Learning, social media, and document sharing modules in an online ICT platform for entrepreneurship can provide a powerful suite of tools that can help entrepreneurs achieve their business goals. By providing access to high-quality training and resources, networking opportunities, and real-world examples of entrepreneurship in action, this type of platform can help entrepreneurs stay competitive and grow their businesses.

5. Need and opportunity to develop an e-Learning tool with social media integration for biotech entrepreneurial students

Biotech is a rapidly growing industry, and as a result, there is a growing demand for biotech entrepreneurs. Biotech entrepreneurial students need to learn not only the technical aspects of industry but also the business aspects, such as finance, marketing, and management. e-Learning tools with social media integration can provide biotech entrepreneurial students with a unique opportunity to learn and grow in this exciting field.

One of the biggest advantages of e-Learning tools with social media integration is that they allow biotech entrepreneurial students to learn at their own pace and on their own schedule. This is particularly important for students who may be working part-time or have other responsibilities outside of school. With e-Learning tools, students can access course materials, lectures, and other resources anytime, anywhere, as long as they have an internet connection.

Social media integration in e-Learning tools can also provide students with a powerful tool for networking and collaboration. Social media platforms like LinkedIn and Twitter can be used to connect with industry professionals, potential mentors, and other students. This can help biotech entrepreneurial students to build their network, stay up-to-date on the latest industry news, and find new opportunities.

In addition, e-Learning tools with social media integration can provide biotech entrepreneurial students with a unique opportunity to learn from industry experts. Guest lectures, online forums, and social media platforms can all be used to connect students with experts in the field. This can provide students with valuable insights into the biotech industry and help them to develop a deeper understanding of the industry's challenges and opportunities.

The need for biotech entrepreneurial students to develop a wide range of skills, from technical to business, is more important than ever. e-Learning tools with social media integration provide an excellent opportunity for students to learn and grow in this exciting field. With their flexibility, networking opportunities, access to industry experts, and cost-effectiveness, e-Learning tools are an essential tool for the biotech entrepreneurs of tomorrow.

Finally, e-Learning tools with social media integration can be more cost-effective than traditional classroom-based training. This is particularly important for biotech entrepreneurial students, many of whom may be working with limited budgets. By eliminating the need for travel, accommodation, and other expenses associated with traditional training, e-Learning tools can help biotech entrepreneurial students to access high-quality training and resources without breaking the bank.

5. Conclusions

As a conclusion the benefits of a the GreenBE ICT Platform with eLearning plus Social Media Capabilities are the Improved Engagement, Accessibility, Personalization and Analytics. The GreenBE ICT Platform with eLearning plus social media capabilities can improve student engagement by creating a sense of community and a shared learning experience. Students are more motivated to learn when they feel connected to their peers and educators. The users can set learning goals, track their progress, and receive feedback on their performance. Additionally, personalized learning paths can be created for each student to ensure they are receiving the best possible learning experience. Personalization is a key benefit of a platform with eLearning plus social media capabilities. With personalized learning paths, students can receive the best possible learning experience tailored to their unique needs and preferences. Analytics can provide valuable insights into student performance, course effectiveness, and areas of weakness.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN TEACHING ENGLISH FOR SPECIFIC PURPOSES

Mariana COANCĂ[1]

Abstract

Globalization and technological breakthroughs have determined the emergence of new jobs and, thus, professional terminologies have enriched with new terms related to work tasks. The development of professional terminologies requires terminology updates, therefore the teaching methodology of English for Specific Purposes (ESP) has to be constantly improved, according to the realities in a profession or industry. The aim of this paper is to highlight the role of ChatGPT in the ESP teacher's methodology. I analyzed this AI language model, taking account of the linguistic features of our digital discourse. The findings suggest that ChatGPT can be a useful tool in planning lessons and assessing students' linguistic competence.

Keywords: artificial intelligence, language model, testing, digital discourse, ESP, methodology

JEL Classification: Z13

1. Introduction

English for Specific Purposes (ESP) focuses on building teaching strategies for the acquisition of professional terminologies. Thus, students get familiar with the specialized vocabulary and language used within the economic field and IT industry. This vocabulary includes the jargon, acronyms and expressions that are used by professionals in this field and industry. When students acquire a standardized set of terms, their communication displays the following characteristics:

- It is precise and clear ensuring effective collaboration between them and other professionals;
- It is efficient and concise because the students express complex ideas and concepts through abbreviations, acronyms and single words that are understood within the respective professional community;
- It highlights their expertise and shapes their professional identity; some students have been working since the first year of study so they master the language used in

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their workplace as they communicate with their peers, build trust with collaborators and follow the professional standards;

- It accelerates knowledge transfer within their chosen profession. When the knowledge transfer occurs, the collaboration among people at work strengthens leading to increased productivity;
- It decreases the stress levels when students have to make presentations in front of an audience or a committee, for example, when they present a project or defend their bachelor thesis.

It is very important in communication, however, that when we address the non-specialized or heterogeneous public, we must explain the specialized terms and reiterate some aspects related to the context to make ourselves understood.The enrichment of the English language with new terms and expressions during the Covid-19 pandemic and the migration of specialized terms to the common language has shown us that the relationship between the specialized lexicon and the common one intensifies not only when technology plays an increasingly important role in the life of each individual but also when humanity faces uncertainty and difficulties at the social, economic, educational, etc. level. For example, many terms from various professions migrated to the common language, due to their frequent use in the media, the political discourse, the leadership discourse, etc. (e.g. state of alert, ordinance, asymptomatic, remote students, remote work, distancing, quarantine, etc.)

From the perspective of external terminology, the specialized terms are frequent in widely circulated texts and in mass media texts which can have a medium degree of specialization or a lower degree of specialization [1]. According to the linguistic research, the variation of the conceptual and semantic content depends on the contexts in which the specialized term appears. This is important for identifying the values correctly and for establishing the degree of decontextualization/contextualization as well as for indicating the semantic deviations made contextually in widely circulated texts [2].

ESP research has been conducted to advance the understanding of ESP as a discipline hence many empirical studies and practical investigations have been published. We consider that Anne Burns is a major contributor to ESP research, especially in the area of language teaching and learning.

Some educators and researchers [3] have voiced the differences between the generations of students who have acquired the foreign language, depending on technological innovations, university curricula and the ability of teachers to introduce digital tools in its teaching. My opinion is that we cannot say about one generation that it is better than the other because it is absolutely normal to see differences among generations, to accept different views of the

members of a generation, preferences and perspectives of technology usage. Indeed, the young people are called "digital natives" but we must identify their needs then we must strive to meet their needs by diversifying the teaching methods and by using as many digital tools as possible to capture their attention and to motivate them to achieve the tasks within the classes. We have also noticed the fact they value autonomy granted by the digital tools they use, which is reflected in their way of handling the tasks in classes.

Furthermore, many studies [4], have contributed to our understanding of the learning style and characteristics of digital natives. Although there are different perspectives on the learning style of digital natives, we believe that young people have diverse learning styles and preferences, therefore the impact of technology should be analyzed in accordance with the major corresponding to the chosen educational program or school. For instance, sometimes a Law School student does not have the same multitasking abilities or information processing speed as a Computer Science student. We constantly see that digital natives are able to skim through content to find relevant information. However, sometimes what is relevant to them while skimming does not comply with the requirements of a subject. Thus, our major concern is their lack of responsibility because sometimes they take the information as is without checking other sources that are scientifically valid.

If we consider such individual differences and various contextual factors we can conduct better and better analysis on students' digital literary, collaboration and attention span & concentration in ESP settings.

2. Testing AI Language Models

ChatGPT is an advanced language model developed by Open AI. It acts like a chatbot relying on natural language processing (NLP) to analyze and generate human-like text in response to text-based inputs or questions. This process entails a combination of computational algorithms, statistical models, and linguistic rules to understand and generate language. Its responses are based on a vast amount of language data that have been inputted into its training. Moreover, the responses indicate various forms of digital discourse, such as conversation, information, persuasion, or description, depending on the context and purpose of the communication. The similarities and differences between ChatGPT and other chatbots are presented below:

Similarities	*Differences*
They use artificial intelligence and natural language processing to converse with users.	ChatGPT boasts flexibility and extended functionality while chatbots may have more limited functionality and flexibility.

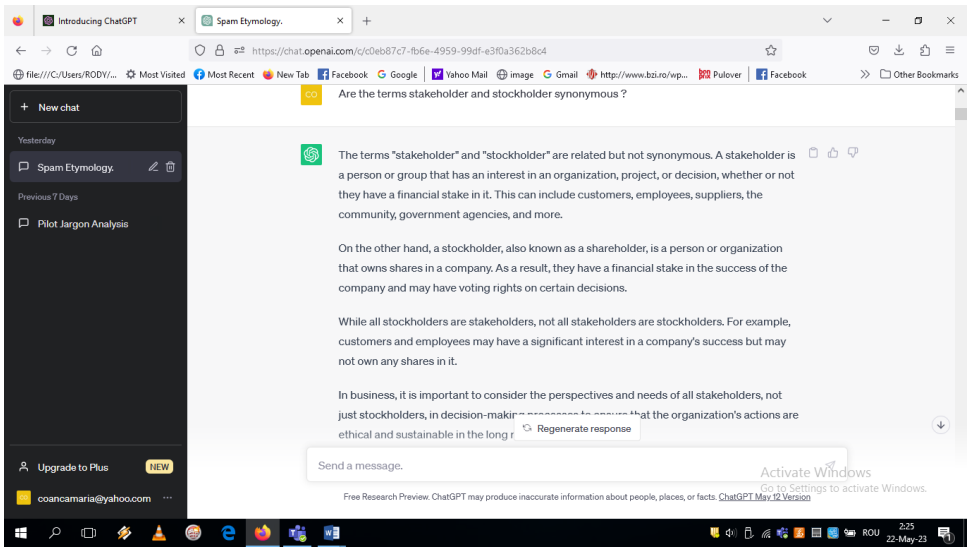
They provide immediate feedback or support as they reply to user questions in real-time.	ChatGPT was created to be a language model that can achieve a wide range of tasks and approach various topics. By contrast, chatbots were designed to achieve specific tasks related to the areas of sales and customer service.
They are programmed to achieve a variety of tasks, such as responding, providing assistance, or achieve tasks on behalf of the user.	ChatGPT relies on machine learning to generate responses similar to texts/answers provided by humans while chatbots often use pre-defined rules or scripts to follow their conversations.

As technology develops, the interest in learning foreign languages grows if the tools used meet the needs of the users. Unlike ChatGPT, Google Bard is a popular tool that uses artificial intelligence to help users learn foreign languages. It is user-friendly as it facilitates the creation of personalized lessons, according to the current language level and individual interests, pronunciation improvement, guiding and feedback from a virtual tutor.

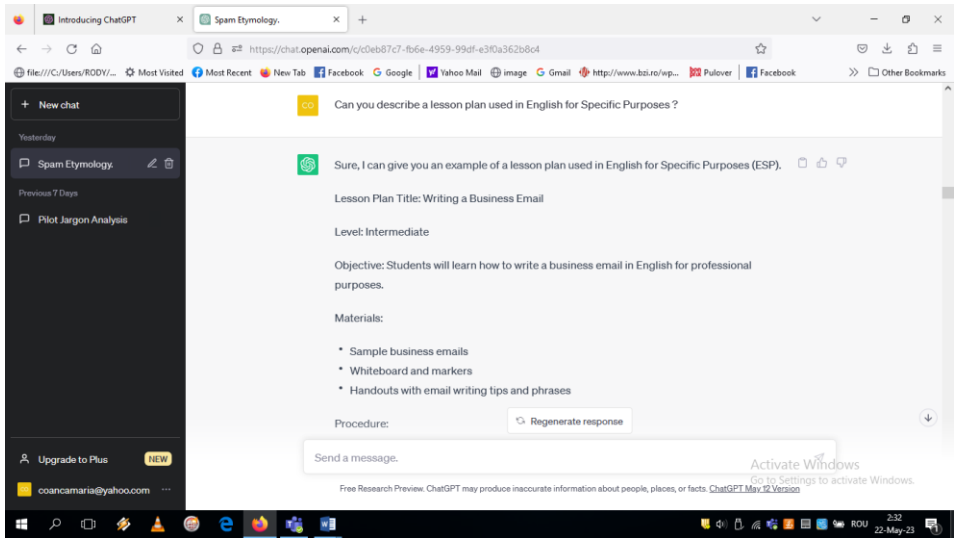
ChatGPT was tested by many experts in various fields. Rodica Zafiu [5], a renowned linguist, contends that "It was not so much the information that impressed me, but the level of the language, the level of grammatical and semantic correctness, the level of discursive coherence. In what I tested, not only was the answer given in sentences that made sense, but there was a coherence of the text, it was seen that a structure was being followed, a general introduction, a conclusion at the end of the answer, an articulation that shows the progress that has been made in this direction."

The first time I tested ChatGPT, I noticed that its answers were more coherent than the answers of my students. In an educational context, our purpose was to ask ChatGPT open ended and probing questions related to the meaning of specialized vocabulary and grammar rules. I also asked it to provide class material such as exercises and tests that could enhance ESP teaching and learning. Therefore, our discourse involved several linguistic features highlighted below:

- complete sentences with clear subjects and predicates, therefore following the rules of sentence structure to convey meaning properly;
- general language that is appropriate to the context and a range of specialized vocabulary, including technical terms and idiomatic expressions;

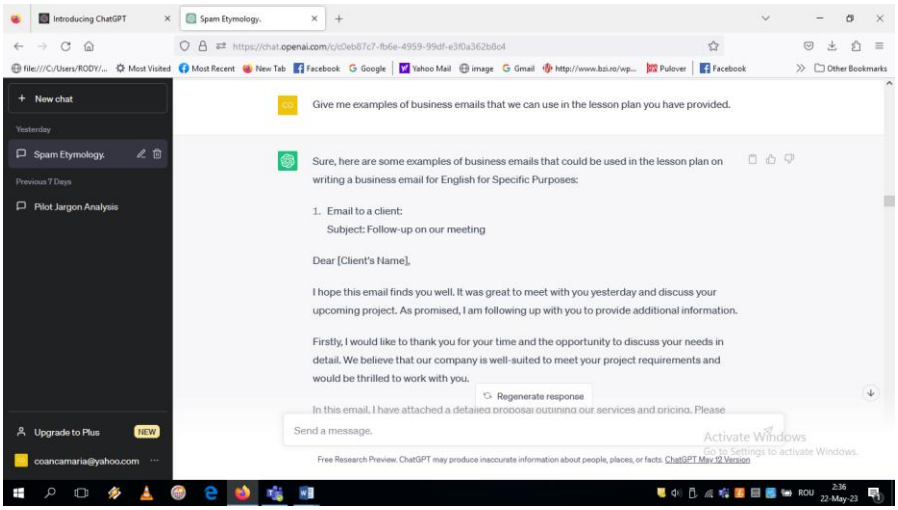


- formal and professional register, as it is expected in many business or academic contexts;



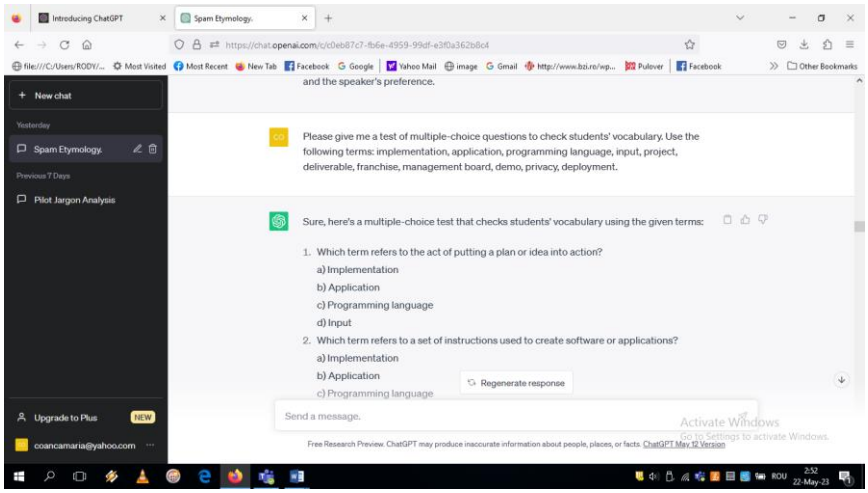
- the rules of syntax were followed, including the use of noun phrases, verb phrases, and other structures, which allow for clear communication;
- cohesiveness as each statement builds on the previous one, and there is a clear connection between ideas;

By examining again the structure of the sentences, the choice of words and phrases, and the overall coherence and clarity of responses, we notice that ChatGPT writes in a logical sequence that is easy to follow, leans on the formal style and uses connectors and linking words adequately.



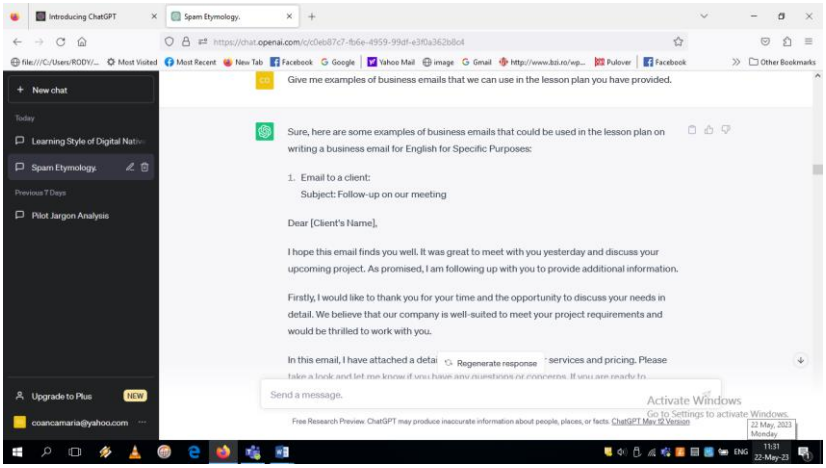
- pragmatic considerations, such as politeness, intention, and ESP context, to ensure that the conversation is appropriate and effective.

I also asked it explicitly to provide class material such as exercises and specific tests that could enhance constant assessment of the notions presented in class.



3. Future Approaches - ChatGPT as a Supplementary Tool in the ESP Methodology

The methodology for teaching Business English incorporates the use of artificial intelligence (AI) as a supplementary tool. This methodology can encompass various approaches as it aims to create an engaging and adaptive learning environment, tailored, as shown in the examples above, to the specific needs of learners. For instance, building a strategy to implement a blended learning approach which combines traditional instruction with digital tools. Resorting to ChatGPT or other language learning apps will give learners additional language practice and feedback through increased interactivity. Given the dynamics of the economic language, we always use authentic business materials such as expert articles, case studies and reports. However, AI can be a reliable partner in this regard as its algorithms can help us select relevant economics-related topics, create content that reflects the etiquette of digital correspondence (see the print screen below), and other material based on students' awareness and preferences, and their language mastery.



Moreover, business communication activities that focus on real-world business scenarios can be empowered by ChatGPT as students will benefit from a safe environment where they can engage in role-plays and simulations related to work procedures.

As for the tutoring and assessment components that we need to include in our methodology, we can implement Intelligent Tutoring Systems, on the one hand, which can check students' performance, identify their strengths and weaknesses and provide guidance for improvement or we can use AI algorithms to assess students' performance in a specific skill of the proficiency spectrum and generate progress reports at individual level or group level, on the other hand. These reports can be used in further research to make comparative analysis to disseminate the findings at international symposia where researchers tackle AI-based teaching methodologies.

Last but not least, we need to evaluate our activity by asking students for constant feedback. This helps us monitor our activity and take measures to make adjustments in the lesson

planning to meet learners' needs or to test other AI-powered tools recommended by our students.

4. Conclusions

Artificial intelligence has already been used not only for teaching foreign languages in general but also for creating differentiated educational content to teach and learn business English. As seen in this study, ChatGPT can be a supplement in the class, and can generate materials that arouse the curiosity of the learners regarding the correct use of specialized terminology.

Moreover, the use of ChatGPT by students to do their homework or various tasks in a few minutes does not stimulate creativity and, at a certain moment, may bring into question ethical considerations. To avoid such situations, teachers must design student tasks that require individual or group intellectual effort.

Our approach emphasizes certain professional situations of using ChatGPT in teaching and learning business English. We also offer concrete examples that reflect the positive role of ChatGBT in creating ESP relevant content given that teacher's requirements are clear, thorough and professional. In conclusion, we would like to pinpoint that ChatGPT is not meant to be a substitute for traditional English learning. It cannot replace human teachers, who through their explanations, guidance and feedback during foreign language courses offer students the opportunity to practice and find out their level of knowledge of the English language.

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ROMANIA'S PRESENT READINESS TOWARDS DIGITAL TRANSITION

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Mona-Maria IVĂNESCU[2]

Abstract

In the present time, the digital economy has become an almost perfectly integrated part of our daily lives, our daily activities, profoundly impacting various sectors and industries and reshaping the global economy. From communication to education, from governance to entertainment, digitalization has filled every aspect of our lives, giving rise to a new concept, namely the digital society. In-depth discussion concerning EU's readiness for digital transition is provided in this article, with a special focus on Romania, it's neighbors members and the EU. Examined are its main causes, how it transforms industries, and how it affects individuals and civilizations. Understanding the dynamics of the digital economy is essential for businesses, policymakers, and individuals alike, as well as for the broader society, as digital technologies continue to evolve at an unprecedented rate.

Keywords: digital economy, digital society, DESI, EU

JEL Classification: O1, O3

1. Introduction

The digital economy refers to the economic all activities that are conducted through digital technologies, networks, and platforms. It encompasses a wide range of sectors, including e-commerce, digital services, online marketplaces, and data-driven innovation. Globally, businesses, governments, and people are all being impacted by the digital economy, which has emerged as a significant driver of economic growth and transformation.

One of the key aspects of the digital economy is the reliance on digital infrastructure. This includes high-speed internet, mobile networks, and data centers that provide the necessary foundation for digital transactions and interactions. Connectivity plays a crucial role in enabling businesses to reach global markets and consumers to access a vast array of products and services. The availability of digital infrastructure is essential for ensuring the smooth functioning of the digital economy.

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Digital technologies are the backbone of the digital economy itself. Innovations as artificial intelligence, blockchain, or the Internet of Things have deeply changed the business environment, almost all industries the society itself. These technologies enable automation, improve efficiency, and drive innovation in various sectors. For example, AI-powered chatbots enhance customer service experiences, while big data analytics provide valuable insights for business decision-making.

New entrepreneurship and innovation opportunities have been made possible by the digital economy. Digital platforms can be used by startups and small companies to penetrate international markets and compete with established firms. The equal playing field created by internet operations' low entry barriers and lower operating expenses has encouraged innovation and economic expansion.

Another significant advantage of the digital economy is enhanced productivity and efficiency. Digital technologies streamline business processes, automate routine tasks, and enable real-time data analysis. This leads to improved productivity and cost savings for businesses. Additionally, the digital economy offers convenience and empowerment for consumers. They have access to a wide range of products and services online, personalized experiences, and convenient shopping options.

In recognition of their critical roles in fostering economic growth, innovation, and societal advancement, the European Union (EU) focuses a lot of attention on both the digital economy and the digital society. The digital economy within the EU refers to the economic activities and transactions that are conducted through digital technologies, networks, and platforms. It encompasses sectors such as e-commerce, digital services, online marketplaces, fintech, digital manufacturing, and data-driven innovation. The EU has been striving to create a digital single market, aiming to remove barriers and harmonize regulations to facilitate cross-border digital transactions, promote fair competition, and enhance consumer trust.

To promote the digital economy, the EU has implemented policies to support innovation and entrepreneurship. The Horizon 2020 program, one of the most important EU's R&I provided framework, and still does, consistent funding and support for digital innovation projects across various sectors. Additionally, initiatives such as the Digital Europe Program[3] and the European Innovation Council[4] focus on driving digital transformation, supporting startups, and fostering digital skills development.

Digital society within the EU focuses on the broader impact of digital technologies on people's lives, communities, and social interactions. It encompasses aspects such as digital inclusion, digital literacy, online safety, and the protection of fundamental rights in the

[3] https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/digital-europe-programme_en
[4] https://eic.ec.europa.eu/index_en

digital realm. The EU recognizes the importance of ensuring that all citizens have access to digital technologies and the skills necessary to navigate and benefit from the digital world.

The EU's digital society initiatives include efforts to bridge the digital divide and promote digital skills development. The Digital Education Action Plan[5] focuses on enhancing digital skills among EU citizens, students, and educators, with a particular focus on promoting digital literacy in schools and vocational training programs. The EU also supports initiatives to enhance online safety, protect personal data, and promote digital rights through regulations such as the General Data Protection Regulation (GDPR)[6].

Furthermore, the EU aims to foster a secure and trustworthy digital environment. Cybersecurity is also a priority, and the EU has established the Cybersecurity Act[7] and the Network and Information Security (NIS) Directive[8] to enhance cybersecurity measures and strengthen cooperation among member states. These initiatives aim to protect critical infrastructure, digital services, and personal data from cyber threats and cyber-attacks.

2. Digital Economy and Society Index

Through the Digital Economy and Society Index (DESI), the European Commission has been constantly evaluating the digital economy and society readiness for all 27 member states. Every year, DESI will release national profiles for each member state, helping every EU member to better identify areas needing urgent action and crucial analysis for supporting policy decisions.

The digital economy landscape today is marked by several key trends and drivers that are shaping its growth and impact:

- technology is advancing quickly, including blockchain, cloud computing, artificial intelligence, and machine learning.
- increasing global internet connectivity and widespread adoption of smartphones
- data has emerged as a distinct asset in the digital economy.
- digital platforms, like the vest ecosystems created by Amazon or Google have become essential instruments of our daily interactions, boosting furthermore the need for digital environment.

[5] https://education.ec.europa.eu/focus-topics/digital-education/action-plan
[6] https://gdprinfo.eu/
[7] https://digital-strategy.ec.europa.eu/en/policies/cybersecurity-act
[8] https://www.enisa.europa.eu/topics/cybersecurity-policy/nis-directive-new

On the other hand, the digital society is characterized by several defining features that shape its operation and collaborations. First, it is characterized by widespread connectivity, with billions of people having access to the internet and digital devices. Secondly, to be able to operate accordingly and to be efficient in all presumed activities, individuals need to possess the ability to navigate digital tools, critically evaluate information, and adapt to evolving technologies.

Overall, the pandemic determined a boost within the existing trends, especially concerning the remote work activities, e-commerce as well as exacerbated labor mobility, specific to some industries. These trends, however, have not affected citizens and enterprises in the same manner, and did not affect all EU member states equally.

Most of the members made significant progress in their digital transformation, the adoption of digital technologies throughout the entire business environment. More and more services, including essential ones, are shifted online.

Finland, Denmark, the Netherlands, and Sweden are the EU frontrunners[9]. The other countries are advancing as well, and some convergence trend can be seen in the EU. Still, there are also members lagged far from the EU average, namely Italy, Poland, Greece, or Romania.

The current geopolitical context, with a war at EU eastern borders make cybersecurity, and the digital society perspective more and more relevant. The risk of online disinformation is a true threat for all of us today, but also to the proper functioning of our democracies, our societies, and our region. As a result, the revision of the EU Code of Practice on Disinformation[10] and the Digital Services Act[11] is expected to ensure decisive measures to counter online disinformation.

In 2021, within the EU, 87% of people (ages 16 to 74) routinely utilized the internet, while only 54% had at least fundamental digital abilities, according to Eurostat statistics. The leaders are the Netherlands and Finland, while Romania and Bulgaria are lagging at the end of the list. Even though most of the employment in the EU demand basic digital skills, a sizable portion of the population still lacks them. Only 19% of ICT professionals and one in three STEM (science, technology, engineering, and/or mathematics) graduates are women, indicating a serious gender imbalance. It is obvious that experts are needed to work in and comprehend the new digital economy and society. In the coming decades, it remains to be seen whether the need for competent work will be met by humans or machines.

In terms of connectivity, even if the EU has full broadband coverage, only 70% of homes have access to fixed very high-capacity networks (VHCN) connectivity, which can provide gigabit speeds[12]. Fixed VHCN encompasses cable DOCSIS 3.1 (data over cable service

[9] https://ec.europa.eu/newsroom/dae/redirection/document/88764 page nr 8
[10] https://digital-strategy.ec.europa.eu/en/policies/code-practice-disinformation
[11] https://digital-strategy.ec.europa.eu/en/policies/digital-services-act-package
[12] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=70034

interface protocol) and FTTP (fiber-to-the-premises) technologies. While DOCSIS 3.1 penetration, according with the same source increased from 28% in 2020 to 32% in 2021, FTTP coverage climbed from 43% in 2020 to 50% in 2021. Coverage of rural fixed VHCN increased as well, rising from 29% in 2020 to 37% in 2021. There is still a considerable disparity between rural and overall statistics. The most advanced Member States in terms of total fixed VHCN coverage are Malta, Luxembourg, Denmark, Spain, Latvia, the Netherlands, and Portugal (all of which have more than 90% of residences covered). Additionally, 5G penetration increased last year, reaching 66% of the EU's inhabited areas.

If, in terms of connectivity, overall, the numbers look good within the EU, only 55% of small and medium-sized businesses had adopted the digital competences to at least a basic level in 2021, a year dominated by the need for online interactions, due to the pandemic. The highest rates of SME digitalization are seen again in Sweden and Finland (86% and 82%, respectively), while the lowest rates are found in Romania and Bulgaria.

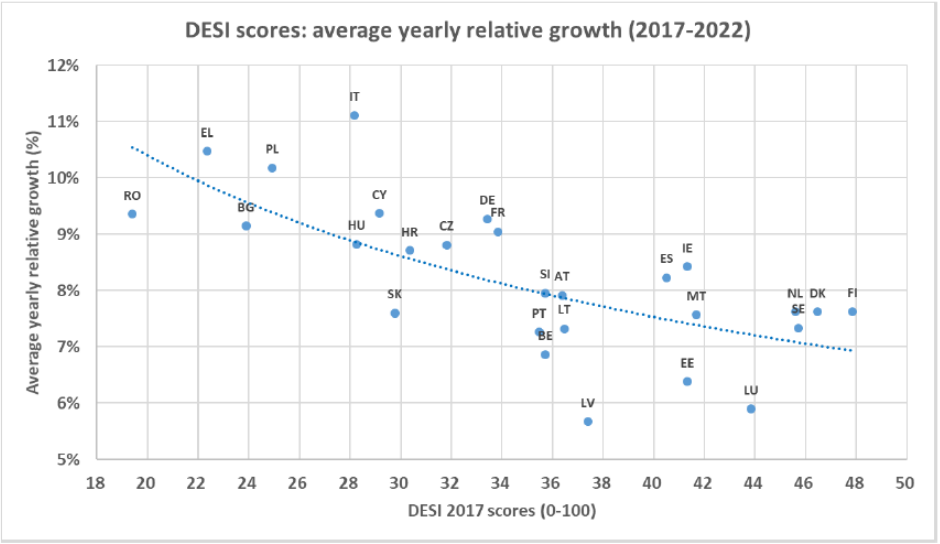

Figure 1. Digital Economy and Society Index – EU Member States' relative progress in the period 2017-2022[13]

The above chart illustrates how Member States have progressed over the past five years in terms of the general degree of digitalization of their economies and societies. Between 2017 and 2022, the EU exhibited a convergence pattern, according to DESI scores. The estimated pattern of convergence is represented by the blue line in the figure. The convergence curve overestimated growth in the nations above the blue line.

[13] https://ec.europa.eu/newsroom/dae/redirection/document/88764 page nr 17

According with the latest report result, Italy is the greatest of the top group because it expanded at a rate that was noticeably faster than anticipated between 2017 and 2022. Germany, Ireland, France, and Poland round out the top 5 overperformers after Poland. In the bottom group of nations, Latvia's score increased significantly more slowly than predicted by the convergence curve, departing from the general pattern of convergence. Along with Luxembourg, Romania, Belgium, Slovakia, and Estonia, these countries significantly stray from convergence.

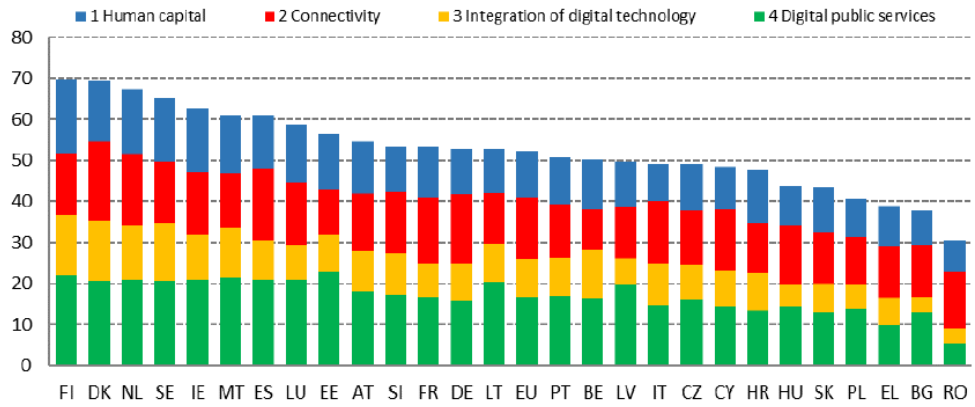

Figure 2. Digital Economy and Society Index, 2022[14]

As it can be seen in the above figure, there are some significant disparities between some western EU member states and most ex-communist eastern countries, one exception here being Baltic member states. Another aspect to be mentioned here is the fact disparities can be identified even among the already group of countries, some countries being better positioned in some categories among their group average or EU average as well.

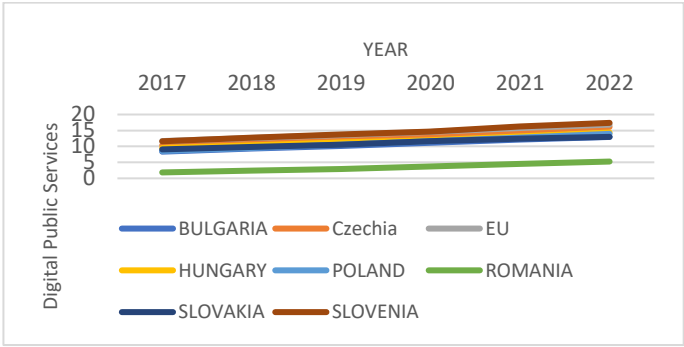

Figure 3. Digital Public Services DESI 2022(EU's average and country selection)[15]

[14] https://ec.europa.eu/newsroom/dae/redirection/document/88764 page nr 19
[15] made by the authors, data source https://digital-agenda-data.eu/datasets/desi/indicators

Discussing the Digital Public Services, we can easily observe the difference between the EU's average and the recorded score obtained by countries such Bulgaria, Poland, or Hungary. But among these countries Romania is showing an almost disastrous situation, with a significant gap compared with Bulgaria or Slovakia, last in line but still ahead of it.

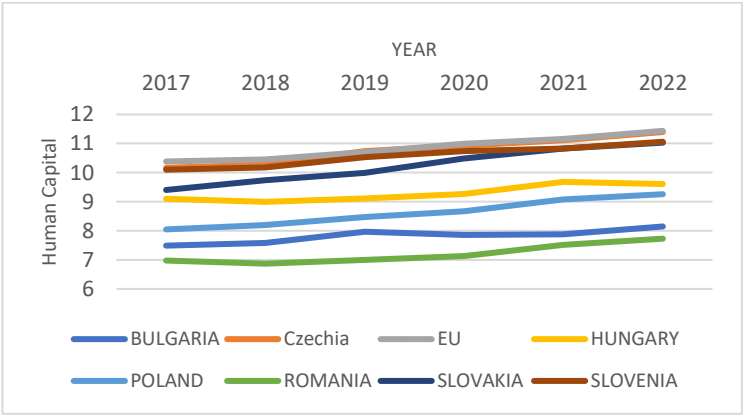

Figure 4. Human capital DESI 2022

(EU's average and country selection)[16]

When we discuss about the Human capital, we may observe in the above figure similar trends for all eastern countries, similar among them and similar with the EU's trend. Still, some countries are closer to the European average score, namely Slovenia or Czech Republic, and countries that are on the right trend but, far from the average, and we can identify in this category Romania, Bulgaria, and Poland.

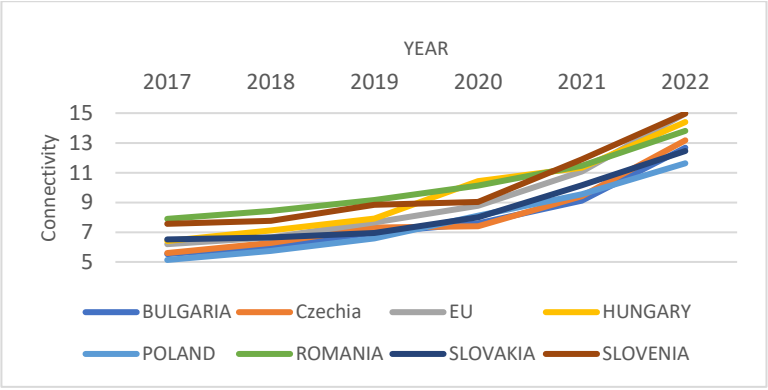

Figure 5. Connectivity DESI 2022, (EU's average and country selection)[17]

[16] made by the authors, data source https://digital-agenda-data.eu/datasets/desi/indicators
[17] made by the authors, data source https://digital-agenda-data.eu/datasets/desi/indicators

Figure 6 reflects maybe the unique place where most former eastern EU member states reflect scores better positioned compared with the EU's average score. Still, countries like Bulgaria, Poland or Slovakia are showing scores below the average, raising a warning signal, because the connectivity is seen as a major communication infrastructure element all over EU. Figure 7, again, reflects the similarities between the recorded scores concerning the Integration of the Digital Technology, and the Human Capital, in a sense of similar trends with, again, most eastern countries lower positioned against the Europe average index.

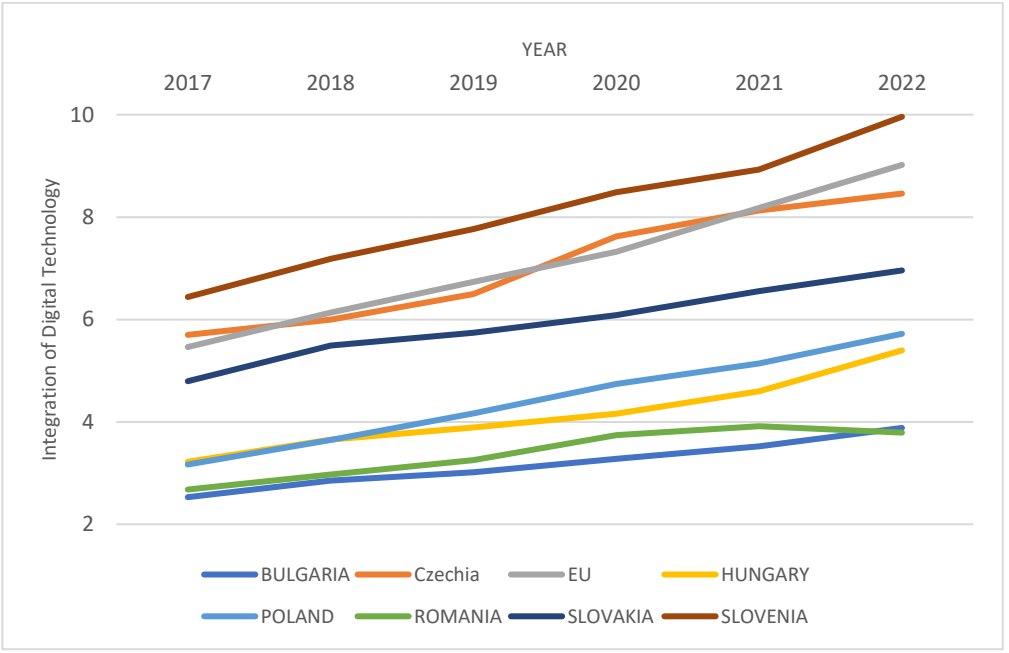

Figure 6. Integration of Digital Technology DESI 2022

(EU's average and country selection)[18]

3. Romania's Digital Economy and Society present situation and perspectives

For our country, as seen, the situation is not good. Romania is ranked 27th out of the 27 EU members in 2022. Importantly, it is not converging with the other Member States as evidenced by the fact that its relative yearly growth lags below that of its peers.

With very low levels of fundamental digital skills compared to the average across the EU, our nation is falling behind on several human capital metrics, but it continues to rank highly for the proportion of female ICT specialists in the workforce (ranking second) and ICT

[18] made by the authors, data source https://digital-agenda-data.eu/datasets/desi/indicators

graduates (ranking fourth). The area where Romania does best is concerning its connectivity, which is comparable to EU's ranks. The adoption of fixed broadband connections with speeds of at least 100 Mbps (57%) and fixed extremely high-capacity network coverage (87%)[19] quite exceeds the EU average.

The slow rate of development and low degree of digitalization are preventing the Romanian economy from fully utilizing the benefits provided by digital technologies. This issue has a very significant impact due to the relatively low level of digital public services for both residents and businesses.

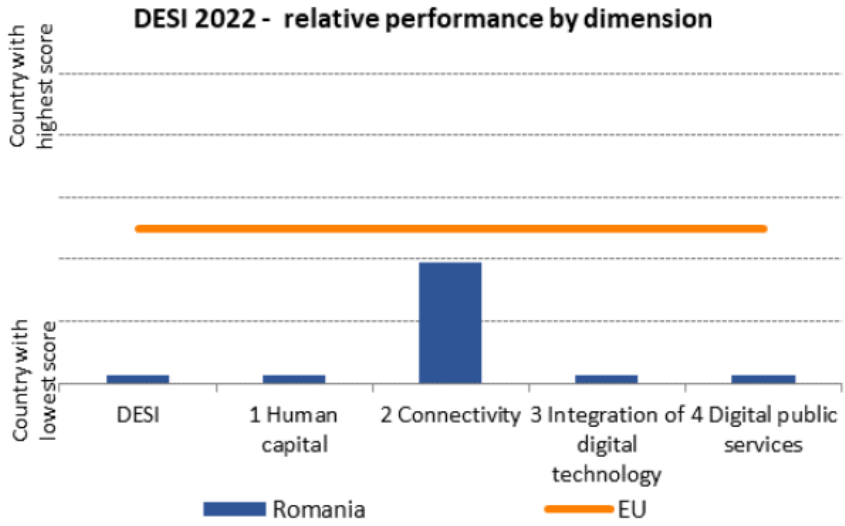

Figure 7. Romania's Digital Economy and Society Index, 2022[20]

In terms of human force, our nation struggles with a lack of fundamental digital skills. Regarding at least basic digital skills (28% vs. 54%) and above basic digital capabilities (9% vs. 26%), Romania performs significantly worse than the EU average. In Romania, just 41% of individuals have at least basic skills for generating digital content, which is lower than the EU average of 66%. With 2.6% of ICT specialists employed as opposed to the norm of 4.5%, Romania falls again short of the average. In contrast, or to be more precise the only above average indicators for our country reflects on the percentages of female ICT specialists and graduates have increased and are now in the top tier at 26% and 6.7%, respectively. The proportion of businesses offering ICT training is 6%, which is again much lower than the EU average.

[19] https://ec.europa.eu/newsroom/dae/redirection/document/88717 page 3
[20] https://ec.europa.eu/newsroom/dae/redirection/document/88717 page 4

	Romania			EU
	DESI 2020	DESI 2021	DESI 2022	DESI 2022
1a1 At least basic digital skills % individuals	NA	NA	28% 2021	54% 2021
1a2 Above basic digital skills % individuals	NA	NA	9% 2021	26% 2021
1a3 At least basic digital content creation skills[3] % individuals	NA	NA	41% 2021	66% 2021
1b1 ICT specialists % individuals in employment aged 15-74	2.3% 2019	2.4% 2020	2.6% 2021	4.5% 2021
1b2 Female ICT specialists % ICT specialists	23.5% 2019	26.2% 2020	26% 2021	19.1% 2021
1b3 Enterprises providing ICT training % enterprises	6% 2019	6% 2020	6% 2020	20% 2020
1b4 ICT graduates % graduates	5.8% 2018	6.3% 2019	6.7% 2020	3.9% 2020

Table 1. Romania's Human Force digital readiness based on Digital Economy and Society Index, 2022[21]

Even though broadband costs are low and very high-capacity networks (VHCN) are widely available, Romania's main connectivity problem is to increase its total fixed broadband take-up, which is currently stagnant at 66% and substantially behind the EU average (78%). Romania has lagged in adoption because of its lopsided demographics and poor level of fundamental digital skills. The Next Generation Access[22] (NGA) and VHCN industries, however, continue to see significant growth. Fixed broadband penetration increased to 94.1% for all households, barely behind the average of 97.9% for the EU. Additionally, the percentage of households using fast broadband increased by 6 points to 93%, above the EU average of 90%. Still, even if the coverage percentages look quite well, this availability is not adopted and transformed into value added neither by individuals, nor by businesses and administration.

	Romania			EU
	DESI 2020	DESI 2021	DESI 2022	DESI 2022
2a1 Overall fixed broadband take-up % households	66% 2019	67% 2020	66% 2021	78% 2021
2a2 At least 100 Mbps fixed broadband take-up % households	49% 2019	51% 2020	57% 2021	41% 2021
2a3 At least 1 Gbps take-up % households	<0.01% 2019	<0.01% 2020	8.98% 2021	7.58% 2021
2b1 Fast broadband (NGA) coverage % households	82% 2019	87% 2020	93% 2021	90% 2021
2b2 Fixed Very High Capacity Network (VHCN) coverage % households	68% 2019	76% 2020	87% 2021	70% 2021
2b3 Fibre to the Premises (FTTP) coverage % households	68% 2019	76% 2020	87% 2021	50% 2021
2c1 5G spectrum Assigned spectrum as a % of total harmonised 5G spectrum	21% 04/2020	21% 09/2021	22% 04/2022	56% 04/2022
2c2 5G coverage[5] % populated areas	NA	12% 2020	25% 2021	66% 2021
2c3 Mobile broadband take-up % individuals	65% 2018	65% 2018	82% 2021	87% 2021
2d1 Broadband price index Score (0-100)	92 2019	97 2020	97 2021	73 2021

Table 2. Romania's connectivity based on Digital Economy and Society Index, 2022[23]

[21] https://ec.europa.eu/newsroom/dae/redirection/document/88717 page 7
[22] https://www.lawinsider.com/dictionary/next-generation-access-nga-networks
[23] https://ec.europa.eu/newsroom/dae/redirection/document/88717 page 9

And we are arriving at the digital integration topic. Romania does poorly in integrating digital technology, coming up again, on the 27th place. Nearly all indicators are way below the average for the EU and have either stayed the same or even declined over the past year. In comparison to the EU average of 55%, 22% of SMEs had at least a basic degree of digital intensity. 34% within the EU compared with only 11% of sophisticated technologies like cloud computing were used by our country. Only 1% of businesses have yet used artificial intelligence technology. Big data usage is still below average in the EU, at 5% vs. the average of 14%. Only 68% percentage of businesses using ICT to take medium-to-heavy environmental action is somewhat higher than the 66% EU average.

	Romania			EU
	DESI 2020	DESI 2021	DESI 2022	DESI 2022
3a1 SMEs with at least a basic level of digital intensity % SMEs	NA	NA	22% 2021	55% 2021
3b1 Electronic information sharing % enterprises	23% 2019	23% 2019	17% 2021	38% 2021
3b2 Social media % enterprises	8% 2019	8% 2019	12% 2021	29% 2021
3b3 Big data % enterprises	11% 2018	5% 2020	5% 2020	14% 2020
3b4 Cloud % enterprises	NA	NA	11% 2021	34% 2021
3b5 AI % enterprises	NA	NA	1% 2021	8% 2021
3b6 ICT for environmental sustainability % enterprises having medium/high intensity of green action through ICT	NA	68% 2021	68% 2021	66% 2021
3b7 e-Invoices % enterprises	20% 2018	17% 2020	17% 2020	32% 2020
3c1 SMEs selling online % SMEs	11% 2019	17% 2020	12% 2021	18% 2021
3c2 e-Commerce turnover % SME turnover	5% 2019	8% 2020	7% 2021	12% 2021
3c3 Selling online cross-border % SMEs	6% 2019	6% 2019	4% 2021	9% 2021

Table 3. Romania's digital integration based on

Digital Economy and Society Index, 2022[24]

Last, but not last, the DESI report is analyzing Romania's performance on digital Public Services, maybe out biggest nightmare.

For Romania, delivering digital public services continues to be challenging. The country performs much lower than the EU average across the board, including the availability of digital public services for consumers and businesses (EU average: 75 for consumers and 82 for business; national score: 44 and 42 respectively). In addition, just 17% of internet users use e-government services, indicating a low level of digital contact between public bodies and the general population. As we speak, there isn't an e-ID scheme in place in Romania.

[24] https://ec.europa.eu/newsroom/dae/redirection/document/88717 page 13

For Romanians, the introduction of e-ID cards and digital signatures is crucial to facilitating interactions between the public and private sectors.

	Romania			EU
	DESI 2020	DESI 2021	DESI 2022	DESI 2022
4a1 e-Government users % internet users	15% 2019	16% 2020	17% 2021	65% 2021
4a2 Pre-filled forms Score (0 to 100)	NA	NA	19 2021	64 2021
4a3 Digital public services for citizens Score (0 to 100)	NA	NA	44 2021	75 2021
4a4 Digital public services for businesses Score (0 to 100)	NA	NA	42 2021	82 2021
4a5 Open data % maximum score	NA	NA	76% 2021	81% 2021

Table 4. Romania's digital public services based on Digital Economy and Society Index, 2022[25]

From the already presented information our country's lack of digital readiness, in terms of public administration, labor force or public services reflects not only a serious gap against the EU's average, but an almost strategic vulnerability with incalculable costs for its development and democracy. Today's situation reflects with no doubt a lack of political commitment shown, not only by the present administration but also a sum of similar behaviors coming from the past administrations.

5. Conclusions

The Recovery and resilience plan for Romania have, among other objectives, a successful transition towards the so-called digital economy and digital society. This includes better connectivity, especially in rural areas, better digital skills, digitalization of education, economic processes, public administration, and public services.

With planned investments and reforms in crucial areas, Romania's recovery and resilience plan supports the digital transition. €1.5 billion will be invested in digitalizing public administration. Additionally, €470 million will be invested in an integrated e-health system. Additionally, investments for the digitalization of education (€881 million) are aimed to enhance digital pedagogical abilities, but also the infrastructure, notably in universities.

In theory it looks fantastic, but based on recent facts and statements, it's probably likely that Romania will send proposals to the European Commission to amend the content of its own National Recovery and Resilience Plan. In this context, the expected new renegotiated context might not reflect the previous expected investments, therefore this digital transformation and transition can be delayed in the short and middle term.

[25] https://ec.europa.eu/newsroom/dae/redirection/document/88717 page 15

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[12] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=70034 15.05.2023

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ARTIFICIAL INTELLIGENCE, INTEGRITY, AND OPPORTUNITY IN INSURTECH

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Abstract

As researchers and practitioners alike seek to identify new ways to solve business challenges, inspire financial innovation, and create and seize new opportunities, insurers around the world are increasingly teaming up with insurtechs, and other tech startups. However, combining the constant caution of traditional insurance with the fast-moving, fast-changing startup-tech of startup culture is rarely straightforward, especially from the perspective of fintech ethics. Insurers need to be well-prepared to ensure these partnerships work for everyone involved – and ultimately deliver significant value. There are many reasons why insurance companies are looking for partners in insurtech, and other technology areas. They usually want to overcome a challenge or solve a vexing problem. The reasons behind successful partnerships often focus on persistent business needs: to help reduce costs, increase revenue, or improve customer experience.

Partnerships between insurers and technology companies are increasingly common, especially because of the development of artificial intelligence applications (for example ChatGPT applications). Therefore, in this paper we propose, based on existing empirical studies, to highlight the financial trends in the insurtech field based on artificial intelligence applications and according to existing European regulations.

Keywords: artificial intelligence, integrity, insurtech, fintech, sustainability

JEL Classification: O31, P48 , G22, G23, Q56

1. Introduction

Generative artificial intelligence (AI) describes algorithms (such as ChatGPT) that can be used to create new content, including audio, code, images, text, simulations, and video [9]. It is worth noting that financial innovations in the field of insurtech have the potential to drastically change the way we approach the creation of content for the field of insurance,

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maintaining the principles of financial ethics, but the orientation being directly towards the optimization and development of fintech (insurtech) activity.

There are some questions that the specialists in the field ask in the studies [9], respectively: can we create innovative financial product content in insurtech by means of Generative Artificial Intelligence (AI)?

Currently, AI applications are increasingly being used to support the creation of content for innovative financial products in the insurtech field. Do tech partners understand what the insurance financial market needs? Do we have the tools to take our creativity to the next level? Can we create innovative financial product content in insurtech through Generative Artificial Intelligence (AI)?

This ingenious form of machine learning allows computers to generate all kinds of new and interesting content[7], from traditional financial products (depending on what we want the machine to define) to virtual worlds using insurtech products and services in the metaverse [3].And it's not just for interactivity – generative AI also has plenty of practical uses[9], such as creating new product models and optimizing business processes in insurtech.

Another concept and service that has been used more and more in recent months is the ChatGPT tool, and which could be successfully used in the insurtech field - GPT stands for pre-trained generative transformer - and currently there is more and more talk about the presence of this application in all industries. Moreover, a free chatbot that can generate an answer to almost any question asked. Developed by OpenAI and released for general public testing in November 2022, it is already considered the best AI chatbot ever. And it's popular too: over a million people signed up to use it in just five days. Fans of this app have posted examples of the chatbot producing computer code, college-level essays, and even financial product concepts. Others, among the wide range of people who make a living creating content, from advertising copywriters to tenured teachers, appreciate that these applications can take over a large part of the activities performed by these professional categories[9].

While many have reacted to ChatGPT (and AI and machine learning more broadly) with reservations, machine learning clearly has the potential for good for everyone. In the years since its widespread implementation, machine learning has demonstrated impact in several industries, enabling things like medical imaging analysis and high-resolution weather forecasting and financial market connectivity. McKinsey's 2022 survey [9] and showing that AI adoption has doubled in the past five years and AI investment is growing rapidly. Generative AI tools like ChatGPT and DALL-E (a tool for AI-generated art) have the potential to change the way several tasks are performed. However, the full extent of this impact is still unknown, as are the risks [10]. Moreover, we know that insurances, regardless of which class or future applications we use, must respond to a varied palette of risks. Therefore, in the latest Global Risk Perception Study (GRPS) using different time intervals to be understood, as can also be seen in the figure below.

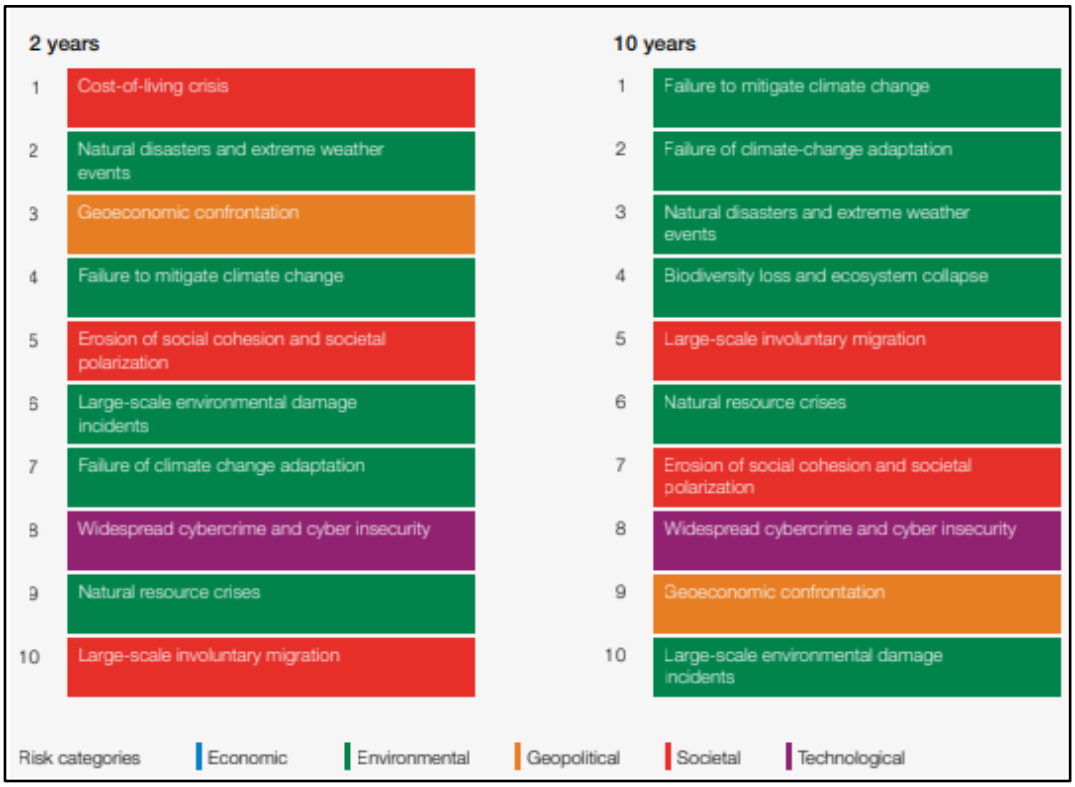

Figure 1. Category of global risks that can be a source of innovation for insuretech [4]

It is very clear that artificial intelligence is taking over for many repetitive activities, but is it important to differentiate between machine learning and artificial intelligence?

Artificial intelligence is pretty much exactly what it sounds like – the practice of making machines imitate human intelligence to perform tasks. You've probably interacted with AI even if you don't realize it—voice assistants like Siri and Alexa rely on AI technology, as do customer service chatbots that pop up to help you navigate websites [9].

Machine learning is a type of artificial intelligence. Through machine learning, practitioners develop artificial intelligence through models that can "learn" from data patterns without human direction. The huge unmanageable volume and complexity of data (ingestible to humans, anyway) that is now being generated has increased the potential for machine learning, as well as the need for it [9].

Therefore, compared to the two conceptual definitions, it is useful to know which knowledge tool we can use successfully in the development and optimization of process

[4] Source: World Economic Forum Global Risks Perception Survey 2022-2023.

activities within insurtechs. Machine learning and artificial intelligence are becoming complex and integrated tools used in the development of innovative insurtech tools.

Machine learning is based on a range of databases, starting with classical statistical techniques developed between the 18th and 20th centuries for small data sets. In the 1930s and 1940s, computing pioneers, including theoretical mathematician Alan Turing, began working on basic techniques for machine learning. But these techniques were confined to laboratories until the late 1970s, when scientists first developed computers powerful enough to mount them [9].

Until recently, machine learning was largely limited to predictive models, used to spot and classify patterns in content. For example, a classic machine learning problem is to start with an image or multiple images of, say, financial innovation icons. The program would then identify patterns among the images and then sift through the random images for those that would match the adorable pattern of the innovative financial instrument icon. Generative artificial intelligence was a breakthrough. Instead of simply perceiving and classifying a photo of an innovative financial instrument, machine learning is now able to create an image or text description of the financial innovation on demand.

2. Research methodology

Based on the data provided by those identified in the specialized empirical studies from academic databases, as well as from research institutions based on interviews/questionnaires applied to the business environment in the financial field, the authors present arguments supported by analytical materials regarding the need to to approach and develop sustainable partnerships in the insurtech field, as well as to define artificial intelligence concepts and solutions in the financial field. At the same time, it makes a general analysis of the problem of the insurtech system, and the risks identified at the international level.

In this study, research methods were applied such as: monograph, data comparison and the graphic method that determines the whole process of financial insurtech innovation in the context of the accelerated development of tech industries in the financial field.

3. Results obtained and discussion

From the beginning of the paper, we emphasized that the partnership between insurtechs and other startups is helping a growing number of insurers to leverage innovative thinking to drive growth, improve customer experience and tackle difficult business problems. In order to make the most of these partnerships, it is important that insurers develop their innovative products according to the needs of the target group, as well as through a comprehensive risk analysis at global level, so that they prepare their business accordingly.

By establishing a solid foundation for success early on, insurers will be well positioned to unlock new paths to success. Among the elements related to supporting a successful insurtech partnership, we identified the following: Pat Kneeland, Manager, Innovation & Enterprise Solutions at KPMG in the US and Kabir Sadarangani, Senior Associate at KPMG Innovation Labs at KPMG in the US. At KPMG's Innovation Lab, Pat and Kabir help insurance carriers understand how their industry and customers are changing and determine where and how to assess, structure, and measure organic (internal) and inorganic (partnership and investment) opportunities) to innovate throughout the business [8] and [9].

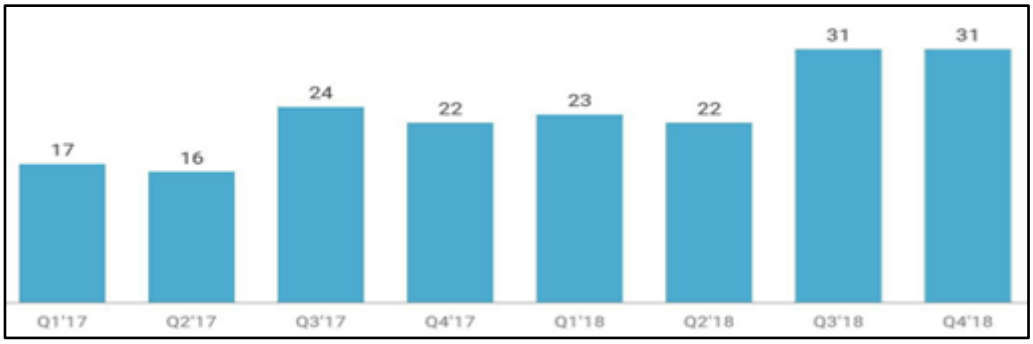

Figure 2. Strategic tech partnerships by (re)insurers are growing[5]

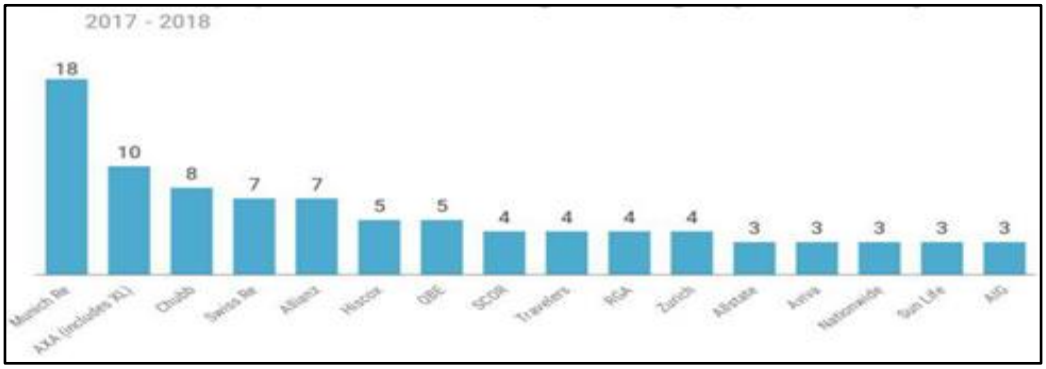

Figure 3. Active (re)insurers striking strategic partnerships[6]

At the same time, following the deterioration of the global economic situation, perspectives bring decisions at the government level, and which decisions face competing social, environmental and security concerns, investments in resilience must focus on solutions that address several risks, such as be the financing of adaptation measures that come with climate mitigation co-benefits or investments in areas that strengthen human capital and

[5] cbinsingths.com
[6] cbinsingths.com

development [9], [10]. Some of the risks described in this year's report [10] are close to a tipping point. Therefore, it is very important that innovative fintech (insurtech) solutions are in line with the priorities for a more positive, inclusive life and stable world [10].

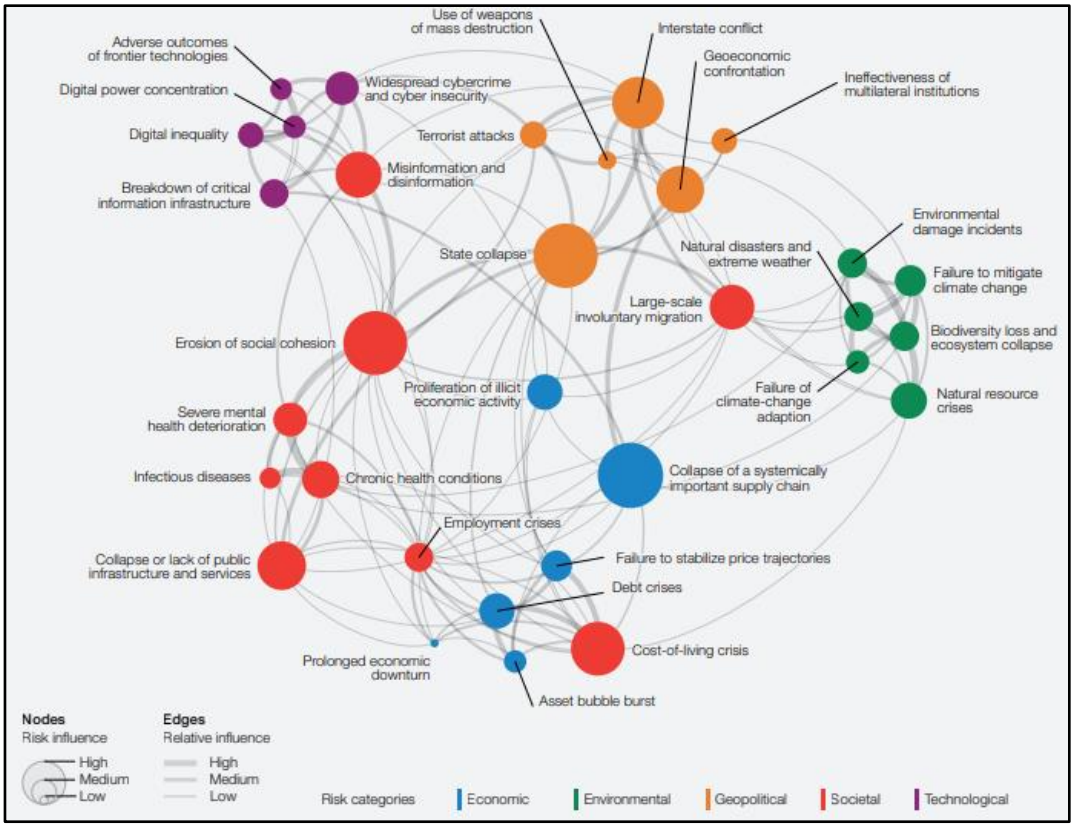

Figure 4. Global risks and their interconnection[7]

The metaverse and insurtech

How should insurtech/finctech founders view the metaverse? Is it a great opportunity or a great risk, how is the metaverse perceived in the context of the global risks mentioned above? From the point of view of financial innovation and the whole process within a fintech (insurtech), the metaverse is an enormous opportunity, and the risk for it can be limited. The IT companies that are involved in building the metaverse have claimed and claim that this is a new stage of the Internet. And as with any technology so vast and all-encompassing (it's like AI in its scope), the potential is enormous. According to research in the field, it is estimated that the metaverse could generate a value of 4 trillion dollars to 5 trillion dollars by 2030[9].

[7] Source: World Economic Forum Global Risks Perception Survey 2022-2023.

In the McKinsey survey and according to the April 2022 McKinsey Global Private Markets Review 2023 study, approximately 95% of business leaders expect the metaverse to have a positive impact on their industry within five to ten years, and 61% expect for it to change the way their industry works. When the market value of the metaverse business was estimated in June 2022, it was calculated to be between $200 billion and $300 billion. Now it's bigger, and in about eight years it could be from $4 trillion to $5 trillion (exhibit), which is roughly the size of Japan's economy, the world's third largest. Exponential growth is possible due to the alignment of several forces: the appeal of the metaverse spans genres, geographies, and generations; consumers have already shown that they are ready to spend on metaverse assets; are open to adopting new technologies; companies invest massively in the necessary infrastructure; and brands that experience the metaverse find that customers are delighted [7] and [10].

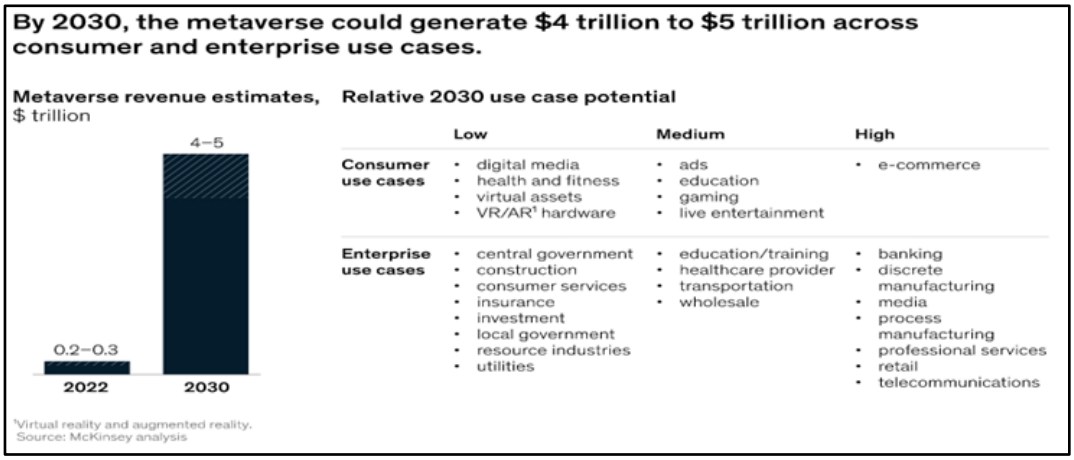

Figure 6. The metaverse and insurtech [8]

Among the main uses of the metaverse in the insurtech field, we can mention the following, namely that the emerging uses of the metaverse are both for policyholders (consumers of insurance financial products) and for insurtechs (insurers and reinsurers). Soon, insurtechs will offer innovative insurtech products, as well as an experience of selecting these products and services unprecedented in the metaverse, all accessed directly and in 3-D format. For now, to understand the potential, consider two of the biggest and most advanced uses, one for consumer businesses and one for B2B companies: Brand Marketing and Consumer Engagement. Many companies have already added the metaverse to their omnichannel marketing mix, considering a presence in virtual worlds such as Roblox, Fortnite and Sandbox. Some are already finding success. Nike hosted more than 26 million visitors to Nikeland, its Roblox space, and sold more than $185 million in NFTs for digital sneakers and related products. And its digital division tripled revenue to surpass $10 billion, almost a quarter of the company's total [6] and [9]. Now, companies are moving into the next wave

[8] McKinsey analysis, 2023

of opportunities, including gamification, virtual reality (VR) and augmented reality (AR) [5].

The metaverse plan will depend on the type of products and services in the insurtech 3600 field. As these solutions are presented, the metaverse appears to have the greatest potential to change sectors in the insurance and reinsurance field with all the supporting partnerships. It is very important for the management of insurtech companies to position their financial innovation as best as possible for the situation in which it will move with all activities into the metaverse.

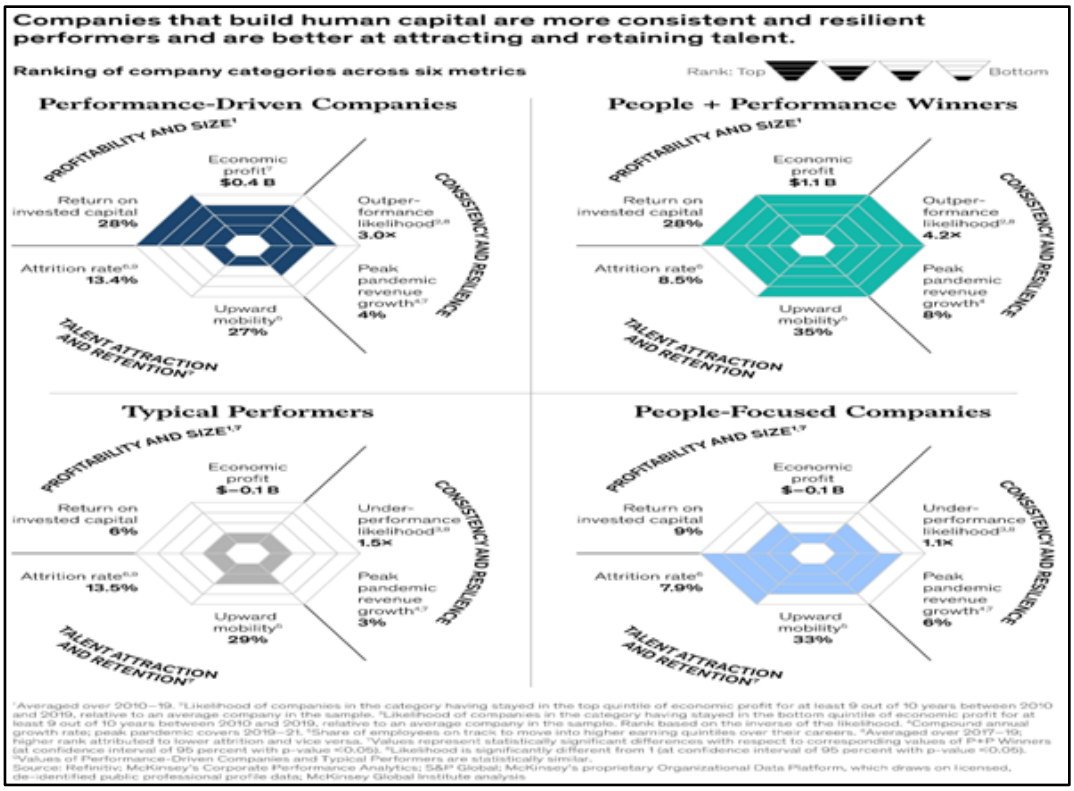

Figure 7. Redefining fintech activity in the metaverse-insurtech context[9]

It is obvious that more and more we can naturally ask ourselves what is the future of work?

Like the world at large, the world of work changes and changes over time. The future of work is about an informed perspective on what businesses and other organizations need to know about how work might change (given digitization and other trends), plus how the workforce and jobs are changing. they can prepare for those changes, big and small[9]. Although we cannot know the future with absolute certainty, it is clear that the jobs of the future are changing, just as society as a whole is changing. Looking ahead to how work,

[9] McKinsey&Company, 2023

work ethics will change, along with the trends affecting the workforce and jobs, it is very important that both in terms of knowledge and the use of financial tools and innovations in insurtech, so that from the point of view of the initiation and development of such companies specialized in insurtech, they are as well understood and applied as possible, so as to generate stability and sustainable business.

To map the future of work at the highest levels, the McKinsey Global Institute considers potential labor demand, the mix of occupations and the workforce skills that will be needed for those jobs. Analysis, McKinsey looks at eight countries (China, France, Germany, India, Japan, Spain, the United Kingdom and the United States) with diverse economic and labor market models, which together account for almost half the world's population and more than 60% of GDP- his The study presented shows that the future of work could be defined as follows: one in 16 workers may have to change their occupation by 2030. That is more than 100 million workers in the eight economies studied – and the pandemic has accelerated the expected transitions of the labor force [9].

What is the future of work?

What is the future of remote work? What about the hybrid version?

5. Conclusions

The rapid evolution of the industry will be fueled by the widespread adoption and integration of automation, deep learning, and external data ecosystems, as well as AI solutions (e.g., metaverse and ChatGPT). While no one can predict exactly what insurance might look like in 2030, carriers can take some steps now to prepare for change.

1. Smartly adapt to AI technologies and trends

The tectonic challenges in the industry will be technology focused, addressing them is not the domain of the IT team. Instead, members of management and customer experience teams should invest the time and resources to build a deep knowledge and understanding

of these AI-related technologies. For example, insurers are unlikely to gain much insight from small-scale IoT pilots in certain parts of the business. Instead, they must proceed with the purpose and understanding of how their organization could participate in the IoT ecosystem at scale. Pilots and proof-of-concept (POC) projects should be designed to test not only how a technology, but also how successfully the operator could operate in a particular role in a data-driven ecosystem or IoT [3] and [6].

2. Develop and start implementing a coherent strategic plan at your Fintech (insurtech) level

Based on insights from AI explorations, industries benefiting from insurtech must decide how to use the technology to support their business strategy. The leadership team's long-term strategic plan will require a multi-year transformation across operations, talent, and technology [1]. Insurers should develop insight into the areas they want to invest in to meet or beat the market and what strategic approach – for example, forming a new entity or building internal strategic capabilities – is best for their organisation. In addition to being able to understand and implement AI technologies, industries must also develop strategic responses to future macro-level changes [2]. As many lines move to a "predict and prevent" methodology, for example carriers will need to rethink their customer engagement and branding, product design and bottom-line earnings. Car accidents will be reduced using self-driving vehicles, home flooding will be prevented through IoT devices, buildings will be rewired after a natural disaster, and lives will be saved and extended through improved healthcare. All these efforts can produce a coherent analytics and technology strategy that addresses all aspects of the business, with a keen eye on both value creation and differentiation [3] and [6].

3. Create and execute a strategy based on blocks of data

Data is quickly becoming one of the most – if not the most – important assets for any organization. The insurance industry is no different: how carriers identify, quantify, place, and manage risk depends on the volume and quality of data they acquire throughout the life cycle of a policy. Most AI technologies will work best when they have a large volume of data from a variety of sources. As such, carriers must develop a well-structured and actionable strategy regarding both internal and external data. Internal data will need to be organized in ways that enable and support the agile development of new insights and analytics capabilities. With external data, carriers must focus on securing access to data that enriches and complements their internal data sets. The real challenge will be gaining access in a cost-effective way. As the external data ecosystem continues to expand, it will likely remain highly fragmented, making it quite difficult to identify high-quality data at a reasonable cost. In general, the data strategy will need to include a variety of ways to obtain and secure access to external data, as well as ways to combine this data with internal

sources. Carriers should be prepared to have a multi-faceted procurement strategy that could include direct acquisition of data assets and providers, licensing of data sources, use of data APIs, and partnerships with data brokers [3].

4. ***Develop insurtechs based on financial innovation and the right technological infrastructure***

The insurance organization (insurtech) of the future will require talent with the right mindset and skills. The next generation of successful insurance workers will be increasingly in demand and must possess a unique mix of followers technological, creative, and eager to work on something that will not be a static process, but rather a mixture of semi-automated and machine-supported tasks that is continuously evolving. Generating value from the AI use cases of the future will require carriers to integrate skills, technology and information from across the organization to deliver unique and holistic customer experiences. This will require a conscious culture change for most operators who will rely on executive suite buy-in and leadership. Developing an aggressive strategy to attract, cultivate, and retain a variety of workers with critical skill sets will be critical to keeping pace [3]. These roles will include data engineers, data scientists, technologists, cloud computing specialists and experience designers. To retain knowledge while ensuring the business has the new skills and capabilities needed to compete, many organizations will design and implement reskilling programs [3]. As a final component of new workforce development, organizations will identify external resources and partners to enhance internal capabilities that will help carriers provide the necessary support for business evolution and execution.

Acknowledgment

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PREDICTIVE MODELING OF CLASS TARGET ACHIEVEMENT BASED ON STUDENTS' SPONTANEOUS INTERACTION DURING COLLABORATIVE LEARNING FOR CLASS MANAGEMENT TOOLS

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Abstract

Educators have difficulty in determining learning interactions in the classroom and in quantifying them, mainly due to lack of sufficient support needed for each student, as the instructor operates the class alone. The authors are developing a system to assist educators in making situational decisions about when to intervene and interact with students within the temporal and spatial constraints of the classroom. In this study, the authors investigated educators' intervention time in an environment where the understanding of the whole class was shared. The results indicate that the data provided by the system may be used to evaluate students by using the value of eigenvector centrality as a measure of instructural leadership. In addition, when learning objectives are achieved by about 20% of the students, the information that solves the question is widely diffused throughout the class.

Keywords: Collaborative learning, Learning analytics, Teacher support, Predictive models

JEL Classification: C61, C92, I21

1. Introduction

1.1. Burden for teacher during collaborative learning using the educational system

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It is difficult for educators to quantitatively determine learning interactions in the classroom. The main reason for that, in general, is the lack of sufficient support for each student, since the instructor operates the class alone. They can evaluate the quality of learning interactions among students by looking around the entire classroom, students' comments in class, and the submissions that students are required to provide. However, with these indicators, it is difficult for them to determine at what point throughout the entire class the interaction progressed and at what point the learners understood the topic during the class. In addition, it was impossible to manually record these data and reflect on the class management. This constitutes a loss of opportunity to receive advice from other teachers. Therefore, it is important for teachers to be able to check the status of learning exchanges in order to improve their classroom management. In order to carry out these goals, it is necessary to introduce an educational e-system, such as ICT equipment, into the classroom management.

A decade ago, the trend in educational electronic systems was ubiquitous learning, such as MOOCs (Massive Open Online Courses) and LMS (Learning Management Systems). These systems are educational services that use the Internet and are mainly utilized in higher education. Although ubiquitous learning systems have attracted a lot of attention, they have revealed issues such as lack of continuity in learning and lack of communication among students. In addition, it is difficult to use these systems face-to-face (F2F). The main cases of using these systems have been for out-of-class learning and unspecified educational services. For example, Mouri proposed a visualization system that integrates mutual learning visualization techniques and maps to connect real-world learners with the logs that the constructed ubiquitous learning system stores in cyberspace (Mouri et al, 2015). In addition, the jigsaw method (De Paz, 2001) can be considered as a learning exchange that takes place F2F, and collaborative learning is a major example.

Collaborative learning is a situation wherein two or more people learn together (Dillenburg, 1999). The use of collaborative learning allows for classes in which students take the initiative and interactively participate in activities with other students. One of the advantages of this class method is that it is possible to provide a class in which the entire classroom achieves the learning objectives. There are prior case studies that were introduced as examples for using collaborative learning. Phielix investigated the effectiveness of peer feedback and reflection tools and reported that students showed a positive attitude toward collaborative problem solving when using the reflection tools (Phielix et al, 2010). Peer feedback refers to the process in which students report on their learning activities to each other, providing feedback on areas for improvement and evaluation, and encouraging course correction. Through their peer feedback, they are able to self-evaluate their learning activities. It is also useful in that it allows students to learn about different approaches to the task. Peer feedback is a form of student feedback in which students critique each other's performance. The students critique each other according to predetermined evaluation guidelines. Peer evaluation differs in that the focus is on the

dialogue between students instead of their grading of each other's performance (Liu N. F. et al, 2006). Setozaki adopted collaborative learning, in which children collaborate with each other to complete learning tasks with the aim of making it easier for students with weak spatial awareness to comprehend the material in astronomy education (Setozaki et al, 2017). One of the advantages of using an educational e-system is the ability to automate the analysis of the collected data. Some of the analyses described in the prior studies mentioned above were conducted primarily by manual labor. However, there are limitations to manual analysis. By using an educational e-system, it is possible to analyze large amounts of data.

However, if the system records and provides teachers with a huge amount of data during the class, it becomes a burden for them. Chatti reported that as the number of groups increases, the amount of available information becomes a burden, a state known as information overload. In general, teachers need to provide appropriate interventions to students with limited resources due to time and space constraints in the classroom (Chatti et. al, 2013). It is not desirable to develop information overload services under such constraints.

Therefore, educational e-systems need to provide services that effectively present an appropriate amount of information to teachers. The educational system presented in this study was developed on the premise that it effectively presents an appropriate amount of information to users (mainly teachers).

In addition, we analyzed the electronic data collected from the students' learning activities that occurred in physical space.

1.2. How the educational system can be used to support teachers

The teacher who manages the classroom operation during collaborative learning does not perform the general knowledge teaching type classroom movements, but rather performs a facilitating type of movement. For example, if students are having trouble solving a problem, they intervene. They may also provide interventions to help the class focus on the same goal. Thus, there are more interventions that are given to the students and are more important than in a typical classroom setting. Prior studies have identified students in need of assistance and support in implementing appropriate interventions. For example, Han have shown that a learning analytics dashboard they developed was effective in facilitating collaborative learning discussions (Han et. al, 2021). It has also shown to be effective in identifying students who need assistance in large classes. Van Leeuwen developed a support tool that provides information about students' cognitive activities to help teachers implement appropriate interventions for students (Van Leeuwen et al, 2015). They reported that their results did not improve teachers' ability to identify groups facing problems but allowed them to focus their interventions more specifically on groups that were experiencing problems.

These prior studies focused on identifying which students or groups of students the teacher should intervene with. However, there were no studies identified regarding situational judgments about when to intervene. It is also difficult for teachers to objectively and quantitatively determine whether or not a learning interaction in the classroom was successful. Therefore, in this study, we developed a system to record students' learning behavior by themselves. Using this system, we investigated whether it is possible to determine at what point the teacher should intervene while checking the progress of the entire class.

2. Hypothesis

The authors are developing a system to assist teachers in making situational decisions about when to intervene with students within the temporal and spatial constraints of the classroom. (Matsishita et. al, 2019) In this study, the authors investigated the teacher's intervention time in an environment where the understanding of the whole class was shared. Thus, the objectives of this study are as follows:

Purpose: To discover innovative indicators of facilitated learning that can be linked to teacher-managed collaborative learning aids by the developed system.

In addition, the hypothesis is as follows:

Hypothesis: Teachers with sufficient experience in classroom management during collaborative learning subconsciously possess indicators of whether the learning exchange was successful or not. They also use these indicators to conduct appropriate classroom management.

3. Experimental method

3.1. Outline

To validate the hypotheses of this study, an experimental study was conducted from February 1st to 4th, 2021. The experimental study used a developed system, described below, to record the students' own learning behavior. The subjects of this experiment were students in public elementary schools in Japan. These subjects were selected because they are more likely to belong to Japanese public schools and making them a suitable population.

3.2. Participants

A total of 31 students and one teacher participated in the experiment; the 31 students were between 11 and 12 years old and belonged to an elementary school (male: 14, female: 17). The teacher was a male in his 20s. This teacher was well experienced in managing collaborative learning. The tablet devices used were Chromebooks. These students were

inexperienced in using Chromebooks in the classroom. Therefore, before the beginning of the experiment, we checked to be sure that the students were able to learn using the Chromebooks. In this experiment, we did not arbitrarily create groups in order to promote natural learning interactions within the class. This will allow us to see how information pertaining to learning behaviors was exchanged within the class. The experiment was conducted three times. Each class session lasted 45 minutes. Of the 45-minute class periods, all class subjects were mathematics. Problems were given in each class. The content of the exercise time problems was prepared by the teachers who participated in the experiment. The exercise expressed in the following refers to each problem that was conducted during class time. There were eight questions presented. One of these questions was excluded from the analysis due to insufficient time for the exercise.

3.3. Developed the system

The system developed for the experimental study is a web application. The system has two functions: the first is to share students' achievement of learning objectives with the entire class; the second is to record students' learning interactions. Both functions were developed to support teacher interventions. An overview of this system is shown in Figure 1.

3.3.1. Sharing student learning objectives with the entire class

The function of sharing the achievement of learning objectives of students throughout the system is described in Figure 2. In order to use this function, the teacher must give the requirements for the achievement of the learning objectives for the students. On the left side of Figure 2 is a part of the screen operated by the student. On this screen, there are four buttons ("Not yet", "Half", "Solved", and "Explainable") operated by the students. By selecting one of these buttons, the student can check and change the status of their learning objectives. The status of students' learning objectives is shared with the entire group in real time via the "Share Screen" on the right side of Figure 2. The purpose of using this screen is to support teacher intervention and to promote collaborative learning among students.

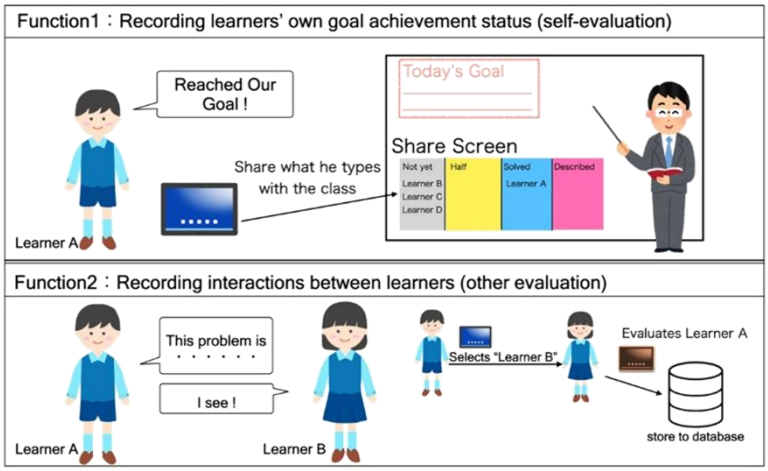

Figure 1. An overview of the system.

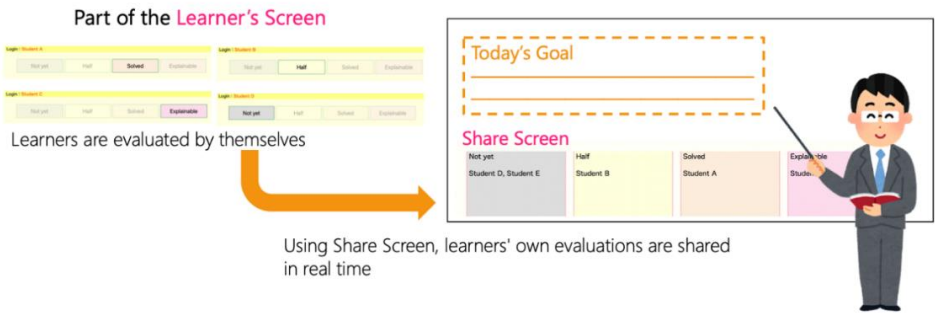

Figure 2. The function of sharing student learning objectives.

3.3.2. Recording students' interactions

The function for recording learning interactions is described in Figure 3. To use this function, the teacher must create a situation in which students are allowed to interact with each other. When students interact with each other, the learning interaction is recorded using a tablet device.

In this example, Student A is the student who gave the hint or explanation of the question, and Student B is the student who received the hint or explanation. Student A teaches Student B, and then Student A presses the button labeled "Student B" on his/her screen. When the button is pressed, a pop-up screen appears on student B's screen. This screen contains the sentence "Do you understand from Student A? and buttons labeled "Yes" and "No". When the "Yes" button is pressed, the "Student B" button on Student A's screen turns blue, and when the "No" button is pressed, the button turns red.

All of this interaction is stored as electronic data on a web server. The teacher can check this interaction on the teacher's private page. Figure 4 is a network diagram displayed on the private page for teachers. Every circle in the diagram represents a student. The arrows represent the interaction of information. The starting point of the arrow represents the student who taught, and the ending point represents the student who learned from the student. From this diagram, the teacher can read the information interaction among the students in the whole class. By looking at this diagram, the teacher can identify the central person in the class and the student with whom they should intervene.

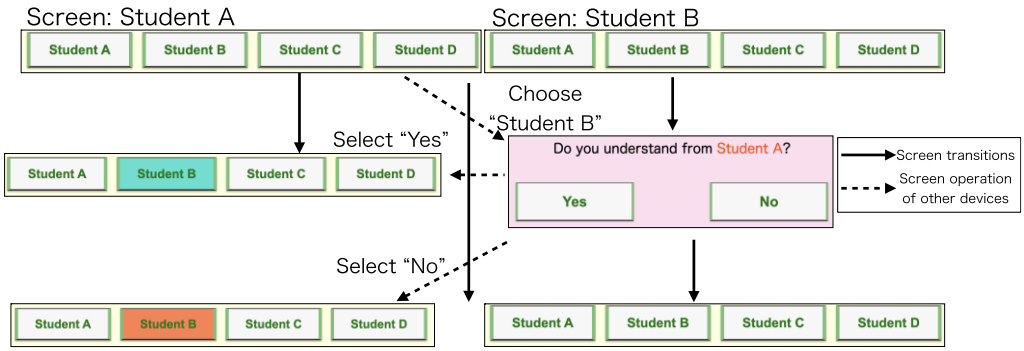

Figure 3. The function of recording interactions between students.

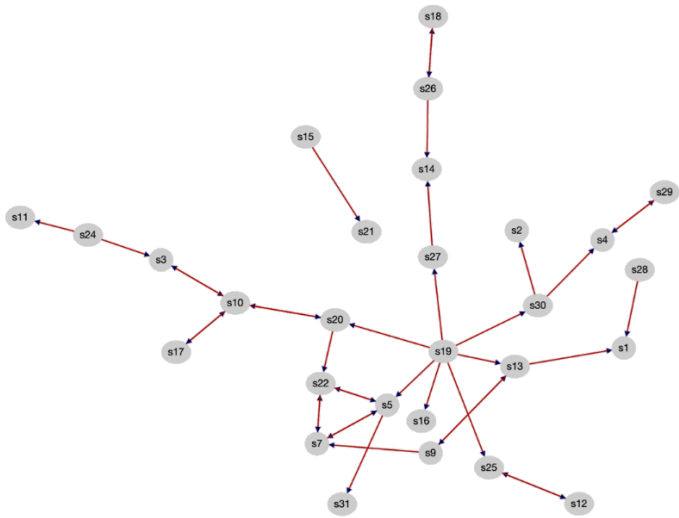

Figure 4. Visualization of learning interaction.

3.4. Procedure

Before the teacher gives the students the questions, he/she confirms the learning objectives with the whole class. In this case, the learning objectives were that all class members should

be able to solve the given questions. This task aims to promote learning interactions throughout the class. This objective required that if one student was able to solve a question, he or she would collaborate by giving hints to others rather than ending the exercise.

After reviewing the learning objectives, the teacher gave the students a question. Initially, they solved the questions alone without any interaction. After that, the students interacted with each other for learning interaction. The decision whether or not to conduct a learning interaction was made by the learners, but if the teacher decided that there was a need for intervention, such as encouraging learning interaction or giving hints on how to solve the questions, they would intervene with the students. The exercise was terminated when the entire class or a sufficient number of students had reached a correct answer.

The system recorded the time from when the teacher gave the question to the student to when the exercise was completed. These series of operations were repeated as a single interval. As a result, we were able to conduct 8 intervals in this experiment, one of which was excluded due to insufficient time for the exercise.

3.5. Data Analysis Methods

In order to discover indicators for facilitating the exercise, which is the purpose of this paper, data analysis was conducted using the collected electronic data. A description of the data analysis used in this paper is presented in the next section.

3.5.1. Social Network Analysis

A social network analysis was conducted based on the network diagram drawn during the exercise time. There are several methods for social network analysis. In this study, we chose centrality analysis. The main reason for performing centrality analysis is to measure the degree of contribution of individuals when analyzing relationships belonging to an organization or society. By utilizing this analysis, it is possible to measure the importance of individuals in a social network. There are several indicators of centrality analysis. In this study, we used three of the most commonly used indicators: degree centrality, betweenness centrality, and eigenvector centrality.

Degree centrality is a measure that represents the ratio of nodes in a network that are connected to other nodes. This centrality is used with the idea that a node that is adjacent to many nodes is central. In this case, it is an indicator of the degree to which a given student interacts with other students. Thus, the higher the degree centrality, the more likely it is that the node is connected to other nodes. In other words, they can be considered to have many relationships. The value of degree centrality is often normalized by dividing the total number of other nodes connected in the network by the total number of nodes in the

network, N, minus 1. The degree centrality DC_i at node i can be obtained using matrix A (N × N) as follows:

$$DC_i = \frac{\sum_j A_{ij}}{N-1}, A_{ij} = \begin{cases} 1 \text{ (There is an edge between node } i \text{ and node } j) \\ 0 \text{ (There is NO edge between node } i \text{ and node } j) \end{cases} \quad (1)$$

Betweenness centrality is an indicator used with the idea that a node that often appears on a path between two nodes is central (Freeman, 1977). In this case, it is an indicator for discovering students who serve as intermediaries between one group and another. Therefore, we can paraphrase that a node that functions as an intermediary in the network is central. The betweenness centrality BC_i at node i can be obtained as follows:

$$BC_i = \sum_{i,j \in V-\{k\}, i \neq j} \frac{\sigma(i,j|k)}{\sigma(i,j)} = \sum_{i,j \in V-\{k\},\, i \neq j} \frac{\sigma(i,k)\sigma(k,j)}{\sigma(i,j)} \quad (2)$$

Note: V is the set of nodes, $\sigma(i,j)$ is the number of shortest paths from node i to node j, and $\sigma(i,j|k)$ is the number of shortest paths from node i to node j via node k.

Eigenvector centrality is a measure that is calculated by taking into account the centrality of neighbouring nodes (Bonacich, 1987). This centrality differs from previous centralities in that it includes the importance of the node. To summarize, this is the concept that anything connected to an important node is equally important. In this case, it is an indicator for discovering the dividers of a group. Thus, eigenvector centrality can be rephrased to say that nodes that are adjacent to other central nodes are central. The eigenvector centrality EC_i at node i can be found recursively using the adjacency matrix A as follows:

$$EC_i^{n+1} = \sum_j A_{ij} EC_i^n \quad (3)$$

For equation (3), using the adjacency matrix A and the column vector x

$$Ax = \lambda x \quad (4)$$

can be expressed as A. The λ in this case represents the maximum eigenvalue of the adjacency matrix A. Therefore, the process of setting the initial column vector EC_i^0, finding the eigenvalues λ and eigenvectors x using equation (4), and putting the obtained variables into equation (4) again is performed multiple times. Through this process, the converged

eigenvector x corresponding to the adjacency matrix A can be calculated recursively. The value of this eigenvector is the eigenvector centrality.

3.5.2. Graph Approximation

In this paper, we use a method to approximate to a sigmoid function from the obtained data. In advance, the method of approximating to a sigmoid function is shown here.

The sigmoid function used in this study is shown in equation (5).

$$Sigmoid(a,b) = \frac{1}{1 + exp\big(-a(x-b)\big)} \tag{5}$$

Equation (5) is characterized by the output of a resultant value between 0 and 1, independent of the value of the input x. Some properties of the sigmoid function are:

- Monotonically increasing
- Symmetry
- Differentiable in all domains, extrema exist
- Only one inflection point exists

Setting the values of the parameters a and b in this function changes the behavior of the graph. For example, if the value of parameter a is increased, the graph rises rapidly. Also, as the value of parameter b is increased, the phase of the graph shifts to the right. Based on this equation (5), the given data is approximated to a sigmoid function. In other words, this is an optimization problem to find the optimal parameters a and b that yield the smallest error for the given data. To solve this problem, the Levenberg Marquardt method (Levenberg, 1944, Marquardt, 1963) was used to find the minimum error function. One of the advantages of this method is its improved convergence by combining the advantages of the steepest descent and Gauss-Newton methods. It should also be noted that what is guaranteed by this method is convergence to a local minimum, and the overall minimum may not be obtained.

3.5.3. Tools Used for Analysis

We used Python to analyze the data. The reason for using this language is that it is a comprehensive environment for performing the network diagrams, their analysis, and statistical analysis that we will create in this study. The version of Python used in this study

was 3.9.16, the version of the graphviz module used for network diagram creation was 2.50.0, the version of the networkx module used for network diagram analysis was 2.8.4, the version of thelearn module used for statistical analysis is 1.2.0, the version of the Scipy module is 1.10.0.

4. Result

In order to analyze 7 intervals in this experiment, each interval was given the name shown in Table 1. Thereafter, the following names will be used to describe the subject of the analysis.

Table 1. Information for each interval

Interval	Date	Execise (min)	Students
Q.1	2/1/23	19	31
Q.2	2/1/23	9	31
Q.3	2/1/23	9	31
Q.4	2/3/23	11	31
Q.5	2/3/23	8	31
Q.6	2/3/23	9	31
Q.7	2/4/23	18	31

4.1. Prediction of The Students' Solution Achievement

This section analyses the trend in the number of students who were able to solve the problems from the beginning of the exercise to the end of the exercise. First, the relationship between the number of students who were able to solve the question and the duration of the exercise is shown in Figure 5. Here, the students who were able to solve the problems are called the "solution achievement group". This solution achievement group indicates the total number of students who indicate "Solved" or "Explainabled" among the system's function 1. Each point shown in the figure is the total number of solution achievement group for each minute from the beginning of the exercise. These points are connected in the line graph displayed in the figure.

Figure 5 confirms that all graphs are monotonically increasing functions. Only the last point in Q.4 was shown to be below the previous point. Examination of the logs indicated that one student moved from a state in which the question was solved to one in which the question was not solved. The reason for the move was unknown, but it could have been that

the solution to the question was incorrect, or that the learner intentionally moved from one state to another in order to move on to the next question. Therefore, it is not considered to have a significant impact on the following analysis. Compare the degree of increase in these graphs. For Q.1 and Q.7, the graphs showed a rise from 10 minutes into the exercise. On the other hand, Q.2, Q.3, Q.5, and Q.6 show a sharp increase immediately after the start of the exercise.

These graphs show that the slope of the graph increases sharply at a specific point. From this fact, it can be predicted that connecting the points in the figure will give the appearance of a sigmoid function. For more information on the sigmoid function, see refer to Section 3.5.2. The sigmoid function is a scientifically important function. It is assumed that the relationship between exercise time and overall goal achievement is explained using the sigmoid function. Then, the properties of the sigmoid function can be used to explain the goal achievement status of the whole class. Therefore, we defined a sigmoid function as in equation (5) and fitted it to each question to obtain the optimal parameters a and b for each question. The results are shown in Table 2. An example of a fitted diagram is shown in Figure 6.

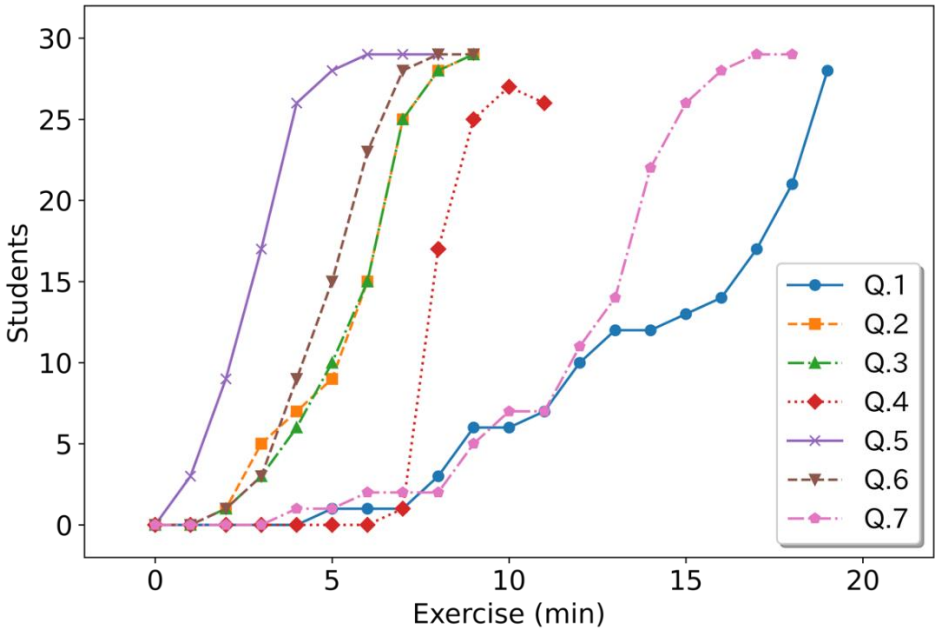

Figure 5. Relationship between solution achievement groups and exercise time

Table 2. Parameters and approximation function

Question	param a	param b	R^2
Q. 1	5. 673	0. 809	0. 956
Q. 2	7. 751	0. 641	0. 984
Q. 3	8. 259	0. 643	0. 993
Q. 4	19. 272	0. 734	0. 968
Q. 5	9. 448	0. 350	0. 990
Q. 6	9. 229	0. 556	0. 997
Q. 7	10. 435	0. 709	0. 989

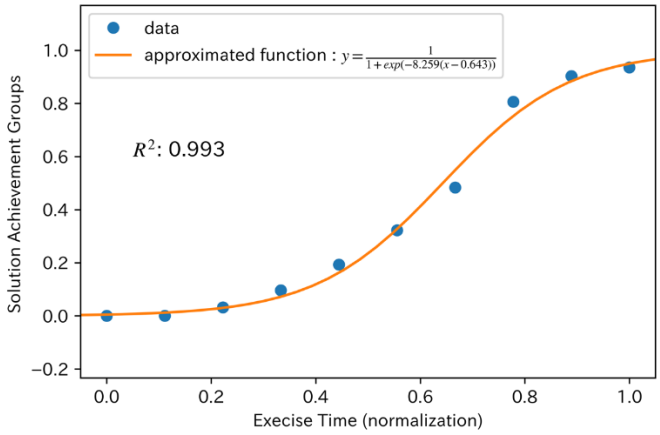

Figure 6. Example of fitting to a sigmoid function

Table 2 shows that the coefficient of determination exceeded 0.95 for all questions. As an example, Figure 6 shows the figure when the coefficient of determination showed the highest value. This figure shows that the data obtained are well adapted to the sigmoid function.

Although other candidate functions for fitting can be assumed, the results of the coefficient of determination values indicate that all questions could be fitted to the sigmoid function. From this result, we can use the properties of the sigmoid function to examine the relationship between exercise time and overall goal achievement.

4.2. Centrality Analyze for Social Network Analysis

From the data collected, we analyzed how many students had a learning interaction with each student during the exercise time of the question. For this analysis, we used the centrality analysis of social network analysis. See Section 3.5.1 for details on social network analysis. Learning interactions have a “teaching” and “learning” orientation, but in this study, the centrality analysis was conducted on an undirected graph in order to focus on with whom students interacted. The results of the seven-question analysis are shown in a box-and-whisker diagram for each indicator (Figure 7). Among the plotted values, the value x that satisfies the following conditions is indicated by a white circle as an outlier.

- $x >$ upper quartile(Q3) $+ 1.5 \times$ IQR
- $x <$ lower quartile(Q1) $- 1.5 \times$ IQR

The figure confirms that there is no significant difference in the distribution of degree centrality for any of the questions. In addition, there were no significant differences in the distribution of the data for betweenness centrality, with the exception of question 7. For question 7, it can be confirmed that four students' values were detected as outliers. On the other hand, eigenvector centrality showed differences in the shape of the graphs from question to question. In questions 1, 3, 6 and 7, values of at most 1 or 2 students were detected as outliers. In the other questions, several students were detected as outliers. Next, Figure 8 shows the students detected as the top five eigenvector centrality students for each question, and Table 3 shows the total number of student appearances. Note that sX is the unique number given to the student. Given the characteristics of the eigenvector, the more appearances a student has in this table, the more likely the student is to show leadership during the exercise time. There are 21 students that appeared in this table. Thus, the results indicate that about 65% of the class engaged in the exercise with leadership.

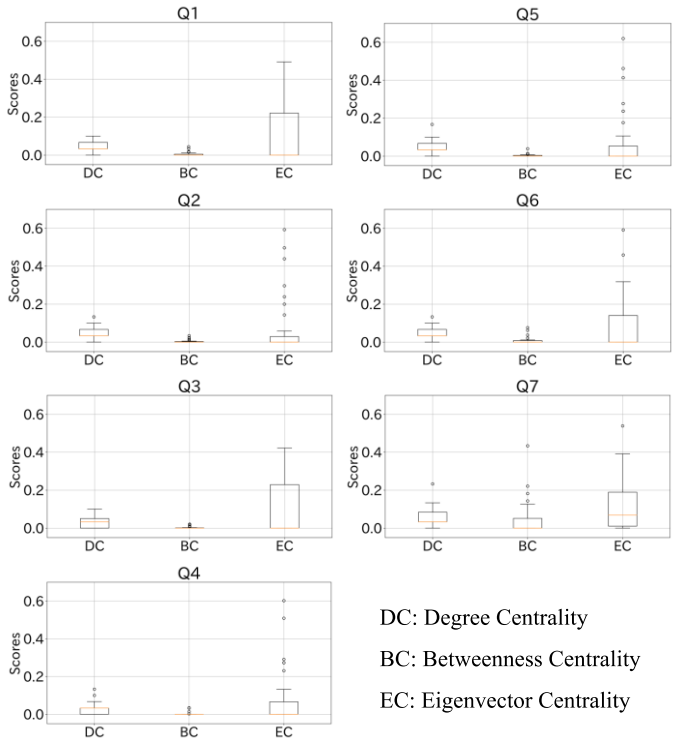

Figure 7. Centrality in Students Network

Rank	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	s15	s9	s6	s9	s13	s17	s19
2	s21	s5	s28	s17	s9	s2	s5
3	s31	s13	s10	s10	s7	s3	s20
4	s10	s12	s21	s7	s5	s14	s22
5	s24	s7	s1	s12	s2	s18	s7

Figure 8. Eigenvector Centrality (Top 5)

Table 3. Eigenvector Centrality Top 5 Appearances

Student	Appearances	Student	Appearances
s7	4	s6	1
s5	3	s14	1
s9	3	s15	1
s10	3	s18	1
s2	2	s19	1
s12	2	s20	1
s13	2	s22	1
s17	2	s24	1
s21	2	s28	1
s1	1	s31	1
s3	1		

5. Discussion

5.1. Assessment and Prediction in Learning Interaction

The relationship between exercise time and solution achievement group was fitted to a sigmoid function for the learning interaction data group, which was collected in time series for seven questions. This analysis showed that the coefficient of determination was extremely higher when parameters a and b were obtained. For all questions, there are three possible reasons for the high coefficient of determination.

The first factor suggests a possibility related to the distribution of information that occurs within a class. There is prior research regarding the role that people play in the actual

distribution of information within a society. For example, Allen & Cohen showed that when new information flows within a group, there are people who have a role in bringing the information together and spreading it to those around them (Allen & Cohen, 1969). In this study, it was possible to identify students who demonstrated leadership during the exercise time by calculating eigenvector centrality. Students with higher values of eigenvector centrality reached the solution faster in the entire class. Thus, they were responsible for sharing the information leading to the solution with the entire class. Figure 8 also shows that the classes that collaborated in the experiment differed from question to question in terms of the students who showed leadership. This result indicates that the role of the students differed from question to question. The fact that we were able to collect data on these results is one example of the usefulness of this system.

The second factor is a possibility regarding the increase in the percentage of solution achievement groups. This possibility is easy to understand. Once students in the solution achievement group have gained sufficient understanding, they will not return to their original state. The transition in which a monotonic increase is expected indicates that the class progressed smoothly. Therefore, we can say that the factor causing the monotonic increase is the teacher. By utilizing these results, it may be possible to evaluate teachers' classroom management.

The third factor suggests that the individual student's own atonement may have been at work. Atonement is the act of agreeing with the opinions and arguments of others, which is different from collaboration, the act of collaborating with one another. Consider a situation such as the Share Screen (see Figure 1), where the class's goal achievement status is recognizable. When about half of the class occupies a solution achievement group, students who do not belong to that group will be willing to join it. It is then conceivable that they may have moved to the learning achievement group regardless of their degree of understanding. We need to conduct an experiment with and without the Share Screen. This experiment should be conducted as a future study.

It is necessary to continue to investigate the degree of fitting of the sigmoid function to the transition of exercise time and solution achievement groups. Assuming that the transition between exercise time and solution achievement group fits the sigmoid function, this can be used to estimate the time to discontinue the exercise time. If this estimation can be achieved, the exercise time can be appropriately managed.

5.2. Prediction of overall class goal achievement

A model was created to predict the subsequent transition in the ratio of students who achieve their goals based on the ratio of students who belong to the goal-achieving group. As a result, it was found that an approximate equation similar to the actual data was obtained when the percentage of students in the target achievement group exceeded 20% of the entire class.

Further research is needed to determine the true meaning of this 20% value, but the following can be expected. The number of students in this class is 31. Therefore, the actual number of 20% students is about 5. It is obvious that a certain number of students is necessary for the initial stage of information diffusion. Therefore, for information to be spread, a certain number of people who have reached the target is necessary. It is highly likely that this number is 20% of the total number of people. As a source of information to explain one hypothesis, we take up “Diffusion of Innovations” (Rogers, 2003). This is a measure of the percentage of diffusion of a new product or service in the market. It classifies the diffusion process of new products as innovators, early adopters, early majority, late majority, and laggards, in descending order of the timing of adoption by consumers. Those classified as innovators have high information sensitivity and curiosity to actively adopt new products. Early adopters are sensitive to trends in between and in the industry and are always on the lookout for information and make decisions. The early majority is strongly influenced by the early adopters and acts as a bridge to the market as a whole. Late Majority are those who tend to carefully listen to what is going on around them and consider hiring. Laggards are those who are the most conservative and have no interest in new things.

Reading the original paper (Rogers, 2003), we found that the combined percentage of innovators and early adopters is close to 20%. Based on this idea, about 15~20% of the population is needed for information to be widely spread. Transferring this indicator to this study, it is suggested that if 15~20% of the students reach the objectives, it may be possible to diffuse the information to reach the objectives to the entire class. Therefore, the emergence of early adopters may be a factor that determines the length of the exercise time. Figure 5 shows that questions 1 and 7, which took longer to reach six solution achievement groups (about 20% of the entire class), took longer exercise time than the other questions. Therefore, this idea could be used to provide facilitation assistance to teachers.

6. Conclusion

In this study, the data presented by the system suggested that new indicators may have been discovered. Specifically, the value of eigenvector centrality could be used to evaluate students as a measure of leadership. When learning objectives are achieved by about 20% of the students, the information that solves the question is widely diffused throughout the class. In other words, this indicator could be used to support teachers' facilitation during the exercise time.

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USING DIGITAL MARKETING AS MEANS OF COMMUNICATION – WITH REFERENCE TO CHILDREN'S AUDIENCE

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Abstract

The last three decades have brought with them a huge development of information technology and communications, and the emergence and proliferation of the Internet has made possible the creation of complex global networks of communication and collaboration. These new technologies have transformed the way we learn, communicate and work - they have fundamentally transformed the way we live. This evolution has brought with it various economic and social opportunities and benefits, but also the emergence of new challenges. One of these challenges is that, although the Internet was not designed focused on children, some of the most of its users are them.

In a society where technology develops daily and children have access to digital devices at a very young age, it is imperative to adapt to the new challenges of developing children's cognitive and socio-emotional skills, as they have specific needs and vulnerabilities that must be recognized.

Keywords: internet, digital marketing, communication, digital devices.

JEL Classification: M19, M21, O31, O49

1. Introduction

Digital marketing is the promotion and sale of products and services using online strategies [12]. This activity is constantly developing according to the habits of Internet users. Therefore, online users must be known well: what they do, what their habits are and what interests they have. This is precisely one of the main advantages of digital marketing compared to classic promotional activities; with the new technologies and information available, we can properly filter the audience to reach the target group. This is also the premise of a successful business.

Thus, using key performance indicators (KPIs) for digital marketing, marketers can understand what marketing strategies to develop and how well they are working. This

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fosters continuous improvement of organizations, driving customer engagement and optimizing the return on marketing investment.

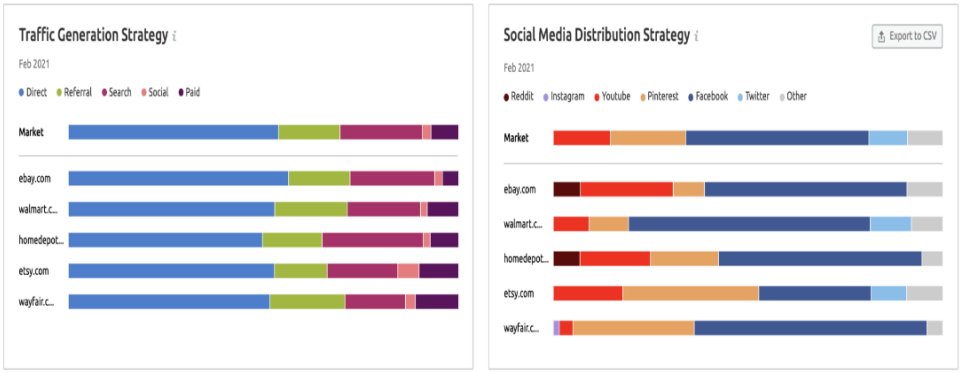


Figure 1. Traffic generation strategy vs social media distribution strategy[3]

Digital marketing strategies foster direct communication between business and customers while those customers follow unique paths to purchase. Innovative marketers use digital marketing to deliver the right content and offers at the right time, on the channels where customers spend most of their time. When it is leveraged correctly, digital marketing is beneficial for both customers and business; by properly personalizing content and offers for each individual, customers feel that the brand understands their needs and can provide them a valuable product.

There are several available digital marketing channels, such as [7]:

- *Affiliate marketing* is the business promotion within the partner affiliate network. It is applicable when a product is marketed within that network; the products are recommended (or they are sold freely) by the partner sites.

Figure 2. How does affiliate marketing work[4]

[3] Source: Semrush - Online Marketing Can Be Easy

[4] Source: https://www.digitalmarketing.org/

- *Search Engine Marketing* - (SEM) is a type of marketing on the Internet which involves promoting websites by increasing their visibility in search engine results pages (SERPs) primarily through paid advertising. SEM may include search engine optimization, which adjusts or rewrites site content and site architecture to rank higher in search engine results pages to improve pay-per-click (PPC) listings.
- *Social Media Marketing* – the use of social media channels (Facebook, Twitter, Pinterest, Instagram, Google+ etc.) in order to market a product or a service. It is a procedure where strategies are made and executed to drive traffic for a website or to gain the attention of buyers on the web using various social media platforms.
- *Content Marketing* – this is a marketing approach which focuses on earning and keeping customers by offering useful content, it improves the buying experience and generates brand knowledge and recognition. Any brand can use this approach in order to draw customer attention aiming to influence the buying decision.

Figure 3. Content strategy[5]

- *Sponsored content* – is using the created and paid content of a brand in order to promote a product or a service.
- *SMS Marketing* –even if its popularity is constantly decreasing, SMS marketing is still playing an important part in earning new customers, offering updates or new products, etc.
- *SEO - Search Engine Optimization* - are the activities that help a certain site rank as well as possible in Internet searches. This means that the position in Google will depend a lot on the optimization of the site.

[5] Source: Sursa: https://www.digitalmarketing.org/

Figure 4.SEO[6]

- *PPC - (Pay-per-Click*) is the form of digital advertising that pays for the number of clicks from users interested in the advertising solution. The ad can be a sponsored post, link, or poster that tells the user to take a specific action. Thus, the user is offered access to the e-commerce site, presentations on social networks, watch video content, etc. For this kind of digital advertising, Google Ads and Facebook Ads are primarily used.
- *E-mail Marketing* – is one of the most efficient (and cheap) promotion strategies; there are different types of e-mails: inviting to subscribe to a newsletter, seasonal promotions, announcements of discounts and special offers within the loyalty program or thank you emails after purchasing or registration.

Figure 5.E-mail marketing[7]

It is important that the company reaches customers and create a bidirectional communication pattern, because digital marketing enables customers to provide feedback to the company on a community-based site or directly to the company via email. Companies

[6] Source: https://www.digitalmarketing.org/
[7] Source:https://smarters.ro/

should seek this long-term communication relationship by using multiple forms of channels and using promotional strategies related to the target consumer as well as word of mouth marketing.

After all, this boosts their confidence and turns them into loyal brand advocates. Digital marketing is also very advantageous for companies, offering:

- **Extended coverage**. Most people start the buying process online, on various digital channels.
- **Precise targeting**. Marketers can reach more qualified buyers by leveraging SEO and social media strategies. In turn, this drives conversions, revenue, and brand promotion.
- **Agility**. It's usually easier to adjust your digital marketing strategies if your goals change.
- **Measurability**. Digital marketing offers a greater degree of attribution, so marketers know which strategies are really driving growth.

2. Technology innovations and the impact of overuse by children

If the audience is made up of children, a number of issues should be considered on several levels. Digital marketing is designed to create addiction for children and extract data; attempts to influence behavior, emotional responses, and preferences. It is also designed to target very specifically, what increases children's vulnerability. It's about entertainment and emotion, so digital marketing can be used to create a connection between an emotion and a brand name in ways we don't realize, the techniques being subliminal [7].

Companies are using more and more digital channels in order to market products to children.

Children that are now teenagers have been born in a digital world. It is a world where they spend a lot of time, considering the Internet opportunities in accessing knowledge, communication and participation; the benefits of its accessing can have an impact in developing the skills necessary for the XXI-st century, but also the extended scope of risks and dangers to which children can be exposed. It is known that children have specific needs and vulnerabilities that must be recognized. Relevant in this sense is the study done in 2018 by the Save the Children Organization - *Romania, entitled Study regarding the use of the Internet by children*, the main conclusions being [13]:

- the average age that children start spending time online is 9 years od; the age that children start accessing the Internet describes a declining trend;
- 96,1% of children are accessing Internet by smart phone ; 99,3% of them declare that they have a profile on a social network;

- the most popular social networks amongst children are Facebook (95,9%), Youtube (90,5%) and Instagram (81,4%);
- 27% of the respondents say that on a typical school day they spend 6+ hours online or constantly check their browsing device;
- referring to the time spent on the Internet, 40% of children say that it happens very often or quite often that they surf the web without a specific purpose, 31% say they spent less time with family or doing things for school in order to surf the Internet and 28% say they tried unsuccessfully to spend less time online;
- almost 13% of children say that it happened very often that they did not eat or sleep in order to be online and 23% did not feel at ease when they could not stay on the Internet
- the online environment is the main source of information for the responding children, 47.6% of the children state that they sometimes, rarely or never check the truth value of the information red online
- 73% of the responding children say that they use the Internet at school; 87.4% of children state that they spend time online during breaks and 40% that they do it, secretly, during class hours;
- 63.5% of respondents state that they play online; most children (79.9%) say they play online because it's fun or to relax (60.6%), and 45.2% say they do it because they are bored.

In a society where technology evolves daily and children have access to digital devices starting at a very young age, it is imperative to adapt to new challenges in terms of developing children's cognitive and socio-emotional skills, and this this study aims to bring more information about how children use the Internet. At the same time, it wants to provide a clearer picture of the impact of new technologies on the emotional well-being of children.

Digital life, including children's, produces a huge amount of data about preferences, habits, desires and fears, which is collected by public and private entities. This creates new opportunities to deliver personalized and targeted information and advertising.

Online advertising can be based on the content a user views (contextual advertising) or based on their individual profile (online behavioral advertising). This profile is often created by "cookies", files placed on a user's device to monitor their preferences and behavior - some of which can never be removed.

Many people also choose to actively participate in online marketing and enjoy it. Users like or share content such as videos and games from brands they identify with. Interactive content is particularly popular.

Protecting children from digital marketing requires a series of actions at EU level, in this regard, in October 2017, a "declaration on digital health societies" was launched during the Estonian Presidency of the Council of the EU. It contains some concepts that can help: citizen control of data, good governance, the need for all EU countries to take a responsible role, including the protecting of the citizens' personal data.

The use of the Internet by children and young people in a creative, useful and safe way should be a permanent concern of all the factors involved (authorities/family); at the same time, the child must be trained in the use of modern information and online communication technologies, with an emphasis on awareness and prevention of dangers on the Internet. In this direction, specialists have warned about the effects - which can be felt for life - of children's excessive use of social networks. [8]

Thus, a first point emphasized is that Facebook and other similar sites infantilize the brain that is attracted to loud noises and bright lights, that has a limited attention span and lives only for the present moment. Participating in such social networks hardly involves any kind of concentration skills, and this fact trains the brain to develop only a limited field of attention.

A second important point is that children no longer learn to communicate in the real world. There are many testimonies from some teachers that state that social media affects children's understanding levels. Also, if children communicate primarily through the screen, they will not be able to learn the subtleties of real-life communication – such as body language, voice tone and inflections, and understanding beyond words.

A third aspect is that social media makes children more self-centered. As Facebook and other sites allow children to create their own page that is just about them, this leads more vulnerable children to think and believe that the world spins around them - which is a starter to the emotional problems they will face later in life.

Fourth, these sites make children—just like tabloids, TV shows, and a large part of the mass media in general—avid for the sensational.

Finally, pediatricians have noticed that some teenagers suffer from the so-called "Facebook depression". After spending a lot of time on Facebook and other popular social networking sites, some teenagers become anxious and moody, irritable, indisposed.

Also, the vulnerable teenager may suffer depression when he reads on his friends' Facebook pages what "wonderful" things are happening to them, while - by comparison - his own life does not seem so great. Teens who suffer from "Facebook depression" generally have trouble with social interactions, according to the American Academy of Pediatrics. [15]

Here can be added narcissism and its connection with another phenomenon represented by the selfie photo trend. A teenager may have thousands of virtual friends, countless likes, a hero in the virtual world, but all this is worth nothing in real life, in a real community; behind the selfie trend [3] hiding, in fact, there is a psychological weakness. Most of them

are self-obsessed youth [9] who have a permanent and childish need for appreciation from others and regarding computer games, they could lead to a low level of concentration, a need for immediate gratification and maybe affect non-verbal skills, such as maintaining eye contact during a conversation.

In order to be effective in real life, real experiences are needed. People who are online on the Internet all day lack this ability to adapt to new situations, having a low emotional intelligence. The lack of experience makes the world an unknown, therefore it can be scary - people can no longer stand to be in a community, to talk face to face, because they lack the ability to emotionally manage the moment. Frustrations, irascibility, aggressive behavior can appear from here.

Specialists from several fields Andrew Weil [1] - researcher and doctor from the USA or Francis Heylighen [2], cybernetician at the Free University of Brussels, draw attention to the fact that information addiction causes depression; the modern flow of information is useless. The huge amount of data produced on a daily basis effectively chokes our brain and the torrent of data characteristic of the contemporary age becomes, in their opinion, "informational smog". Most of these so-called crucial pieces of information are truncated, decontextualized and misinterpreted pieces of information. This means that they serve us absolutely nothing.

Nowadays, there is more and more value based on intelligence, understanding things or technical skills - those of the mind. In his book *Emotional Intelligence*, Daniel Goleman [5] collected the results of decades of research on intelligence, reaching the conclusion that we have a general tendency to underestimate the importance of social and emotional skills.

In the long run, there are much better predictors than IQ, so Goleman underlines the dramatic decline in "emotional competence" over the past two decades — what some researchers have named the "emotional deficiency disease."

In the United States, where most of the research has been conducted, on average, children showed a declining level of emotional skills on no less than 40 indicators of emotional and social well-being (between mid the seventh decade and the end of the eighth decade of the 20th century). These findings are worrying given that Goleman attests that IQ (intelligence quotient) contributes only about 20% to financial and personal success; the remaining 80% strongly depends on socio-emotional skills.

This study and many others clearly demonstrate that, beyond IQ, there are factors associated with effective mental skills. An important cause of the decline of these skills is precisely the fact that more and more children spend more and more time in front of the TV or computer, distancing themselves from other children and even from their parents, and most of the emotional skills are not learned alone but through interaction with other people.

Many employers in technical or financial professions around the world have begun, for several years, to show an even greater interest in "social and emotional intelligence" than

in the specialized skills of future employees, as they seek to hire people with a series of qualities such as: self-control, initiative, ability to concentrate, communication skills, creativity, the ability to work in a team, flexibility, honesty, enjoyment of working with people - exactly those skills that are in decline today .

As a result, since many of the children think more about the computer than about themselves and their values, therefore they must be helped to develop all their attributes and qualities, values, the ability to introspect, to take care of others, to develop spontaneous game skills, and personal satisfaction.

In our increasingly technological world, we are witnessing an unprecedented increase in problems such as attention deficit disorder, antisocial behaviors, poor motivation, depression and ineffective work habits. All of these originate in the emotional centers of the brain and are formed during childhood. The most important neural pathways that regulate these behaviors can only be developed through frequent and affectionate interaction with people, following the development of responsible thinking models.

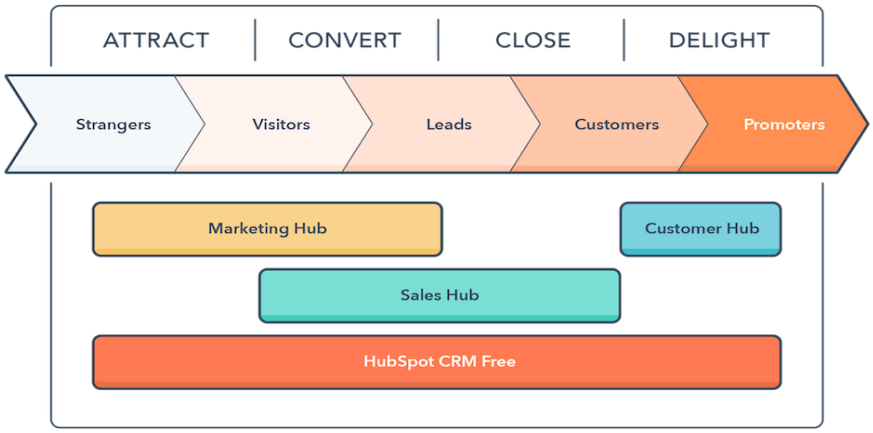
The famous professor Howard Gardner [4] from Harvard said that if we really want our children to learn to be creative, we should emphasize activities that stimulate inventiveness and ingenuity, done together with other children.

3. Conclusion

Customer behavior has changed over time, they now expect more from brands, real-time interaction, digital marketers are facing a new challenge: to present relevant marketing messages, that make their life better and don't distract them from what they are doing.

Today, customers expect seamless, connected, perfect experiences across all channels and instant gratification. There is only one "micro moment" (interaction between a customer and a brand in real time, at the touch of a button) [10] to gain and keep customer attention with a relevant message and a pleasant and interactive experience. Failing that, they move on to the next offer; that is why the old marketing techniques have perished.

Also related to attention, emphasis has recently been placed more and more on the notion of Inbound Marketing - as a new approach to marketing, based on three stages: ATTRACT, ENGAGE, ENJOY.[11]



Source: https://smarters.ro/

Modern marketers must adopt a mobile-first approach to global audiences.

- Customers want a unique experience.
- Customers have the last word. Customers decide when, where and how they interact with your brand.
- Customers want a seamless experience and the ability to start a conversation on any channel and be able to seamlessly switch to another channel if they want.
- Customers want to be served in the shortest possible time and in the most convenient way.

On the contrary, when it comes to children, it must be known that they are the most vulnerable in the age of technology and socialization through the devices made available by the modern world. Affective states, emotions have great value for the child's life and existence. [14] They help the child to be in touch with his mental or emotional needs. Emotional development is especially aimed at the child's ability to perceive and express his emotions, to understand and respond to the emotions of others.

Children who are exposed to advertising can be influenced by advertising messages and can develop consumption patterns and buying habits that can have a long-term impact on their buying behavior.

In order to prevent the situation [8] that they experience the syndrome of attention deficit, hyperactivity, etc., they should be presented with the real world from the perspective of some positive aspects. Excessive and obsessive use of the Internet can produce certain changes in the adolescent's psyche. Studies show that internet addiction can lead to mental

health problems, such as anxiety, depression, sleep disorders and low self-esteem. In addition, it can affect interpersonal relationships, decrease academic performance and cause behavioral problems.

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EVALUATING IMAGE CONTRAST: A COMPREHENSIVE REVIEW AND COMPARISON OF METRICS

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Abstract

Image contrast plays a pivotal role in the realm of digital imaging and computer vision, significantly influencing the visual quality and subsequent interpretation of images. Evaluating and quantifying this contrast has emerged as a critical need in a wide spectrum of applications, including medical imaging, remote sensing, and digital photography, among others. This paper offers a comprehensive review of various metrics available for the evaluation of image contrast, focusing on their underlying formulas, interpretations, advantages, disadvantages, and pertinent usage scenarios. The study compares metrics from histogram-based, spatial frequency-based, and statistical perspectives. It explores the computational complexity, accuracy, and robustness of these metrics, including their sensitivity to noise and other image degradations. Further, we discuss the real-world applications of these metrics in the domains of image enhancement, image quality assessment, and image compression. We also outline current challenges and propose future research directions for developing more robust and versatile contrast metrics. Our findings underscore the importance of an appropriate choice of contrast metric for effective image analysis and processing in various application settings.

Keywords: Image Contrast, Contrast Metrics, Histogram-based Metrics, Spatial Frequency-based Metrics, Statistical Contrast Metrics, Image Processing, Computer Vision, Image Quality Assessment

JEL Classification: C80, C65

1. Introduction

1.1. Background on the Importance of Image Contrast in Visual Perception and Computer Vision

Image contrast, a crucial element of digital imaging and visual perception, directly impacts the clarity, sharpness, and overall quality of an image. It serves as the foundation for distinguishing different objects and features within an image [1][2]. In computer vision,

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image contrast is central to image segmentation, feature extraction, object detection, and image recognition tasks [3][5]. A vital aspect of image enhancement techniques like histogram equalization [4] and Retinex-based methods [6], is their capacity to adjust image contrast to improve visual quality and facilitate subsequent image processing tasks [2].

Moreover, image contrast is pivotal in various application domains. In medical imaging, for instance, the fine contrast nuances can be indicative of health abnormalities [1][7]. Similarly, in remote sensing, the contrast within satellite imagery can reveal critical details about terrestrial phenomena [7]. Furthermore, in digital photography, image contrast significantly affects the aesthetic appeal and perception of images [5]. Thus, image contrast bears crucial importance in both visual perception and the field of computer vision [2][7].

1.2. Need for Accurate and Efficient Metrics for Evaluating Image Contrast

Given the crucial role of image contrast, the ability to accurately measure and quantify it is of paramount importance. This requirement is not merely for image enhancement techniques but also for evaluating image quality and performance of image processing algorithms [8][9][12]. Accurate contrast metrics serve as benchmarks for assessing the effectiveness of image enhancement algorithms and can guide the development of new methodologies [13][14].

Contrast metrics also play a significant role in automatic thresholding and segmentation, where accurate contrast evaluation can lead to improved results [10][14]. Consequently, the use of inappropriate or inaccurate contrast metrics can result in the suboptimal performance of these algorithms and lead to errors in subsequent image analysis tasks [9][14].

1.3. Overview of the Various Metrics Discussed in the Paper

In light of the importance of accurate contrast evaluation, this paper presents a detailed overview of several widely used contrast metrics. These include both global and local histogram-based metrics [4], spatial frequency-based metrics such as Fourier Transform-based Contrast (FTC) and Wavelet Transform-based Contrast (WTC) [3], and statistical metrics like Root Mean Square (RMS) Contrast, Michelson’s Contrast, and Weber's Contrast [11][12].

Each of these metrics has unique characteristics, advantages, and disadvantages that make them suitable for specific applications and scenarios. We will discuss these metrics in detail, providing mathematical formulas, interpretations, and examples of usage scenarios. This thorough review aims to offer a comprehensive understanding of these metrics, illuminating their importance, potential applications, and the ongoing need for their advancement [15].

2. Image Contrast: Concept and Importance

2.1. Definition and Theory of Image Contrast

Image contrast is defined as the difference in color or luminescence that distinguishes one object in an image from other objects and the backdrop [1][2]. More formally, it refers to the difference in intensity between the lightest and darkest parts of an image, which enables differentiation between features and objects within the image [3]. The concept of contrast is rooted in the human visual system's inherent sensitivity to differences in light intensity, enabling it to discern shapes, textures, and boundaries in visual scenes [2].

Contrast is usually quantified using a contrast metric, which provides a scalar value representing the degree of contrast within an image [11][12]. These metrics leverage various mathematical and statistical approaches, including spatial frequency analysis, statistical variance, and histogram analysis [4][10].

2.2. Role and Importance of Image Contrast in Various Domains

Image contrast holds paramount importance across a wide array of application domains. In medical imaging, for instance, subtle differences in contrast can indicate disease conditions, such as tumors in MRI scans or calcifications in mammograms [1][7]. Thus, effective contrast analysis can aid in early disease detection and diagnosis [1].

In remote sensing, contrast within satellite imagery can provide significant insights into environmental phenomena. Differences in contrast can help distinguish between different land use types, detect changes in vegetation cover, and identify areas affected by natural disasters [7].

Furthermore, in digital photography and graphic design, image contrast is a crucial aspect of image aesthetics [5]. High-contrast images often appear more vibrant and engaging, whereas low-contrast images can create a muted, softer impression [5]. Therefore, photographers and designers frequently manipulate image contrast to achieve desired visual effects.

2.3. Overview of the Impact of Low/High Contrast on Image Perception and Analysis

The level of contrast within an image profoundly influences its perception and interpretation. High contrast can enhance an image's sharpness, making features more distinguishable [3]. This can be particularly beneficial in applications such as remote sensing or surveillance, where distinguishing fine details is essential [7].

However, excessively high contrast can lead to saturation, where the brightest parts of an image appear washed out, and the darkest parts lose detail, a phenomenon often termed 'clipping' [5][13].

On the other hand, low contrast can make an image appear dull or hazy, causing difficulties in discerning features or objects within the image [1][2]. This is frequently encountered in medical imaging or under poor lighting conditions in photography [1][5]. But, similarly, certain artistic effects might leverage low contrast intentionally.

Therefore, the manipulation and evaluation of image contrast is a balancing act, dependent on the specific requirements of each application domain. Developing a thorough understanding of image contrast and its metrics is thus critical for optimal image analysis and processing [14][15].

3. Metrics for the Evaluation of Image Contrast

3.1. Definition and Understanding of Contrast Metrics

Contrast metrics are mathematical techniques designed to quantify the contrast of an image, representing it as a scalar value [3][12]. These metrics can evaluate contrast on a global scale—analyzing the entire image—or a local scale—focusing on specific regions or objects within an image [4].

While there are myriad contrast metrics, they typically fall under three primary categories: histogram-based, spatial frequency-based, and statistical metrics [3][4,][11]. Histogram-based metrics evaluate the distribution of pixel intensities across an image, with a wider distribution indicating higher contrast [4]. Spatial frequency-based metrics assess the rate of change of pixel intensities across an image, with faster changes denoting higher contrast [3]. Statistical metrics, on the other hand, typically calculate the dispersion of pixel intensities, such as through standard deviation or root mean square calculations [11].

Each metric comes with its own advantages and disadvantages, making them suitable for specific scenarios and applications [12][14]. Moreover, each metric may interpret contrast slightly differently, reflecting the various aspects of contrast that can be important in different contexts [9][15].

3.2. Importance of Contrast Metrics in Image Processing and Computer Vision

Contrast metrics are fundamental tools in the realm of image processing and computer vision. They serve as the basis for numerous applications, including image enhancement, quality assessment, and compression [1][6][13].

In image enhancement, contrast metrics can guide the adjustment of contrast to improve image quality. For example, histogram equalization techniques aim to spread out the histogram of an image to enhance contrast, based on the histogram-based contrast metric [4]. Similarly, Retinex-based enhancement methods manipulate the spatial frequencies within an image to adjust contrast, following the theory behind spatial frequency-based metrics [6].

Contrast metrics also serve as benchmarks for evaluating the performance of image processing algorithms. For instance, they can assess the effectiveness of enhancement techniques in improving image contrast [8][14]. In the field of image compression, contrast metrics can guide the compression process to preserve important contrast details and assess the quality of compressed images [1][13].

Furthermore, contrast measures are important in computer vision applications such as segmentation, feature extraction, and object recognition. They provide a means to quantify and compare the contrast of different regions or objects, aiding in distinguishing these features within an image [2][10].

Given their extensive applications and vital role in image analysis, a thorough understanding of contrast metrics is imperative. In the following sections, we will delve into the specifics of various contrast metrics, discussing their formulas, interpretations, advantages, disadvantages, and usage scenarios [15].

3.3. Histogram-based Contrast Metrics

3.3.1. Global Histogram Contrast

Global histogram contrast is a broadly used metric for evaluating image contrast that focuses on the overall intensity distribution of the image [4]. The principle underlying this metric is that an image with a wider distribution of intensities, covering the complete range from black to white, exhibits high contrast. Conversely, an image with pixel intensities clustered around a narrow range is considered to have low contrast.

The global histogram contrast (GHC) is typically calculated using the following formula:

$$GHC = Max(I) - Min(I)$$

where $Max(I)$ and $Min(I)$ represent the maximum and minimum pixel intensity values in the image I, respectively [4].

In terms of interpretation, a high GHC value suggests a high-contrast image, while a low GHC value implies a low-contrast image. A picture with pixel intensities that vary from 0 to 255, for example, would have a GHC value of 255, indicating great contrast. On the other hand, an image with all pixel intensities clustered around 128 would have a GHC value close to 0, suggesting low contrast [4].

Global histogram contrast provides several advantages. It is computationally efficient, as it only requires a single pass over the pixel intensities in the image. Furthermore, it is intuitive and straightforward to understand, making it a commonly used metric in many image processing tasks [4].

However, GHC also has its limitations. As a global metric, it is unable to account for local contrast variations within an image. Therefore, two images with the same global contrast

could have vastly different local contrast details [3][14]. Additionally, GHC is sensitive to outliers, such as noise, which can artificially inflate the contrast estimate [13].

Despite these limitations, GHC remains useful in many scenarios, particularly in image enhancement applications such as histogram equalization techniques. By spreading out an image's pixel intensity histogram, these strategies strive to increase the global histogram contrast, hence boosting the image's visual quality [4]. Moreover, GHC is beneficial in preliminary image analysis, providing a quick and efficient estimate of the overall image contrast [1][2].

3.3.2. Local Histogram Contrast

Unlike the Global Histogram Contrast, which provides a single contrast estimate for the entire image, Local Histogram Contrast (LHC) aims to quantify contrast variations within smaller regions of the image [4][8]. By analyzing contrast locally, LHC is capable of capturing more intricate contrast details, making it suitable for images with significant local contrast variations.

The LHC is frequently calculated by breaking the image into smaller chunks or regions and then calculating the histogram contrast for each of these regions separately. A common formula for calculating LHC is as follows:

$$LHC(x,y) = Max\big(I(x,y)\big) - Min(I(x,y))$$

where $Max\big(I(x,y)\big)$ and $Min(I(x,y))$ signify the highest and minimum levels of pixel intensity in the image I in the block situated at (x, y), respectively [4].

The interpretation of LHC is similar to GHC, with higher values indicating higher local contrast. However, as LHC provides a contrast estimate for each block, it results in a contrast map rather than a single scalar value, giving a more detailed depiction of the contrast distribution within the image [4][8].

The primary advantage of LHC is its ability to account for local contrast variations. This can provide a more nuanced understanding of the image contrast, particularly in images with complex intensity distributions or localized features [8][14]. Additionally, as LHC analyzes contrast on a block-by-block basis, it is less sensitive to outliers and noise compared to GHC [13].

However, LHC also has its disadvantages. It is computationally more intensive than GHC, given the need to calculate the histogram for multiple blocks. Furthermore, the choice of block size can significantly impact the contrast estimate, with smaller blocks capturing more local details but potentially being more sensitive to noise [9][14].

LHC is commonly employed in image segmentation, feature extraction, and object detection tasks in computer vision, where capturing local contrast details is crucial [10]. It

is also valuable in image enhancement techniques that focus on improving local contrast, such as adaptive histogram equalization methods [6]. Furthermore, LHC can provide a more accurate estimate of image quality in scenarios where local contrast variations are significant, such as in medical imaging or high dynamic range (HDR) imaging [7][15].

3.4. Spatial Frequency-based Contrast Metrics

3.4.1. Fourier Transform-based Contrast (FTC)

Fourier Transform-based Contrast (FTC) is a spatial frequency-based metric that quantifies image contrast by examining the frequency spectrum of the image. This metric is built upon the theory that high-frequency components correspond to rapid changes in pixel intensities—indicative of high contrast—while low-frequency components correspond to slow intensity changes—suggestive of low contrast [3][12].

The FTC metric is computed by first performing the Fourier Transform (FT) on the image and then examining the frequency spectrum that results. The FT transfers it from the spatial domain to the frequency domain, with each point in the modified image representing a different frequency from the original image. The magnitude of each point in the transformed image signifies the contribution of that frequency to the overall image [3].

The FTC can be computed using the following formula:

$$FTC = \sum |FT\big(I(u,v)\big)|^2$$

where $FT\big(I(u,v)\big)$ represents the Fourier Transform of the image I at the frequency coordinate (u,v) [3]. The square of the magnitude (denoted by $|.|^2$) is summed over all frequencies to yield the FTC.

In terms of interpretation, a high FTC value implies that the image contains a high proportion of high-frequency components, suggesting high contrast. Conversely, a low FTC value indicates a predominance of low-frequency components, suggesting low contrast [12].

One of the main advantages of FTC is its ability to account for contrast variations at different scales, given its focus on the frequency spectrum [3][12]. Furthermore, unlike histogram-based metrics, FTC is not sensitive to shifts in pixel intensities, as the FT is based on relative intensity changes rather than absolute intensity values [3].

However, FTC also has its limitations. As a global metric, it might overlook local contrast variations within the image. Additionally, FTC is computationally more intensive than histogram-based metrics, given the need to perform a Fourier Transform [9][14].

FTC is commonly used in image enhancement methods that focus on manipulating the spatial frequencies within an image to adjust contrast, such as the Retinex-based methods

[6]. Additionally, it is employed in quality assessment tasks that require a comprehensive understanding of the frequency spectrum, such as the evaluation of compressed images or the quality assessment of medical images [1][13][15].

3.4.2. Wavelet Transform-based Contrast (WTC)

Wavelet Transform-based Contrast (WTC) is another spatial frequency-based metric that measures image contrast using the wavelet transform, a tool that analyzes frequency content at different scales and locations within the image. This allows the WTC to provide a more localized contrast evaluation compared to FTC [3][7].

The WTC is calculated by first applying the Wavelet Transform (WT) to the image, creating a series of sub-band images each representing different frequency scales and spatial locations within the original image [3].

A common formula for computing WTC is as follows:

$$WTC = \sum |WT(\mathrm{I}(\mathrm{x}, \mathrm{y}))|$$

where $WT(\mathrm{I}(\mathrm{x}, \mathrm{y}))$ stands for the Wavelet Transform of the image I at the spatial coordinate (x, y), and the sum is taken over all the sub-band images [3].

The interpretation of WTC is similar to FTC, with higher WTC values indicating a high proportion of high-frequency components and thus high contrast, and lower WTC values indicating a predominance of low-frequency components and thus low contrast [7].

WTC's capacity to perform a multiscale and localized contrast analysis, capturing more fine contrast features inside an image, is one of its key benefits [7][14]. It is also less sensitive to noise compared to FTC, as the wavelet transform inherently suppresses noise within higher frequency sub-bands [5][14]. However, similar to FTC, WTC is computationally more intensive than histogram-based metrics due to the need to perform a Wavelet Transform [9]. Furthermore, the choice of wavelet function can significantly impact the contrast estimate, making WTC somewhat dependent on the choice of parameters [3][9].

WTC is commonly employed in tasks requiring multiscale and localized contrast analysis, such as image segmentation and feature extraction in computer vision [10]. Additionally, it is useful in image enhancement methods focusing on manipulating the spatial frequencies at different scales, such as wavelet-based methods [6]. Moreover, in quality assessment tasks that necessitate a comprehensive understanding of local frequency content—such as in medical imaging or texture analysis—WTC provides a powerful tool [7][15].

3.5. Statistical Contrast Metrics

3.5.1. Root Mean Square (RMS) Contrast

Root Mean Square (RMS) contrast is a statistical contrast metric that quantifies image contrast by measuring the standard deviation of pixel intensities. The principle behind RMS contrast is that images with a larger dispersion of pixel intensities, and hence larger standard deviation, have higher contrast [11].

The RMS contrast is typically computed using the following formula:

$$RMS\ Contrast = \sqrt{\frac{1}{M \cdot N} \sum (I(x,y) - \mu)^2}$$

where $I(x,y)$ indicates the intensity of the pixel at location (x, y) in the image, μ is the mean intensity of the image, and M and N are the dimensions of the image [11].

The interpretation of RMS contrast is straightforward: a higher RMS contrast value indicates a larger dispersion of pixel intensities and thus higher contrast, while a lower RMS contrast value indicates a smaller dispersion and thus lower contrast [11].

RMS contrast has the advantage of providing a statistical measure of contrast, which can supplement the information offered by histogram- and frequency-based metrics [3][11]. Furthermore, as a simple mathematical operation, the RMS contrast is computationally efficient and easy to implement.

However, similar to the Global Histogram Contrast, RMS contrast is a global metric and hence can overlook local contrast variations within an image [3][14]. Furthermore, it is sensitive to extreme values and noise, which can artificially inflate the standard deviation and thus the contrast estimate [13].

RMS contrast is useful in many scenarios, particularly in preliminary image analysis and quality assessment tasks, where it provides a quick and efficient estimate of image contrast [1][2]. It can also be used in conjunction with other contrast metrics to provide a more comprehensive analysis of image contrast. For example, it can complement histogram-based metrics in image enhancement applications, where the objective is to spread out the pixel intensity histogram and increase the standard deviation of pixel intensities [4].

3.5.2. Michelson's Contrast

Michelson's Contrast, named after the American physicist Albert A. Michelson, is a historical measure of contrast typically used for simple periodic images such as sinusoidal gratings. It is determined using the variation between the image's maximum and minimum intensity [14].

The Michelson's Contrast (MC) can be calculated using the following formula:

$$MC = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

where I_{max} stands out for the image's greatest intensity, and I_{min} stands out for the minimum intensity [14].

Interpreting MC is straightforward: a value close to 1 signifies high contrast, while a value close to 0 indicates low contrast. However, this measure of contrast is best suited to images with two predominant intensity levels [14].

One of the key advantages of Michelson's Contrast is its simplicity. It offers a clear, easy-to-calculate measure of contrast. However, its simplicity is also a limitation, as it does not consider the distribution or frequency of different intensities within the image [3]. Moreover, MC is sensitive to extreme values, with a single very bright or very dark pixel potentially having a disproportionate effect on the contrast estimate [9][13].

Given these characteristics, Michelson's Contrast has found usage in scenarios involving periodic or binary images, or those with two main intensity levels. It has also been employed in the field of visual perception research, where simple stimuli with periodic intensity patterns are often used [14]. However, for complex real-world images, other contrast metrics might provide a more comprehensive evaluation [1][2][11].

3.5.3. Weber's Contrast

Weber's Contrast, named after the pioneering psychophysicist Ernst Heinrich Weber, is a perceptual measure of contrast that quantifies the change in intensity relative to the background intensity. It is frequently used in psychophysics and vision research to assess an object's visibility against its backdrop. [14].

The Weber's Contrast (WC) can be computed using the following formula:

$$WC = \frac{I - I_b}{I_b}$$

where I represent the intensity of the object, and I_b represents the background intensity [14].

The interpretation of WC is as follows: a higher WC value means the object is more distinguishable from the background, indicating high contrast, while a lower WC value means the object is less distinguishable, indicating low contrast [14].

One of Weber's Contrast's main advantages is that it reflects the human visual system's relative sense of contrast. It simulates the finding that our perception of contrast is affected not only by the distinction in intensity between an item and its backdrop, but also by the intensity of the background [14]. However, a limitation of Weber's Contrast is that it's only defined for images or scenarios with a clear object and background, which limits its

applicability to complex real-world images [3][9]. Additionally, it assumes a linear response to contrast, which may not accurately reflect the human visual system's response in all conditions [13].

Weber's Contrast is extensively used in psychophysics and vision research to assess object visibility and simulate the human visual system's reaction to contrast [14]. It's also employed in image processing jobs that need a measure of contrast that reflects perceptual visibility, such as watermarking and steganography, where the goal is to hide information inside an image in an unnoticeable to the human eye [10].

4. Comparison of Contrast Metrics

Contrast metrics have been extensively used in image processing, computer vision, and related fields to evaluate and enhance the quality of images. However, the effectiveness of each metric can vary based on several factors including computational complexity, accuracy, robustness, and sensitivity to noise and other image degradations. In this part, we compare the contrast measures mentioned in this work across different dimensions.

4.1. Comparison in terms of Computational Complexity

When it comes to computational complexity, global metrics such as Global Histogram Contrast, RMS Contrast, Michelson’s Contrast, and Weber's Contrast typically have a lower computational load. They either require basic statistical calculations or simple operations on pixel intensities [1][2][11].

On the other hand, spatial frequency-based metrics such as Fourier Transform-based Contrast (FTC) and Wavelet Transform-based Contrast (WTC) are more computationally demanding. They require performing either a Fourier Transform or a Wavelet Transform on the image, operations which can be computationally intensive, especially for larger images [3][7][9].

4.2. Comparison in terms of Accuracy and Robustness

The accuracy and robustness of a contrast metric depend largely on the type and complexity of the images being evaluated. Global metrics can provide accurate contrast estimates for simpler images but can overlook local contrast variations in more complex images [3][14].

Conversely, FTC and WTC can provide more accurate and robust contrast estimates for complex images as they capture local variations in contrast. However, the choice of the Fourier or Wavelet function and other parameters can significantly impact the accuracy of these metrics [3][9].

4.3. Comparison in terms of Sensitivity to Noise and Other Image Degradations

Regarding sensitivity to noise and other image degradations, histogram-based and statistical metrics tend to be sensitive to extreme values and noise, which can artificially inflate the contrast estimate [13].

Spatial frequency-based metrics such as FTC and WTC are generally less sensitive to noise, as the Fourier and Wavelet Transforms inherently suppress noise within higher frequency bands [5][7]. However, they can be sensitive to other image degradations such as blurring, which can affect the image's high-frequency components [6][8].

The choice of contrast metric depends on the specific requirements of the application, including the computational resources available, the complexity of the images, and the level of noise and other degradations present in the images. While no single metric is universally superior, a combination of metrics can often provide a comprehensive and accurate evaluation of image contrast [3][14][15].

5. Practical Implications and Applications

Contrast measurements are important in a variety of real-world applications, which include but are not restricted to image enhancement, imagery evaluation, image compression, and others. They are integral to the analysis and optimization of image quality and also heavily impact the effectiveness of several image processing tasks.

5.1. Role of These Metrics in Real-World Applications

In image enhancement, the goal is to augment the visual quality of images, often by manipulating the image contrast. Image enhancement algorithms make use of contrast metrics to assess the quality of an improved image and direct the improvement process [11]. For instance, metrics such as the RMS Contrast can provide feedback on the overall contrast of an image, while Local Histogram Contrast, FTC, and WTC can provide spatially varying contrast details that guide local enhancement procedures [2][3][9].

Image quality assessment is another domain where contrast metrics are pivotal. In tasks such as watermarking and steganography, the objective is often to insert data into an image in a manner that's imperceptible to the human eye. Contrast metrics, particularly those that model human contrast perception like Weber's Contrast, are crucial in assessing the perceptual impact of these manipulations [10][13].

Contrast metrics also play a role in image compression, which involves reducing the storage size of an image without significantly compromising its quality. The contrast measure used can influence the apparent quality of the compressed image as well as the compression ratio obtained. [1][11].

5.2. Discussion on How the Choice of Contrast Metric Can Impact the Outcome of Such Applications

The choice of contrast metric can significantly impact the effectiveness and outcomes of the above-mentioned applications. For instance, in image enhancement, using a global contrast metric might result in an image with good overall contrast but poor local contrast in specific regions. On the other hand, using a local contrast metric like the FTC or WTC might result in an image with enhanced local details but potentially over-enhanced noise [7][8].

The use of a contrast metric in image quality evaluation might influence the perceived quality of the image. For example, a compression algorithm evaluated with a simple statistical metric like RMS Contrast might be deemed acceptable, but if evaluated using a perceptual metric like Weber's Contrast, the same algorithm might reveal noticeable artifacts due to the differences in how these metrics evaluate contrast [10][14].

Overall, the choice of contrast metric should align with the specific requirements and characteristics of the application. Understanding the strengths and limitations of each contrast metric can enable researchers and practitioners to select the appropriate metric and improve the outcomes of their image processing tasks [15].

6. Future Research Directions

Image contrast is a key characteristic influencing image quality and the effectiveness of many computer vision and image processing tasks. Despite the wide variety of contrast metrics currently available, there exist numerous challenges and opportunities for future research in this area.

6.1. Discussion on the Challenges in Current Contrast Metrics

Existing contrast metrics, while offering valuable insights into image quality, face several limitations. Metrics such as Global Histogram Contrast, and RMS Contrast often fall short in capturing local variations in contrast, and are sensitive to extreme values and noise [3][13][14]. On the other hand, Fourier Transform-based Contrast (FTC) and Wavelet Transform-based Contrast (WTC), which are better equipped to capture local contrast variations, demand more computational resources and can be affected by parameter selection and to image degradations like blurring [5][7][9].

Another challenge lies in the gap between these metrics and the human visual perception of contrast. Weber's Contrast, although designed to mimic human visual perception, assumes a linear response which may not hold true in all conditions [13]. Future research

should aim to address these challenges to develop contrast metrics that are robust, efficient, and perceptually relevant.

6.2. Suggestions for Future Research in Developing More Robust and Versatile Contrast Metrics

Future research in contrast metrics should seek to combine the advantages of existing metrics while minimizing their limitations. One promising direction could be to explore hybrid metrics that incorporate both global and local contrast measures [3]. This could potentially yield more robust and versatile contrast metrics capable of providing a comprehensive evaluation of image contrast.

Another area of exploration could be the integration of machine learning techniques. Deep learning algorithms, for example, could be trained to learn contrast features directly from image data, leading to metrics that better capture the complexity of real-world images [15].

Furthermore, because contrast is perceptual, future research should seek to produce measurements that closely correlate with human visual perception. This could involve integrating insights from vision science and psychophysics into the design of contrast metrics.

6.3. Potential Applications of Future Contrast Metrics

The development of more robust and versatile contrast metrics has the potential to advance a wide range of applications. In medical imaging, for example, improved contrast metrics could enhance the visibility of anomalies and aid in earlier and more accurate diagnoses [1][2].

In the field of remote sensing, better contrast metrics could improve the quality of satellite images and lead to more accurate earth observation data [4]. Similarly, in digital photography, enhanced contrast measures could help in developing better image enhancement algorithms and improve the quality of photographs [2][11].

Moreover, the development of perceptually relevant contrast metrics could advance areas such as virtual reality and computer graphics, where the goal is often to generate images that are as perceptually realistic as possible [15].

While tremendous progress has been achieved in the domain of contrast metrics, there remain several opportunities for future research. We may design more robust and adaptable contrast measures that better suit the demands of diverse image processing and computer vision applications by addressing present constraints and leveraging the promise of upcoming methodologies [1][2][3][15].

7. Conclusion

Image contrast, as a vital aspect of image quality, carries significant implications for image analysis and processing, as well as computer vision. Through this paper, we have presented an in-depth review of a range of contrast metrics, each offering unique advantages and facing particular limitations.

We have discussed global metrics, such as Global Histogram Contrast, RMS Contrast, Michelson's Contrast, and Weber's Contrast, and their strength in providing an overall estimate of contrast, which can be computed with relatively low computational complexity [1][2][11]. However, their inherent limitation lies in their inability to capture local contrast variations, as well as their sensitivity to noise and extreme values [3][13][14].

On the other hand, we have explored spatial frequency-based metrics, like Fourier Transform-based Contrast (FTC) and Wavelet Transform-based Contrast (WTC), which excellently capture local contrast variations. These metrics, though computationally demanding, offer more accurate and robust contrast estimates for complex images [3][7][9].

These metrics carry vast implications for fields like medical imaging, remote sensing, digital photography, and more [1][2][4]. They are essential for evaluating and improving the quality of images, and they have a substantial impact on the results of many image processing activities such as image enhancement, image quality assessment, and image compression [11][15].

However, the contrast measure used is determined by the specific requirements of the application, considering factors like computational resources, the complexity of the images, and the level of noise and other degradations present [3][14][15]. This balance underlines the need for continued research towards developing more robust and versatile contrast metrics, with an emphasis on aligning them more closely with human visual perception.

The quest for improved contrast metrics remains, with future work ideally focusing on addressing current challenges and harnessing the potential of emerging techniques like machine learning. The goal is to develop more robust and versatile contrast metrics that offer a comprehensive evaluation of image contrast and can adapt to a variety of image characteristics [1][2][3][15].

In conclusion, the journey towards the development of perfect contrast metrics continues, promising significant advancements in various fields related to image processing and computer vision. This journey will undoubtedly carry a transformative potential, shaping the future of how we perceive, understand, and utilize images [1][2][3][15].

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COMPREHENSIVE EVALUATION OF METRICS FOR IMAGE RESEMBLANCE

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Abstract

In order to measure image similarity in the field of Computer Science, this study will analyze the main metrics in-depth. Image resemblance metrics play a significant role in various domains, including but not limited to, digital image processing, computer vision, and machine learning. This study embarks on a journey through various pixel-based and structural similarity metrics such as Mean Absolute Error (MAE), Mean Squared Error (MSE), Peak Signal to Noise Ratio (PSNR), Structural Similarity Index (SSIM), Multi-Scale Structural Similarity Index (MS-SSIM), and other advanced metrics like Feature Similarity Index (FSIM), Universal Quality Index (UQI), and Visual Information Fidelity (VIF). A comparative analysis of these metrics is conducted, shedding light on their specific pros and cons and their applicability in different contexts. The paper also addresses the importance and role of these metrics in the evolving field of deep learning. Lastly, we discuss the current challenges, and limitations of these metrics, and envision the future scope and advancements in image resemblance metrics.

Keywords: Mean Absolute Error, Mean Squared Error, Peak Signal to Noise Ratio, Multi-Scale Structural Similarity Index (MS-SSIM), Deep Learning for Image Resemblance

JEL Classification: C80, C65

1. Introduction

As computer science continues to progress, the role of image resemblance measures becomes increasingly important across a broad range of applications [1][2][3]. These metrics underpin many fields, including but not limited to digital image processing, computer vision, machine learning, and deep learning, highlighting the necessity for a robust understanding of these measures [3][4][5].

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1.1. Purpose of the study

The primary aim of this research is to deliver a comprehensive exploration of the critical metrics employed to assess image resemblance. These metrics are vital for comparing various images and evaluating the performance of different image processing algorithms, serving as a fundamental tool in the rapidly evolving domains of digital image processing and computer vision [2][3].

1.2. Brief overview of image resemblance metrics

Image resemblance metrics, ranging from traditional pixel-based measures such as Mean Absolute Error (MAE) and Mean Squared Error (MSE), to more recent measures like Peak Signal to Noise Ratio (PSNR), provide the basis for this study [6-new|5]. Further, we delve into structural similarity metrics like the Structural Similarity Index (SSIM) and the Multi-Scale Structural Similarity Index (MS-SSIM) [1][10]. Additionally, advanced metrics such as the Feature Similarity Index (FSIM), Universal Quality Index (UQI), and Visual Information Fidelity (VIF) will be analyzed in depth [11][12][13].

1.3. Importance and applications of image resemblance in computer science

In addition to detailing these metrics, the paper explores their importance and role in the burgeoning field of deep learning. With the application of deep learning algorithms, researchers can achieve superior results in tasks related to image resemblance [4][5][14][12]. Despite significant strides in the field, there are still numerous challenges and limitations with these metrics that need addressing. Consequently, an integral part of this study involves an in-depth examination of these issues, aiming to lay the groundwork for future research in this area [2][3][13]. The objective of this comprehensive study is to provide researchers and practitioners with a detailed understanding of the range of image resemblance metrics currently available. The hope is that this investigation will facilitate a better selection and application of these metrics across different scenarios, thereby significantly improving the efficacy and precision of tasks related to image processing and computer vision [1][2][3].

2. Image Resemblance: An Overview

Image resemblance, at its core, is a measure that allows for the comparison of two or more images to assess their similarity. A detailed understanding of this concept is integral to many aspects of computer science, particularly in fields such as image processing, computer vision, and machine learning [1][2][3].

2.1. Definition and need for Image Resemblance Metrics

In simple terms, image resemblance metrics provide quantitative means of assessing the degree of similarity between two or more images [2]. These metrics work by evaluating various features, such as color, intensity, texture, or structure of the images, and then providing a quantified value representing the degree of resemblance [1][2]. Traditionally, these metrics relied on pixel-level comparisons where individual pixel values in the images were compared directly. These pixel-based metrics included the Mean Absolute Error (MAE) and the Mean Squared Error (MSE), which offered a simple and straightforward way of comparing image similarity [6]. Although these metrics have served a purpose, they have limitations in capturing perceived similarities or differences in image content due to their inability to model the complex characteristics of human visual perception [6][7].

As a result, more sophisticated measures such as the Peak Signal to Noise Ratio (PSNR), Structural Similarity Index (SSIM), and Multi-Scale Structural Similarity Index (MS-SSIM) were developed [1][10]. The last two measures go beyond pixel-level comparisons to evaluate structural and statistical similarities between images, thereby aligning better with human visual perception [1][7][10]. The need for image resemblance metrics is widely recognized across various fields of computer science. In image processing, for instance, these metrics are crucial in quantifying the effectiveness of algorithms designed for image restoration, compression, and enhancement [2][3]. They provide a benchmark to evaluate the performance of these algorithms and guide their development [2][3].

Furthermore, in the broader fields of machine learning and deep learning, image resemblance metrics have significant applications. They are used for training models to recognize patterns in images, guiding the optimization process and providing a measure to evaluate the performance of models [4][5]. Applications in these fields range from object recognition and image segmentation in computer vision to more advanced tasks in deep learning such as generating synthetic images with Generative Adversarial Networks (GANs) [5][14][12].

As our reliance on digital images continues to grow, the need for robust, reliable, and sophisticated image resemblance metrics becomes more pronounced. Therefore, understanding these metrics and their applications is critical for researchers and practitioners in the field of computer science [2][3][4][5].

2.2. Brief history and evolution of image resemblance metrics

The history of image resemblance metrics parallels the evolution of computer science and digital imaging technologies. Initially, the simple task of comparing images necessitated measures that were straightforward and computationally inexpensive. This requirement led to the development of pixel-based metrics like Mean Absolute Error (MAE) and Mean

Squared Error (MSE), which worked by performing direct comparisons of individual pixel values between two images [6].

While MAE and MSE offered a rudimentary form of image comparison, it soon became apparent that these measures had limitations. Specifically, they were insufficient for capturing perceptual similarities and differences between images due to their simplistic approach [6][7]. Moreover, they failed to account for spatial and structural information, which are key aspects of how humans perceive images. As the field matured and the need for more sophisticated image comparison metrics grew, Peak Signal to Noise Ratio (PSNR) was introduced [6]. PSNR provided a more nuanced measure than MAE or MSE by comparing the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Although a significant advancement, PSNR still primarily relied on pixel-level comparisons and thus carried some of the limitations of its predecessors [7]. The realization of the limitations of pixel-based metrics and the necessity for measures that mirrored human visual perception led to the development of structural similarity metrics. Among these, the Structural Similarity Index (SSIM) became a popular measure due to its ability to capture structural and statistical similarities between images [1][10]. It represents a significant step forward in the field, as it considers that the human visual system is highly adapted to extract structural information from a visual scene [10].

Furthermore, the Multi-Scale Structural Similarity Index (MS-SSIM) was introduced to account for the fact that human perception of image quality can change based on the viewing conditions, such as the distance from the screen [1]. By considering different scales of viewing conditions, MS-SSIM provides a more comprehensive measure of image resemblance. The latest advancements in this field have led to the creation of more complex metrics like the Feature Similarity Index (FSIM), Universal Quality Index (UQI), and Visual Information Fidelity (VIF) [11][12][13]. These metrics represent the latest efforts to create measures that not only mimic human visual perception more closely but also capture a broader array of image features and properties.

In sum, the evolution of image resemblance metrics has been marked by a constant strive to develop measures that are both computationally efficient and align more closely with human visual perception. The quest for the ideal measure continues, fostering the ongoing development and refinement of image resemblance metrics [2][11][13].

3. Pixel-Based Metrics

Pixel-based metrics form the bedrock of image resemblance measurement. These measures operate by directly comparing pixel values between images, providing a fundamental and straightforward method for assessing similarity [6]. Despite their simplicity, pixel-based metrics have played an integral role in the evolution of image resemblance measures and continue to be employed widely across various applications [6][7].

Two of the earliest and most prevalent pixel-based metrics are Mean Absolute Error (MAE) and Mean Squared Error (MSE) [6]. Both metrics quantify the discrepancy between corresponding pixels in two images, with MAE calculating the average absolute difference and MSE determining the average squared difference [6]. These metrics provide a straightforward means of comparing images and have been extensively used for tasks such as image compression and restoration, where the objective is to minimize the difference between the original and processed images [6][7]. Despite their widespread use, pixel-based metrics like MAE and MSE have limitations. Specifically, they fail to capture perceptual similarities and differences between images adequately. This failure stems from their emphasis on individual pixel values, which neglects the spatial and structural information that is central to human visual perception [6][7]. Moreover, these measures are sensitive to the precise alignment of structures in the images, meaning that even minor misalignments can result in significant differences in the calculated metric [6]. Although, pixel-based metrics continue to serve as a fundamental tool in the arsenal of image resemblance measures. They provide a simple and computationally efficient means of comparing images, and their shortcomings have driven the development of more sophisticated measures [2][7]. While more advanced metrics are increasingly employed to better mirror human visual perception, pixel-based metrics like MAE and MSE remain valuable for tasks where a direct pixel-level comparison is adequate or desired [2][6][7].

3.1. Mean Absolute Error (MAE)

Mean Absolute Error (MAE) is one of the most fundamental pixel-based metrics used in the field of image processing for assessing the level of resemblance between two images [6].

3.1.1. Definition and Formula

MAE is often used in applications such as image compression and restoration, where the objective is to minimize the difference between the original and processed images [6][7]. It offers a simple and straightforward way to quantify the discrepancy between two images and is computationally efficient, making it useful for tasks where rapid comparison is necessary [6]. However, MAE has some limitations. Firstly, it treats all errors equally, regardless of their context. This means that it does not take into account the spatial relationships between pixels, which can be a critical aspect of human visual perception [6][7]. Secondly, MAE is sensitive to the precise alignment of structures in the images, meaning that even minor misalignments can result in significant differences in the calculated metric [6]. Moreover, the metric's simplistic nature means it may not accurately reflect perceived image quality or similarity [6][7]. Despite these limitations, MAE remains a useful tool in many image processing tasks due to its simplicity and computational

efficiency [6]. Its shortcomings, however, have driven the development of more sophisticated metrics that better account for human visual perception [2][7].

3.2. Mean Squared Error (MSE)

Mean Squared Error (MSE) is another fundamental pixel-based metric that quantifies the difference between two images. It is one of the most widely used metrics in the field of image processing, particularly for the assessment of image quality [6].

3.2.1. Definition and Formula

MSE measures the average squared difference between corresponding pixel intensities of two images. For two $M\ x\ N$ grayscale images, I and K, the MSE is calculated using the following formula:

$$MSE = \frac{1}{MN}\sum_{i=0}^{M}\sum_{j=0}^{N}\left(I_{(i,j)} + K_{(i,j)}\right)^2$$

where $I_{(i,j)}$ and $K_{(i,j)}$ are the pixel values at the ith row and jth column in images I and K, respectively, and the sum $\sum$ is over all the M rows and N columns of the images [6]. This formula calculates the average of the squares of the differences between the pixel intensities of the two images.

3.2.2. Applications and Limitations

MSE, like MAE, is often used in tasks such as image compression and restoration, where the goal is to minimize the difference between the original and processed images [6][7]. By squaring the differences, MSE gives more weight to larger errors, making it a useful measure when large discrepancies between images are particularly undesirable [6]. However, MSE also shares some of the limitations of MAE. It does not consider the spatial relationships between pixels and is sensitive to the precise alignment of structures in the images, leading to potentially significant differences in the calculated metric for minor misalignments [6][7]. Furthermore, because MSE treats all squares of differences equally, it can be overly influenced by outlier pixel values that are not necessarily perceptually significant [7]. Despite these limitations, MSE remains a standard measure for image comparison due to its simplicity and the ease with which it can be calculated [6]. Nevertheless, the evolution of more sophisticated metrics that better capture the complexity of human visual perception have supplemented its use [7].

3.3. Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) is a more sophisticated pixel-based metric that measures the quality of a reconstructed or compressed image in comparison to the original [7].

3.3.1. Definition and Formula

PSNR is defined as the ratio between the maximum possible power of a signal (image) and the power of the noise (error) that corrupts the fidelity of its representation [7]. PSNR is often expressed in decibels (dB), which is a logarithmic scale. The formula for PSNR is as follows:

$$PSNR = 20 \cdot log_{10}(MAX_I) - 10 \cdot log_{10}(MSE)$$

Here, MAX_I is the maximum possible pixel value in the image. For instance, for an 8-bit grayscale image, $MAX_I$is 255. MSE is the Mean Squared Error between the original and the reconstructed or compressed image [6][7].

3.3.2. Applications and Limitations

PSNR is commonly used in the field of image and video coding. Here, it serves as a performance measure for compression algorithms, quantifying the fidelity of the reconstructed image or video in comparison to the original [7][9]. The higher the PSNR, the closer the reconstructed image is to the original, and therefore, the better the quality of the reconstruction or compression. Despite being a step up from MAE and MSE, PSNR also carries limitations. Like MSE, it doesn't fully account for human visual perception and can provide a high score for images that appear of poor quality to the human eye [7][9]. PSNR is sensitive to changes in image brightness, noise distribution, and structural information, factors that are not always accurately reflected in a single PSNR value [7][9]. Additionally, PSNR assumes that the noise is signal-independent, which is not always the case in real-world scenarios [9]. Despite these shortcomings, PSNR continues to be widely used in the field of image and video coding due to its simplicity and the meaningful insight it provides into the quality of reconstruction or compression algorithms [7][9]. Its limitations have driven the development of more sophisticated measures that better capture human visual perception [9][10].

4. Structural Similarity Metrics

Recognizing the limitations of pixel-based metrics in capturing human visual perception, researchers have developed more sophisticated metrics that focus on the structural similarity between images. These metrics, known as structural similarity metrics, aim to reflect the way humans perceive images by considering factors such as luminance, contrast,

and structural information [1][10]. Two of the most well-known structural similarity metrics are the Structural Similarity Index (SSIM) and the Multi-Scale Structural Similarity Index (MS-SSIM) [1]. Both metrics measure the structural similarity between two images, going beyond simple pixel comparisons to consider the spatial relationships between pixels and other aspects of human visual perception [1][10]. The development of structural similarity metrics represents a significant step forward in the field of image resemblance metrics. By considering the way humans perceive images, these metrics offer a more nuanced and perceptually relevant measure of image resemblance [1][10]. However, like all metrics, they have their limitations. They are computationally more intensive than pixel-based metrics, and their performance can vary depending on the specific image content and application [1][10][11]. Nevertheless, the development and refinement of structural similarity metrics continue to be a vibrant area of research in the field of image processing, and these metrics are increasingly being employed in applications where a more perceptually relevant measure of image resemblance is required [1][10][12].

4.1. Structural Similarity Index (SSIM)

The Structural Similarity Index (SSIM) is a method for predicting the perceived quality of digital television and cinematic pictures, as well as other types of digital images and videos [1].

4.1.1. Definition and Formula

The SSIM index is a full reference metric; in other words, the measurement or prediction of image quality requires an ideal original reference image for comparison. The SSIM index measures the similarity between two images, where a value of 0 denotes no structural similarity and a value of 1 suggests complete structural similarity [1]. The SSIM is calculated over windows of an image rather than on a per-pixel basis. A window is typically chosen to be Gaussian, reflecting the fact that pixels that are closer together are more strongly interrelated in the human visual system [1].

The SSIM is given by the following formula:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

where μ_x and μ_y are the averages of x and y, σ_x^2 and σ_y^2 are the variances of x and y, σ_{xy} is the covariance of x and y, and c_1 and c_2 are variables to stabilize the division with weak denominator [1][12].

4.1.2. Applications and Limitations

SSIM is widely used in various fields such as image processing, computer vision, and machine learning, where it serves as a robust method for comparing image similarity [1][12]. It is particularly useful for tasks involving image compression, transmission, and restoration, where a more perceptually relevant measure of image quality is desired [1][12].

Despite its utility, SSIM is not without limitations. One key drawback is its higher computational cost compared to simpler pixel-based metrics [12]. Also, SSIM, like all full-reference metrics, requires an ideal reference image for comparison, which is not always available in real-world scenarios [1][12]. Furthermore, SSIM's performance can vary depending on the specific image content and task, and it may not always align perfectly with human perception [1][12]. Even with these challenges, the SSIM continues to be a highly valuable tool for image comparison and quality assessment. Its ability to capture structural similarities and consider factors beyond simple pixel intensity differences makes it a more perceptually relevant measure of image resemblance [1][12]. The ongoing development of SSIM and related metrics is a testament to the importance of this area in the field of image processing and computer vision [12].

4.2. Multi-Scale Structural Similarity Index (MS-SSIM)

The Multi-Scale Structural Similarity Index (MS-SSIM) is an extension of SSIM that considers image details at multiple scales, reflecting the multi-scale nature of the human visual system [1][13].

4.2.1. Definition and Formula

Like SSIM, MS-SSIM is a full-reference metric, meaning that it requires a reference image for comparison. Unlike SSIM, however, MS-SSIM applies the SSIM algorithm at various scales to capture the multi-scale nature of the human visual system [1][13].

MS-SSIM is calculated by first applying a low-pass filter to the images to generate scaled versions, then computing SSIM at each scale. The final MS-SSIM value is the product of the SSIM values at each scale, where each SSIM value is raised to a power corresponding to the relative importance of that scale [1][13].

The formula for MS-SSIM is as follows:

$$MS - SSIM(x, y) = \frac{1}{M}\sum_{i=0}^{M}\big(SSIM(x_i, y_i)\big)$$

where x_i and y_i are the images at scale i, $SSIM(x_i, y_i)$ is the SSIM value at scale i. The sum is over all M scales of the window [1][13].

4.2.2. Applications and Limitations

MS-SSIM is used in various areas of image processing, computer vision, and machine learning, where it serves as a robust method for comparing image similarity at multiple scales [1][13]. It is particularly useful for tasks that involve changes in scale, such as image resizing and multi-resolution image fusion [1][13]. However, MS-SSIM shares many of the limitations of SSIM. It is computationally more expensive than pixel-based metrics and requires a reference image for comparison, which may not be available in all scenarios [1][13]. Additionally, the performance of MS-SSIM can vary depending on the specific image content and task, and it may not always align perfectly with human perception [1][13].

Despite these challenges, MS-SSIM represents a significant step forward in the field of image resemblance metrics. By considering image details at multiple scales, it offers a more nuanced and perceptually relevant measure of image resemblance [1][13]. The ongoing development of MS-SSIM and related metrics underscore the importance of this area in the field of image processing and computer vision [13].

5. Advanced Image Resemblance Metrics

Regardless of the remarkable strides in the development of image resemblance metrics, there remain challenges that call for more advanced methods. The growing complexity of image processing tasks, the increasing variety of image and video data, and the ongoing pursuit of metrics that more closely align with human visual perception have all fueled the development of advanced image resemblance metrics [4][10].

Advanced image resemblance metrics extend and combine the principles of pixel-based and structural similarity metrics, while also incorporating novel concepts from related fields such as machine learning and statistical analysis [4]. For instance, some advanced metrics employ deep learning to automatically learn features and patterns that are relevant for image resemblance, while others use sophisticated statistical methods to model the relationships between pixels and image structures [4][10].

Two representative examples of advanced image resemblance metrics are the Feature Similarity Index for Color Images (FSIMc) and the Deep Image Quality Metric (DIQM) [4][8]. Both metrics represent significant advancements in the field, offering improved performance and more nuanced insights into image resemblance [4]. However, like all metrics, they are not without their limitations, including higher computational costs, more complex implementation requirements, and the need for large volumes of training data in the case of deep learning-based metrics [4][10].

Despite these challenges, the development and application of advanced image resemblance metrics continue to be a vibrant area of research, promising to open new possibilities and capabilities in the field of image processing and beyond [4][10].

5.1. Feature Similarity Index (FSIM)

The Feature Similarity Index (FSIM) is an advanced image resemblance metric that emphasizes image features in its calculation, providing a more robust and comprehensive measure of image similarity [4].

5.1.1. Definition and Formula

The FSIM method is based on the premise that human visual perception is highly sensitive to low-level features, such as edges and corners, in an image. Therefore, FSIM assigns larger weights to the regions containing such features when calculating image similarity [4].

The FSIM formula is given by:

$$FSIM(x, y) = \frac{1}{N \sum_{i=1}^{N} s_i}$$

where N is the total number of pixels in the images, $\sum_{i=1}^{N} s_i$ is the sum of similarity measures at each pixel location i, and s_i is the similarity measure at location i, calculated as:

$$s_i = \frac{2x_i y_i + c_1}{({x_i}^2 + {y_i}^2 + c_1)T_i}$$

where x_i and y_i are the pixel intensities at location i in the two images, c_1 is a small constant to prevent division by zero, and T_i is a topological feature similarity map that assigns larger weights to feature-rich regions [4].

5.1.2. Applications and Limitations

The FSIM method has been widely applied in various areas of image processing, including image quality assessment, image compression, and image fusion, where it has demonstrated superior performance compared to traditional metrics such as SSIM and PSNR [4]. Despite its robustness and versatility, FSIM also has its limitations. The calculation of the topological feature similarity map T_i can be computationally intensive, making FSIM less suitable for real-time applications [4]. In addition, FSIM, like other full-reference metrics, requires an ideal reference image for comparison, which may not always be available [4]. Nevertheless, the continued development and refinement of FSIM and related feature-based metrics underscore the importance of incorporating human visual perception principles into

image resemblance metrics. By assigning larger weights to feature-rich regions, FSIM and similar metrics provide a more nuanced and perceptually relevant measure of image similarity [4].

5.2. Universal Quality Index (UQI)

The Universal Quality Index (UQI) is a sophisticated metric that aims to provide a comprehensive and general evaluation of image quality, considering luminance, contrast, and structural information [8].

5.2.1. Definition and Formula

UQI quantifies the degree of similarity between the reference and the test image by measuring the correlation between the two images, thereby providing a more generalized assessment of image quality [8].

The UQI formula is expressed as follows:

$$UQI(x,y) = \frac{4\sigma_{xy}\bar{x}\bar{y}}{(\sigma_x^2 + \sigma_y^2)[(\bar{x})^2 + (\bar{y})^2]}$$

where $\bar{x}$ and $\bar{y}$ are the mean intensities of x and y, σ_x^2 and σ_y^2 are the variances of x and y, and σ_{xy} is the covariance of x and y [8].

5.2.2. Applications and Limitations

UQI has wide applications in fields such as image processing, image analysis, and computer vision. It is particularly useful in scenarios where a measure of image quality that balances luminance, contrast, and structure is required [8]. However, like all full-reference metrics, UQI requires a reference image for comparison, which may not always be available [8]. Moreover, UQI assumes a linear relationship between the test and reference images, which may not always hold, especially in cases of non-linear transformations [8]. Despite these limitations, UQI represents a significant step forward in the field of image quality assessment. By incorporating luminance, contrast, and structural information, UQI provides a more comprehensive measure of image quality. Its universal nature makes it a valuable tool in a wide range of applications, testifying to the importance of developing advanced, generalized metrics for image resemblance [8].

5.3. Visual Information Fidelity (VIF)

The Visual Information Fidelity (VIF) metric, developed with a clear grounding in the principles of information theory, presents an innovative approach to image resemblance

assessment by estimating the amount of information shared between reference and test images [10].

5.3.1. Definition and Formula

The VIF metric is built on the idea that image quality or resemblance is best judged by the extent to which the test image preserves information from the reference image [10]. Specifically, VIF estimates how much information that could be extracted from the reference image is still extractable from the test image [10].

Given a reference image x and a test image y, VIF is computed as follows:

$$VIF(x,y) = \frac{I(x;y)}{H(x)}$$

where $I(x;y)$ denotes the mutual information between x and y — a measure of the amount of information that x and y share — and $H(x)$ is the entropy of x, which measures the amount of information contained in x [10]. The ratio therefore represents the proportion of information in the reference image that is preserved in the test image.

5.3.1.1. Mutual Information ($I(x;y)$)

Mutual information measures the amount of information that can be obtained about one random variable by observing another. In the context of image resemblance, the mutual information between a reference image x and a test image y measure how much information about x can be inferred by observing y.

The mutual information $I(x;y)$between x and y is defined as follows:

$$I(x;y) = \sum_y \sum_x p(x,y) log\left(\frac{p(x,y)}{p(x)p(y)}\right)$$

where $p(x,y)$ is the joint probability density function of x and y, and $p(x)$ and $p(y)$ are the marginal probability density functions of x and y, respectively.

5.3.1.2. Entropy ($H(x)$)

Entropy is a measure of the unpredictability or randomness of a set of data. For a reference image x, the entropy $H(x)$measures the amount of *information* contained in x.

The entropy $H(x)$of x is defined as follows:

$$H(x) = -\sum_x p(x) log\, p(x)$$

where $p(x)$ is the probability density function of x.

In the context of the VIF metric, $H(x)$ serves as a normalization factor, allowing $I(x;y)$ to be interpreted as a proportion of the total information in the reference image x. In both formulas, the logarithm can be taken to any base, but the base 2 logarithm is commonly used in the context of information theory, resulting in measures in bits. Note that these definitions assume discrete images and require estimation of the probability density functions, which can be challenging for continuous or high-dimensional data. Various methods exist to approximate these measures for real-world images.

5.3.2. Applications and Limitations

The VIF metric finds broad applications in fields such as image processing, compression, restoration, and quality assessment. It is especially useful in contexts where it's crucial to preserve information content in images, such as in medical imaging or satellite imaging [10]. However, as with many advanced image resemblance metrics, VIF comes with its own set of limitations. The computation of mutual information and entropy can be computationally demanding, especially for large or high-resolution images [10]. Additionally, the concept of 'information' as used in VIF may not always align with perceptual notions of image quality or similarity. Lastly, VIF, like other full-reference metrics, requires the availability of a reference image, limiting its applicability in some scenarios [10]. Despite these challenges, VIF represents a notable advance in the development of image resemblance metrics. Taking an information-theoretic approach, it offers a novel perspective on image quality assessment that complements and extends traditional pixel-based and structure-based methods [10].

6. Image Resemblance Metrics in Deep Learning

The advent and rapid development of deep learning has had profound implications for the field of image resemblance metrics. With the ability to learn highly complex, non-linear mappings from large datasets, deep learning models have been increasingly deployed for tasks requiring the evaluation of image resemblance [2][3][5][14]. Traditional image resemblance metrics are typically hand-designed, based on a priori assumptions about the task at hand and the nature of images. These metrics, while useful in many scenarios, may not always be suited to the intricacies of complex real-world images or specialized tasks. On the contrary, deep learning offers an alternative, data-driven approach to the design of image resemblance metrics. By training on large datasets, deep learning models can learn to measure image resemblance in ways that are tailored to specific tasks and types of images [2][3].

A common approach in deep learning is to use convolutional neural networks (CNNs) to learn feature representations of images, and then compute image resemblance in the learned

feature space [5][14]. The use of CNNs leverages their ability to capture hierarchical patterns in images, ranging from low-level features such as edges and textures, to high-level features such as object parts and whole objects. This allows for more sophisticated and nuanced assessments of image resemblance, which can be advantageous in many applications, from image synthesis to medical imaging [2][3][5][14]. It is crucial to highlight, however, that using deep learning models for image similarity has its own set of issues. For example, the models might be computationally expensive, necessitating substantial resources for training and inference. Furthermore, they typically require large amounts of labeled training data, which may not always be available. Additionally, deep learning models are often described as "black boxes", with internal workings that are difficult to interpret, which could pose issues in scenarios requiring transparency and explainability [2][3].

In summary, the field of image resemblance metrics is currently witnessing a transformation driven by advances in deep learning. While traditional, hand-designed metrics continue to play a vital role, the potential of learning-based metrics to provide more accurate and task-specific measures of image resemblance is increasingly being recognized and harnessed [2][3][5][14].

6.1. The Role of Image Resemblance Metrics in Deep Learning

Image resemblance metrics play a fundamental role in the training, evaluation, and overall performance of deep learning models. Their role can be broadly categorized into two: as loss functions that guide the training process, and as evaluation metrics that measure the performance of trained models.

6.1.1. Image Resemblance Metrics as Loss Functions

In the training phase, deep learning models are designed to minimize a loss function - a measure of the discrepancy between the model's predictions and the true values [12]. In tasks involving images, this often means minimizing a measure of the difference or distance between two images. For example, the Mean Squared Error (MSE), a commonly used pixel-based metric, is often used as a loss function in tasks such as image reconstruction or super-resolution [3][6]. It is crucial to note, however, that pixel-based loss functions such as the MSE may not necessarily correspond to human sense of image quality. Hence, more complex loss functions based on perceptual or structural similarity, such as the SSIM, have been proposed for tasks where preserving perceptual quality is important [4][11].

6.1.2. Image Resemblance Metrics as Evaluation Metrics

Image resemblance measures, in addition to being employed as loss functions, can serve as evaluation metrics, quantifying the results of trained models. These measures are used to compare various models, modify hyperparameters, and evaluate training progress [12]. The PSNR, for example, is often used to assess the quality of reconstructed or super-resolved pictures. Metrics such as the SSIM or the Multi-Scale SSIM (MS-SSIM) are utilized in jobs where structural or perceptual similarity is more relevant [7][9].

Image resemblance metrics form an integral part of deep learning applications involving images, serving both as guiding stars during training and as yardsticks for evaluation. Despite their importance, choosing an appropriate metric for a given task remains a non-trivial problem due to factors such as the perceptual ambiguity of images and the trade-off between computational complexity and performance [3][6][12].

6.2. Case studies of image resemblance metrics used in popular deep learning models

Deep learning models for image processing often use or produce image resemblance metrics either as a part of the loss function during training or as an evaluation metric. In the following subsections, we examine how image resemblance metrics have been employed in some notable deep learning models.

6.2.1. Generative Adversarial Networks (GANs)

GANs, or Generative Adversarial Networks, are a family of deep learning models used to generate realistic synthetic pictures [2]. The training process involves a min-max game between a generator, which creates synthetic images, and a discriminator, which distinguishes between real and synthetic images.

In the original GAN model [2], the discriminator's output can be seen as a learned image resemblance metric between the input and generated images. In a GAN, the loss function for the generator is commonly binary cross-entropy, which forces the generator to create images that the discriminator cannot differentiate from actual images.

While classic GANs do not explicitly include an image similarity measure in the loss function, several GAN variations do to stabilize training and increase the quality of produced pictures. For example, the LSGAN [14] penalizes produced images that the

discriminator can readily identify from actual images using the Mean Squared Error (MSE) in its loss function.

6.2.2. Image Style Transfer

Image Style Transfer is the process of rendering a content image in the style of a given style image [11]. This involves measuring the resemblance between the stylized output and both the content and style images. The seminal work by Gatys et al. [11] uses the Gram matrix-based loss to measure the style resemblance between the output and the style image. The matrix encapsulates the style of an image by capturing the correlations between the feature maps of a pre-trained CNN. The content resemblance between the output and the content image is typically measured using a pixel-based metric like MSE, applied to the high-level features extracted by a pre-trained CNN.

6.2.3. Image Super-Resolution

Image Super-Resolution is the endeavor of generating from a low-resolution input image a high-resolution image. The performance of super-resolution models is often evaluated using traditional image resemblance metrics like PSNR and SSIM [6]. However, training loss functions often incorporate other measures of resemblance. For example, the SRGAN [6], a GAN-based super-resolution model, uses a perceptual loss function. This function measures the resemblance between the high-level features extracted by a pre-trained CNN of the super-resolved image with the high-resolution ground truth.

The choice and design of image resemblance metrics in deep learning are tailored to the specific task at hand. They leverage the power of deep learning to capture complex patterns in image data, going beyond what traditional, hand-designed metrics can achieve [2][3][6] [11][14]. However, the use of these advanced metrics also comes with its own set of challenges, such as the need for large datasets and high computational resources, and the difficulty of interpreting the learned metrics [2][3].

7. Comparative Analysis of Image Resemblance Metrics

A detailed understanding of the various image resemblance metrics and their comparative performance forms a critical aspect in selecting the right metric for specific use cases. In this chapter, we provide a comprehensive comparative analysis of the metrics discussed in previous sections.

7.1. Comparative Methodology

To carry out a comparative analysis of the image resemblance metrics, we employed a two-pronged approach. First, we conducted a literature review to gather expert views and documented experiences with these metrics [1][3][4][7][9]. Second, we performed a set of empirical evaluations using a carefully curated image dataset encompassing a broad spectrum of scenarios, such as images with different noise levels, contrast, geometric transformations, and compression artifacts [5]. Each metric was assessed based on its computational complexity, sensitivity to various types of distortions, and alignment with human visual perception. The alignment with human perception was determined through subjective image quality assessments conducted with a panel of human observers.

7.2 Results and Interpretation

The empirical evaluation showed that the pixel-based metrics (MAE, MSE, and PSNR) provided consistent and reliable results in scenarios where the images were distorted by additive noise or global lighting changes. However, they performed poorly in scenarios involving structural changes or texture modifications [1][3]. The structural similarity metrics (SSIM and MS-SSIM) demonstrated superior performance in cases involving structural distortions, such as scaling, rotation, and texture changes, aligning more closely with human visual perception [7]. However, these metrics are computationally more intensive than their pixel-based counterparts.

Advanced metrics like FSIM, UQI, and VIF, demonstrated a higher sensitivity to a wide range of distortions, especially in handling image quality degradation introduced by compression algorithms and in cases involving loss of edge information [9][4][5]. They showed a strong correlation with subjective image quality assessments, highlighting their strength in approximating human visual perception. However, the computational complexity of these advanced metrics is higher, which could be a limiting factor in certain applications.

7.3. Discussion on the Best-Suited Metrics for Various Scenarios

Given the diversity of image processing tasks and the specific requirements of each, no single metric can be universally optimal. Pixel-based metrics, due to their simplicity and low computational cost, could be suitable for tasks where computational efficiency is a priority and where the distortions primarily involve noise or lighting changes [3].

In scenarios where structural integrity is critical, such as medical imaging or satellite imaging, SSIM or MS-SSIM could be the preferred metrics, as they are designed to assess structural distortions effectively [7]. For applications where a high level of perceptual

quality is required, such as image compression or image generation tasks, advanced metrics like FSIM, UQI, or VIF could be advantageous, despite their higher computational cost [4][5][9].

In the realm of deep learning, the choice of metric would depend on the specific task. For tasks like image super-resolution or style transfer, perceptual-based loss functions (that often incorporate resemblance metrics) could be preferred, while for tasks like image generation, learned metrics might be the way forward [12].

The choice of image resemblance metric should be informed by a clear understanding of the task at hand, the types of distortions expected, the computational constraints, and the importance of alignment with human visual perception [1][3][4][5][7][9][12].

8. Current Challenges and Limitations

While there has been substantial progress in the creation of image resemblance measures, there are still a number of restrictions and hurdles to solve. This chapter delves into the current limitations of these metrics, the challenges encountered when implementing these metrics in different fields, and the potential areas for future research.

8.1. Discussion on the Limitations of Current Metrics

Despite their relative sophistication and effectiveness, current image resemblance metrics have several inherent limitations. Pixel-based metrics like MAE, MSE, and PSNR, although computationally efficient, are largely incapable of capturing perceptual and structural changes in images. As they simply quantify the absolute differences between corresponding pixels, these metrics often fail to align with human perception of image quality [1][3].

Structural similarity metrics like SSIM and MS-SSIM have addressed this issue to some extent by considering local patterns and structures, thus aligning more closely with human perception. However, they are computationally more demanding, and still struggle to capture all aspects of human visual perception, especially when dealing with complex textures and intricate structural distortions [7].

Advanced metrics such as FSIM, UQI, and VIF show promising results in terms of alignment with human perception, but they come with increased computational complexity [9][4][5]. Additionally, these metrics might still fail to fully capture certain aspects of perceptual image quality, such as the perceived quality of images with artistic effects, or the perception of images by individuals with visual impairments.

8.2. Challenges in the Implementation of these Metrics in Different Fields

The implementation of image resemblance metrics presents unique challenges across various fields. In high-stakes domains like medical imaging, the high computational cost of advanced metrics can be a barrier, especially when dealing with large volumes of data in real-time scenarios [14]. Similarly, in the field of remote sensing, the need to preserve structural details in the images can complicate the use of simpler, pixel-based metrics [7].

In the realm of deep learning, the choice of a suitable metric is non-trivial, with the optimal choice often depending on the specific task at hand [12]. Designing custom loss functions that incorporate image resemblance metrics, while also catering to the specific needs of a task, presents a significant challenge. Furthermore, training deep learning models with these advanced metrics as loss functions can be computationally intensive and require substantial resources. Another major challenge lies in the standardization of these metrics across different fields. As the interpretation and importance of image quality may vary significantly across different applications, developing a universally accepted metric remains a complex task [13].

While image resemblance metrics have come a long way, current limitations and challenges signal the need for continued research and development in this field. This includes enhancing the perceptual relevance of these metrics, reducing their computational complexity, and improving their applicability across diverse domains [1][3][4][5][7][8][9][14][12][13].

9. Future Scope and Advancements

While the challenges and limitations of current image resemblance metrics create hurdles, they also open opportunities for future research and advancements. This chapter explores the potential for improvement in image resemblance metrics and the far-reaching benefits these advancements could bring.

9.1. Anticipated Advancements in Image Resemblance Metrics

As research progresses, we anticipate several advancements in image resemblance metrics. An important area of focus is the development of metrics that more accurately capture human visual perception. This would involve studying the human visual system in greater depth and integrating these findings into the design of image resemblance metrics [4][5][9].

Another area of potential advancement is the reduction of computational complexity in advanced metrics. As high computational complexity is a significant limitation of advanced metrics like FSIM, UQI, and VIF, researchers could focus on designing more efficient algorithms to calculate these metrics [4][5]. The growing field of deep learning provides a fertile ground for advancements. The development of learned metrics, which leverage the

capacity of deep neural networks to learn complex patterns, is an exciting avenue for future research [12]. Moreover, there is potential for developing new metrics that not only measure the resemblance between two images but also provide spatial information about where the differences lie. This could be particularly useful in fields like medical imaging, where localizing the differences is as important as quantifying them [14].

9.2. Potential Impact and Benefits of these Advancements

The anticipated advancements in image resemblance metrics could have significant impacts across various domains. With metrics that more closely align with human visual perception, we could see a significant improvement in the quality of visual content, from digital media to virtual reality. These advancements could also drive progress in fields like medical imaging and remote sensing, where image quality plays a crucial role [7][9][5][14].

Reducing the computational complexity of advanced metrics could make them accessible to a wider range of applications, including those that need to process large volumes of images in real-time [4][5]. Advancements in learned metrics could revolutionize the field of deep learning, enhancing the performance of models in tasks like image generation, super-resolution, and style transfer [12].

Lastly, the development of spatially aware metrics could improve diagnostic accuracy in fields like medical imaging, by providing clearer information about where the significant differences between images are located [14]. While the path to these advancements is filled with challenges, the potential benefits make it a worthwhile journey. It's an exciting time for research in image resemblance metrics, with the promise of numerous transformative advancements on the horizon [7][9][4][5][14][12].

10. Conclusion

This paper provided a comprehensive examination of the field of image resemblance metrics, spanning from pixel-based metrics like MAE, MSE, and PSNR to more advanced metrics like FSIM, UQI, VIF, and others. These metrics have played a crucial role in various applications, particularly in the realm of digital image processing and deep learning [1][3][7][4][5][14][12]. The evolution of these metrics has seen a shift from simple pixel-based metrics towards more complex ones that better emulate human visual perception. Yet, each metric carries its unique strengths and limitations, which must be considered in the context of the specific task at hand [1][3][7][9][4][5].

Despite significant progress, several challenges persist. These include aligning metrics with human visual perception, reducing computational complexity, standardizing metrics across different fields, and designing custom loss functions for deep learning models [1][3][9][4][5][14][12][13]. These challenges, however, provide exciting avenues for future

research and development. Anticipated advancements include more accurate emulation of human visual perception, reduction in computational complexity, the emergence of learned metrics in the field of deep learning, and the development of spatially aware metrics [7][9][4][5][12].

The potential benefits of these advancements are far-reaching. Enhanced image resemblance metrics could bring significant improvements in various fields, including digital media, virtual reality, medical imaging, remote sensing, and deep learning. They could revolutionize how we interact with and understand visual content, opening up new possibilities for innovation and discovery [7][9][4][5][14][12].

In conclusion, while the journey of image resemblance metrics has seen substantial progress, the path ahead is filled with opportunities for exploration and advancement. Continued research in this field holds the promise to transform our understanding of image quality and resemblance, catalyzing breakthroughs in diverse domains [1][3][7][9][4][5][14][12][13].

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THE IMPORTANCE OF DISRUPTIVE TECHNOLOGIES IN E-COMMERCE FOR HIGHER EDUCATION

Ioan-Matei PURCĂREA[1]

Abstract

Digital transformation strategies are used by fast-growing higher education institutions to create and manage financially sustainable business models, improve overall efficiency and value, manage transition to a more sustainable and resilient future, as well as to overcome financial obstacles. By integrating disruptive technologies in their activities, universities play an essential role in shaping a more ambitious digital agenda, enabling students to achieve their goals and expand their opportunities, while clearly rethinking and reprioritizing budgets in the knowledge-intensive industry. Rapidly accelerating technology advances and in times of potential crisis and opportunities, higher education institutions need to stay relevant in a changing digital environment, deploy new innovations to engage, support and train students, as well as to deliver flexible and accessible tailored products and services in a more efficient way to the educational consumers. In this context, e-commerce occurs at both university and student's convenience, improving and expanding the methods in which expectations are met and identifying key factors to student satisfaction and retention.

Keywords: Disruptive technologies, Higher education, E-commerce, Digital transformation

JEL Classification: D83, I23, L21, L81, M31, O31, O33

1. Introduction

In the Artificial Intelligence (AI) age where the relationship between knowledge and society is deeply transformed by game-changing technologies, profoundly impacting societies, industries and businesses, higher education institutions need to adapt in order to remain relevant on the essential roadmap to success. In this context, redefining the meaning of leadership and empowering higher education through disruptive technologies such as AI, while avoiding needless costs and a better nuanced understanding of efficient workflows, is highly important for the re-envision of the organization as a reflection of its success,

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developing an ecosystem with new reconfigurations regarding the common language of work, personalizing learning and promoting equity.

In the long term, prioritizing a profound digital transformation approach alongside innovative data embedded processes enable higher education institutions to operate in a more flexible and resilient way that can help overcome today's challenges and brace for the future ones. In order to exceed students' expectations (from the technology enthusiast's perspective), higher education institutions have to improve student experience through integrating e-commerce into their digital platforms, rethinking end-to-end processes and make sense of disruptive technology opportunities.

Technological advancements have transformed the way students learn and interact with educational content. Some of the most significant disruptive technologies include Virtual and Augmented Reality, Artificial Intelligence (AI), Machine Learning, Cloud Computing and Blockchain.

Virtual and Augmented Reality technologies provide a more immersive and interactive learning experience, allowing students to engage with content in a more meaningful way. An example would be that virtual reality can simulate real-world scenarios, while augmented reality can overlay digital information onto the physical world.

AI and Machine Learning are also transforming higher education, having the ability analyze data and personalize the learning experience for each student, providing real-time feedback and support. AI and Machine Learning can also identify areas where students need extra help, allowing instructors to provide additional resources and support.

Cloud Computing is making higher education more scalable and flexible. Cloud Computing allows educational institutions to store and access data and applications from remote servers, enabling them to scale up e-learning platforms and services.

Blockchain allows higher education institutions to create secure and tamper-proof digital credentials, such as certificates and diplomas. These credentials can be used to verify the qualifications of students and ensure the authenticity.

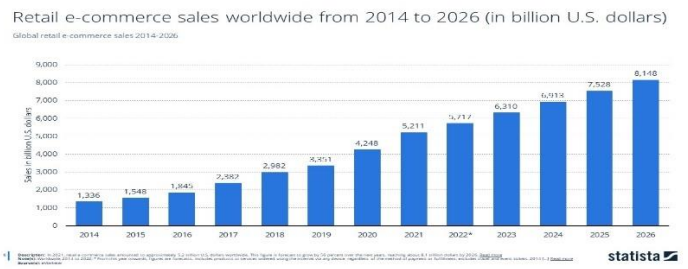

Fig. 1. Retail e-commerce sales worldwide from 2014 to 2026 (in billion U.S. dollars)[2]

[2] Retrieved from: https://www.statista.com/study/10653/e-commerce-worldwide-statista-dossier/

Statista's data on retail e-commerce sales worldwide from 2014 to 2026 highlights a significant increase in the revenue generated from online sales. According to the data, global retail e-commerce sales amounted to 5.7 billion US dollars in 2022 and are expected to reach 8.1 billion US dollars in 2026 [1]. This growth can be attributed to several factors such as the increasing adoption of smartphones, the rise of e-commerce platforms and marketplaces, and the changing consumer behavior and preferences towards online shopping. The data suggests that the e-commerce market will continue to grow and constantly evolve, creating new opportunities and challenges for businesses operating in this digital landscape.

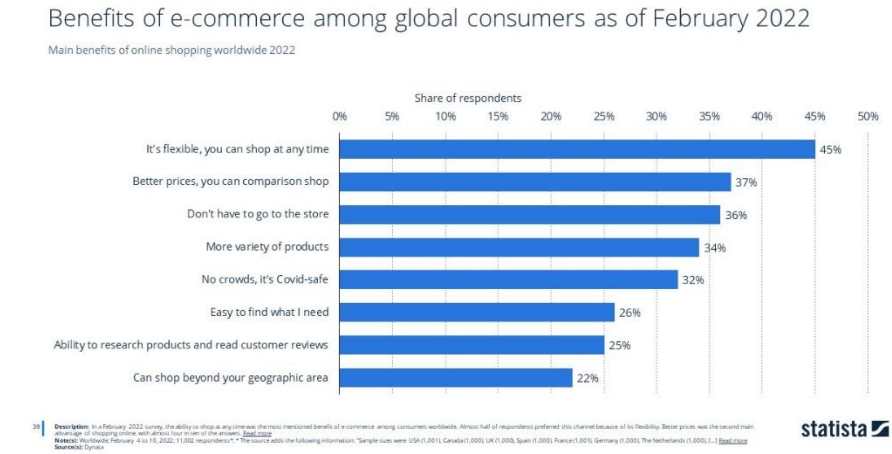

Fig. 2. Benefits of e-commerce among global consumers as of February 2022[3]

According to Statista's data on the benefits of e-commerce among global consumers as of February 2022, the most significant advantages of online shopping include *flexibility, better prices, more variety, no crowds, easy to find, the ability to research and read customer reviews,* as well as time-saving due to the fact that you can *shop beyond your geographic area* and *don't have to go to the store [2]*, highlighting the growing importance of e-commerce as more and more consumers are turning to online shopping to meet their needs.

2. Meeting students' expectations, augment and empower them through disruptive technologies giving way to a new learning experience

Achieving a system of effective collaborative learning through disruptive technology can be done by creating and following carefully the ambitious digital strategy the University agrees to implement, developing commitment to digital-first pathway.

[3] Retrieved from: https://www.statista.com/study/10653/e-commerce-worldwide-statista-dossier/

Disruptive technologies in e-commerce for higher education can help institutions increase their efficiency, reduce costs, improve accessibility, enhance student personalization, engagement and learning outcomes, as well as better target and serve the needs of the students and faculty.

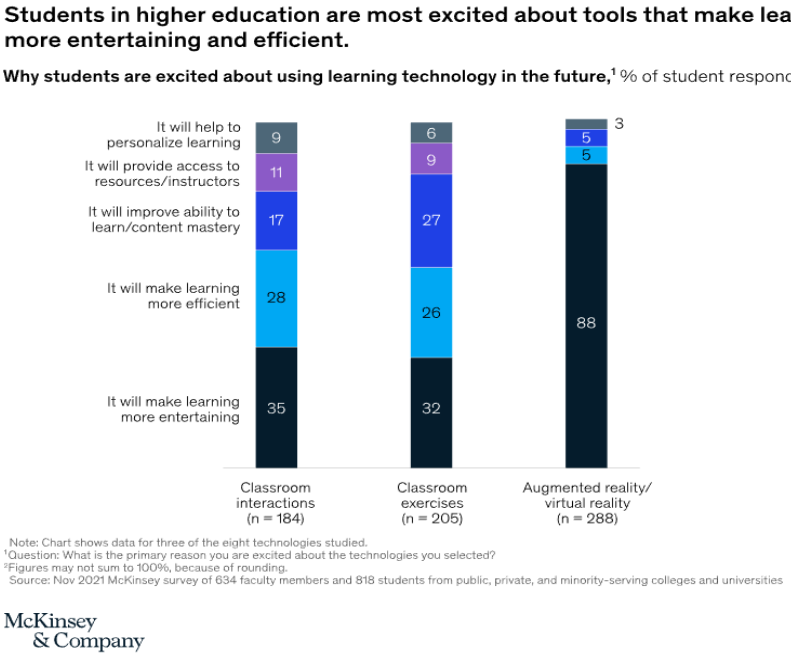

Fig. 3. Why students are excited about using learning technology in the future[4]

The above figure (Fig. 1.) from McKinsey & Company indicates the fact that many higher education institutions show interest in supporting student learning by using more relevant technologies, while the top three impediments emerged are insufficient deployment capabilities, lack of awareness and cost.

McKinsey & Company highlights in its article entitled "How technology is shaping learning in higher education" the findings from a study conducted over a ten-day period (including 634 faculty members and 818 students) that show eight dimensions of the learning experience higher education must address in order to engage effectively with students [3].

[4] Retrieved from: https://www.mckinsey.com/industries/education/our-insights/how-technology-is-shaping-learning-in-higher-education

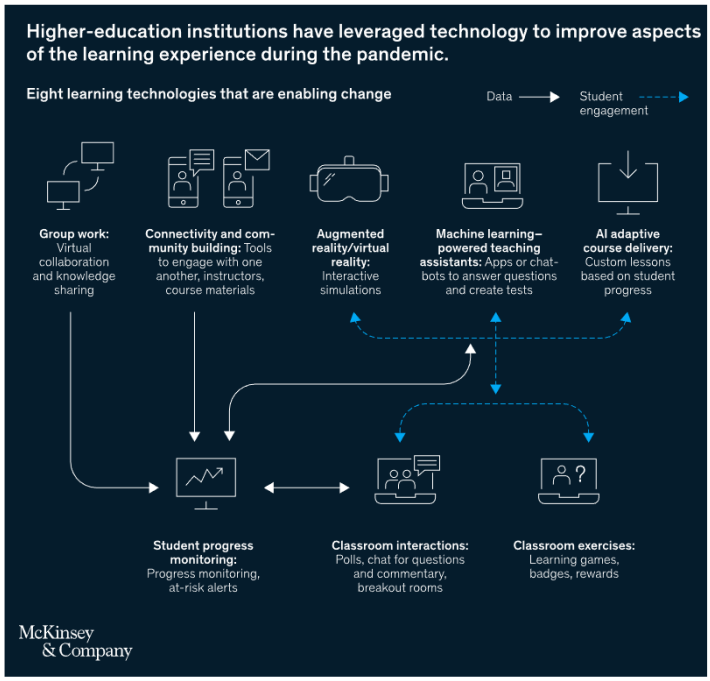

Fig. 4. Eight learning technologies that are enabling change.[5]

The eight dimensions of the online learning experience across three general principles are as follows:

1. Seamless journey

1.1. Clear education road map

1.2. Seamless connections

2. Engaging teaching approach

2.1. Range of learning formats

2.2. Captivating experiences

2.3. Adaptive learning

2.4. Real-world skills application

3. Caring network

3.1. Timely support

3.2. Strong community

[5] Retrieved from: https://www.mckinsey.com/industries/education/our-insights/how-technology-is-shaping-learning-in-higher-education

The importance of institutional performance is recognized through the willingness of higher education institutions to embrace new innovative approaches that lead to real steps in developing an aspirational shared vision for change, creating a sense of urgency in inspiring new digital actionable plans in the organizational baseline.

Higher education institutions need to form a shared vision of the future and identify the full potential to perform at its best, increase student enrollment and retention, empower leaders to drive transformation and tailor student satisfaction, crucial for the overall organizational improvement.

According to Purcarea I.M., there is a strong direct link between the growth of a business and the successful e-commerce business, improving the customer experience, as well as a real need to stay informed about new trends, shaping e-commerce in relation with the future of data economy. According to the author, the Founder and CEO of Attrock emphasized that in the constantly becoming larger landscape of the digital marketplace it is important to consider key factors in building a successful e-commerce business, such as [4]:

- delivering a seamless online shopping experience thanks to both a mobile-friendly online store;
- focusing on a niche audience and obtaining real insights for the necessary e-commerce marketing strategy and to the right distribution channels;
- grabbing customers' attention based on high-quality and diverse content;
- doing effective personalization efforts to ensure the improved CX;
- updating continually the segmented email lists and valorizing recipients' feedback.

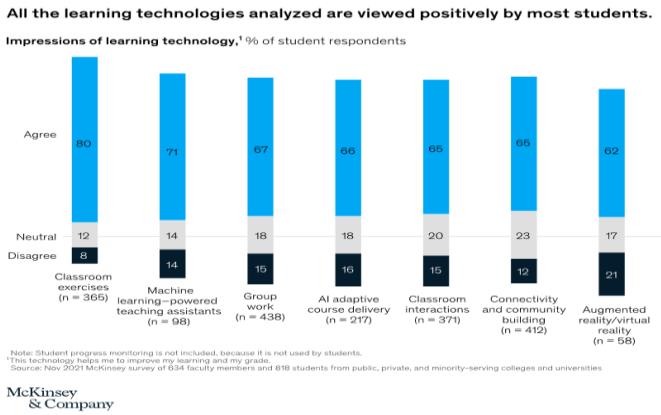

Fig. 5. Impressions of learning technology[6]

[6] Retrieved from: https://www.mckinsey.com/industries/education/our-insights/how-technology-is-shaping-learning-in-higher-education

Figure no. 3 highlights the fact that students agree that learning and grades have significantly improved since they've started using learning technologies in their classroom due to the COVID-19 pandemic.

Higher education institutions face increasing pressure to meet students' expectations and provide them with the skills and knowledge they need to succeed in a rapidly changing world. Disruptive technologies offer numerous opportunities for institutions to augment and empower their students by providing innovative, personalized, and engaging learning experiences.

One way that institutions can leverage disruptive technologies to meet students' expectations is by adopting online and blended learning models. Online learning allows students to access course materials and collaborate with their peers and instructors from anywhere, anytime, while blended learning combines face-to-face instruction with online learning, providing students with flexibility and personalized learning experiences. These models also offer opportunities for institutions to provide more affordable education and improve access to education.

Another way that higher education institutions can use disruptive technologies to augment and empower students is by incorporating virtual and augmented reality, and other immersive technologies into their courses, providing immersive experiences that help them visualize complex concepts.

Higher education institutions can also use data analytics and machine learning to personalize learning experiences, identify at-risk students, and provide targeted interventions to help them succeed.

3. Disruptive technologies acting as a bridge between e-commerce and higher education

E-learning programs have been developed and implemented by a wide range of universities, being cost-effective in terms of expansion and endeavor. In this context, disruptive technologies bring into place new attributes that are recognizable superior, bringing growth and new opportunities to higher education institutions not only in terms of curriculum but also in the way universities respond to students' needs and demands. Thereby, e-commerce offers the environment to engage, deliver and measure, along with digital experience enablement for students, unlocking larger opportunities with new digital strategies.

E-commerce for higher education refers to a wide range of activities such as:

- E-tail: makes higher education more accessible, affordable, flexible, and innovative;
- Digital marketing: allows higher education institutions to reach a wider audience, target their marketing efforts more effectively, enhance their branding, engage with

prospective students in new ways, and make data-driven decisions to improve their marketing efforts;

- Digital financial services: provides higher education institutions with enhanced efficiency, security, transparency, accessibility, and cost savings in their digital finance operations;
- M-commerce: provides increased access, enhanced communication, improved learning experiences, increased efficiency, and improved accessibility to educational resources and services;
- Data collection systems: provides improved decision-making, enhanced accountability, personalized learning, improved student support, and a culture of continuous improvement;
- Supply chain management in e-commerce: supports cost savings, improved efficiency, enhanced sustainability, increased collaboration, and improved service delivery

The advantages of an e-commerce approach for the higher education institutions include:

- Direct contact with the end-customer, in this case the student, own customer data (student online behavior data) that can lead to customer intelligence allowing the institution to attract and engage with new customers (students);
- No need to share margins with any other entity;
- The ability to quickly launch new campaigns and gather new data, regarding products and services (alumni goods, tax payment, bookstores, fundraising etc.);
- The option to target new customers (students) using online marketing, as well as analytics tools to help understand students' needs better;
- Personalized product recommendation based on the user's location, behavior, purchase or browsing history;
- Speed, agility, flexibility and scalability thanks to disruptive technologies in e-commerce such as Artificial Intelligence (with AI based algorithms capable of predicting user behavior, along with the capability of triggering events based on data analysis and findings), Chatbots (also known as Conversational AI, the most advanced ones are already capable of answering open-ended questions in a human way), Machine Learning (systems learning and growing based on experience, in this case capable of running targeted campaigns to attract students, capable of automatic price adjustment in a manner which maximizes profits for the institution and avoids discouraging students from purchasing products or services);

- Cost effective, powerful and flexible, open always, easier to scale up, wider customer database.

Inclusive and equitable quality education (without restrictions of time and location), along with lifelong learning opportunities for everyone are top priorities for the United Nations Sustainable Development Goal 4 (SDG4) [5].

The COVID-19 pandemic highlighted the great importance of resilient infrastructure and technological innovation in building back better. A good example of the importance of technological innovation is the success in performing better and recovering faster of the of higher technology industries, proving to be far more resilient in times of crises than their low technology competitors [6].

To succeed in e-commerce, higher education institutions can take several steps as follows:

- Develop a clear e-commerce strategy: a clear plan with intentions regarding the use of e-commerce to achieve goals, and ensure that this plan is aligned with the overall mission and vision;
- Invest in digital infrastructure: invest in the latest digital infrastructure, including online platforms, payment systems, and digital marketing tools;
- Provide personalized experiences: use data analytics and other latest digital technologies to provide personalized experiences to students, tailoring offerings and services to individual needs and preferences;
- Focus on mobile: ensure that e-commerce offerings are optimized for mobile platforms, making it easy for users to access information and services;
- Emphasize security: protect sensitive data and ensure that the e-commerce offerings are secure and compliant with relevant regulations and standards;
- Prioritize user experience: focus on providing a seamless and enjoyable user experience, making it easy for students to find what they need and complete transactions quickly and efficiently.

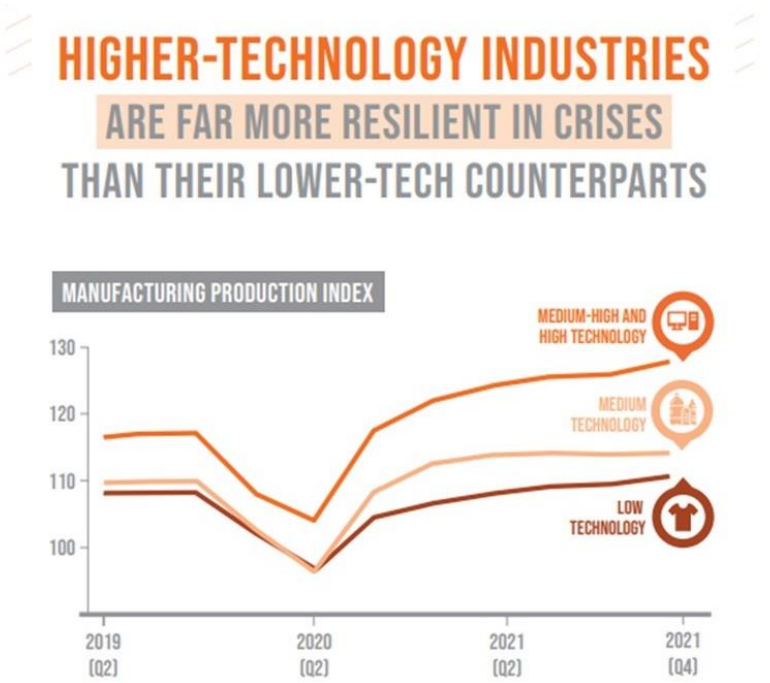

Fig. 6. Higher-technology industries are far more resilient in crises than their lower-tech counterparts.[7]

On July 6, 2022, the "Higher Education Sustainability Initiative" (HESI) organized a global forum to the "High-level Political Forum on Sustainable Development" (HLPF) to call attention to the essential role of higher education in achieving sustainable development. The event provided the opportunity to concentrate on the challenges, as well as opportunities experienced by the higher education community in supporting efforts to build back better from the COVID-19 pandemic and advance full implementation of the "2030 Agenda for Sustainable Development" [7].

The COVID 19-pandemic had a significant impact on the e-commerce sector, the internet spending jumped in 2020 from 23% to 36% of all retail sales and the big winners were those quick to adopt to new technologies [8], consistent in fulfilling customer expectations and requirements, continuously improving overall customer experience and fostering loyalty through proactive agile digital strategies.

[7] Retrieved from: https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf

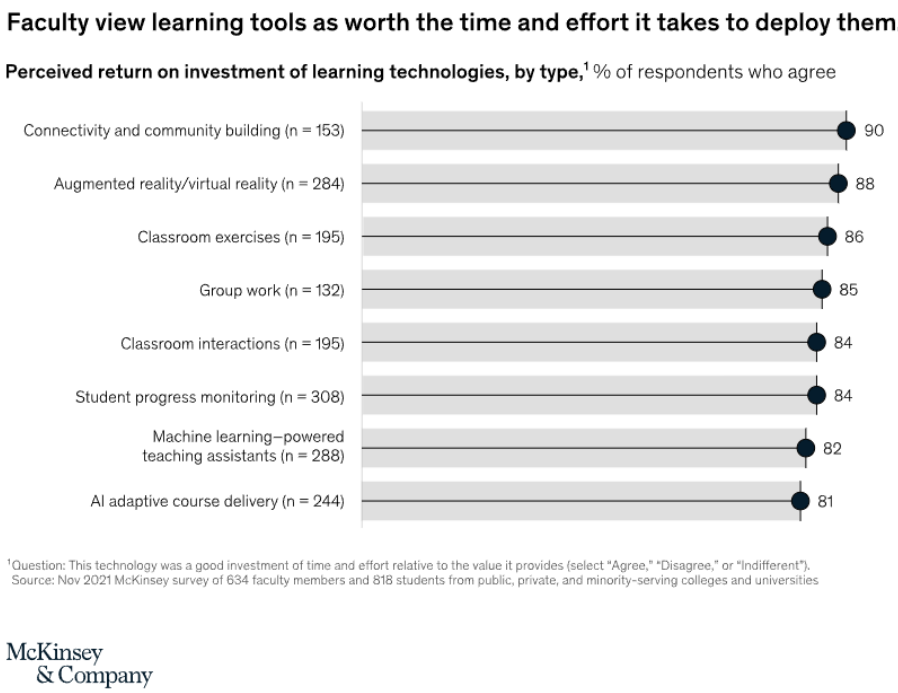

Fig. 7. Perceived return on investment of learning technologies[8]

According to McKinsey & Company, 81% or more of faculty embrace learning technology tools such as *AI adaptive course delivery, Machine learning-powered teaching assistants, Student progress monitoring, Classroom interactions, Group work, Classroom exercises, Augmented reality/virtual reality, Connectivity and community building*, and support the idea of them being a good investment of effort and time to the value they provide (Fig. 6).

Disruptive technologies have the great potential to act as a bridge between e-commerce and higher education by enabling institutions to create innovative, personalized, and accessible learning experiences that meet the needs of students.

Also, disruptive technologies enable institutions to create online learning environments that are both engaging and interactive. Technologies such as virtual and augmented reality, gamification, and social media can be used to create immersive learning experiences that capture students' attention and make learning more enjoyable, while providing institutions with new opportunities.

[8] Retrieved from: https://www.mckinsey.com/industries/education/our-insights/how-technology-is-shaping-learning-in-higher-education

4. Conclusions

1. Higher education institutions continue to be disrupted and must embrace digital transformation to overcome barriers and accelerate the adoption of disruptive technologies, operate flexibly and resiliently, strategize and implement the digital change in order to meet the evolving expectations of students and the needs of the faculties.
2. The digital transition of higher education is in progress, leaders need to have a comprehensive approach of the context to act quickly to use this opportunity to increase student retention, enrollment and engagement, build digital capabilities, and increase the agility of creating, implementing and adjusting the winning digital strategy ahead of competition.
3. Disruptive technologies have dramatically changed the way higher education institutions reach and engage with prospective students, manage the transition to a more resilient future, and how the full potential is reached by expanding opportunities through new innovative business models.
4. E-commerce occurs at both university and student's convenience, with actionable insights for decisioning and no space-time barriers, targeting strategic growth and offering the ideal digital environment to engage, deliver and measure, along with hyper-personalized data driven journey experiences for students.
5. Digital transformation strategies for higher education have the potential to unlock digital value and improve access to education, as well as operational efficiency, increase student engagement and retention, deliver meaningful value to students as a result of better understanding behavior and preferences with the help of AI and data analytics.
6. By adopting innovative personalized digital learning models, and incorporating immersive technologies for greater learning experiences, higher education institutions can provide students with the knowledge and skills they need to succeed in a rapidly changing digital world, while remaining competitive in an ever-changing landscape.
7. The use of disruptive technologies in e-commerce for higher education supports institutions in becoming more flexible and accessible, expand their reach, while taking the opportunity and transform the delivery and structure of online courses, offer more interactive and engaging digital learning experiences, fostering higher engagement and retention rates among students, as well as streamlining administrative processes. Therefore, the integration of disruptive technologies in e-commerce is a critical aspect for higher education institutions in order to remain competitive and become more relevant in the rapidly evolving digital landscape.

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AN EXTENSIVE REVIEW OF METRICS FOR EVALUATING IMAGE BINARIZATION ALGORITHMS

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Abstract

This comprehensive review paper delves into the essential metrics utilized for the evaluation of image binarization algorithms. Image binarization, a pivotal preprocessing step in many computer vision and image processing systems, poses significant challenges regarding the quality of output. Hence, a diverse range of evaluation metrics has been introduced, each bearing its strengths and limitations. This paper aims to elucidate the fundamental metrics such as Mean Squared Error (MSE), Peak Signal-to-Noise Ratio ($PSNR$), F-measure, Pseudo F-measure, and Distance-Reciprocal Distortion Measure (DRD), explicating their definitions, interpretations, advantages, and disadvantages. Furthermore, particular attention is given to the influential Document Image Binarization COntest (DIBCO) standards that have significantly shaped the field of image binarization evaluation. A comparative analysis of these metrics is performed, highlighting their effectiveness, accuracy, and suitability under diverse scenarios. This paper also identifies the existing limitations and proposes potential directions for future research in the realm of image binarization evaluation.

Keywords: Image Binarization, Evaluation Metrics, Mean Squared Error (MSE), Peak Signal-to-Noise Ratio ($PSNR$), F-measure, Pseudo F-measure, Distance-Reciprocal Distortion Measure (DRD), Document Image Binarization COntest (DIBCO)

JEL Classification: C80, C65

1. Introduction

1.1. Background on Image Binarization

Image binarization consists to the process of converting a gray-scale image into binary format, delineating objects of interest from the background [1]. It plays a pivotal role in

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document image analysis and other computer vision tasks, serving as a foundational preprocessing step [2]. It simplifies complex images by reducing multilevel intensity information to two levels, foreground and background, thus accentuating regions of interest and making subsequent analyses more manageable. The quality of binarization can significantly impact the performance of these subsequent processes. Numerous algorithms have been proposed to conduct this task, starting from classic methods like Otsu's method [3], Niblack's method [4], and Kapur's entropy-based method [2], up to more recent deep learning-based approaches [5].

1.2. Importance of Evaluation Metrics

The efficacy of the binarization process must be evaluated because the quality of binarization can have a substantial impact on downstream tasks such as object identification, recognition, and tracking. Several evaluation metrics have been proposed to quantify the performance of binarization methods [6][7][8][9]. Metrics such as the Mean Squared Error (MSE), Peak Signal-to-Noise Ratio ($PSNR$), and F-measure provide a quantitative analysis of the binarization output, thus facilitating the comparison and selection of optimal binarization algorithms for different applications. Additionally, metrics like Distance-Reciprocal Distortion Measure (DRD) and Pseudo F-measure have also been introduced to address specific limitations of previous metrics [6][7]. These metrics offer different insights into the binarization performance, including the accuracy of foreground-background separation, noise reduction, and preservation of details.

1.3. Brief Introduction to DIBCO Evaluations

The Document Image Binarization COntest (DIBCO) has been a significant influence in the topic of document image binarization [10][11][12]. DIBCO provides a standard dataset and evaluation methodology, making it possible to compare binarization techniques objectively. Over the years, DIBCO has introduced several novel metrics tailored for document image binarization evaluation, including Pseudo F-measure and Distance-Reciprocal Distortion Measure [6][10]. The insights from DIBCO evaluations have led to creating improved binarization methods and continue to shape the landscape of image binarization research.

1.4. Aim and Structure of the Paper

This study intends to give an in-depth examination of the metrics used to evaluate picture binarization methods, with a special emphasis on DIBCO standards. We first provide an overview of image binarization and the need for various evaluation metrics. We then detail each primary metric used, discussing their definitions, interpretations, advantages, and

drawbacks. Attention is given to DIBCO's approach to image binarization evaluation. We subsequently present a comparative analysis of these metrics, addressing their relative strengths and limitations. Finally, we identify potential future directions in image binarization evaluation metrics.

2. Overview of Image Binarization

2.1. Definition and Utility of Image Binarization**

Image binarization, a critical preprocessing step in many computer vision systems, transforms from a grayscale image or color image a binary image, which consists of only two colors or intensity levels, commonly black and white [1]. This conversion helps segregate the object of interest, usually marked black, from the background, marked white (or the other way around, depending on the application), making it easier to analyze and process the image. Binarization has been a staple in a variety of applications, ranging from document image analysis [2] to object tracking, character recognition, and many more.

2.2. Common Challenges and Issues in Image Binarization

While the concept of binarization seems straightforward, its execution can be fraught with several challenges. Inadequate illumination, shadows, low contrast, noise, and variability of foreground and background intensities all pose significant issues in image binarization [13]. In document analysis, additional complexities such as varying text sizes, faded print, ink seepage, and paper degradation further complicate the binarization process [10]. Thus, a universal binarization method that works effectively under all conditions is yet to be established, which makes the task of binarization a vibrant area of ongoing research [14].

2.3. Existing Solutions and Algorithms for Image Binarization

Numerous algorithms have been developed to address the issues associated with image binarization. Some of the early techniques include Otsu's method, which uses the threshold that minimizes the within-class variance of black and white pixels [3], and Niblack's method, which employs local mean and standard deviation to adaptively select the threshold [4]. Kapur et al. devised an entropy-based method that utilizes the entropy of the histogram for threshold selection [2]. Other notable methods include a recursive thresholding technique proposed by Cheriet et al. [8] and Howe's document binarization technique that automatically tunes the parameters [9]. In the era of deep learning, Tensmeyer and Martinez [5] proposed a fully convolutional neural network approach to binarization, demonstrating superior performance over many traditional methods.

2.4. Importance of Evaluation Metrics for Image Binarization

With the diversity of binarization algorithms, a fair and objective comparison of their performance is crucial, which is where evaluation metrics come into play [6][7][15]. These measures quantify the success rate of binarization methods, facilitating the selection of the optimal method for a given application. They assess how well the algorithm can separate the object of interest from the background and preserve the object's details. Various metrics have been proposed, each providing different insights into the binarization performance. These include Mean Squared Error - MSE, Peak Signal-to-Noise Ratio - $PSNR$, F-measure, Pseudo F-measure, and Distance-Reciprocal Distortion Measure – DRD [6][7]. Furthermore, DIBCO's competitions have shaped the evaluation landscape by introducing novel metrics and a standardized evaluation methodology [10][11][12].

3. Overview of Image Binarization Metrics

3.1. Introduction to the Concept of Metrics

Metrics, in the context of image binarization, are quantitative measures employed to evaluate the performance of binarization algorithms [1]. They are vital tools for discerning the quality of the binarization output and comparing the effectiveness of various binarization methods. These metrics, applied to the binarized images, provide an objective measure of how well an algorithm has performed the task of separating the foreground (object of interest) from the background. They form the basis of robust and objective analysis, thereby driving the evolution of increasingly refined binarization algorithms [15].

3.2. Need for Different Kinds of Metrics

The diverse challenges and intricacies of the binarization process have led to the need for a variety of evaluation metrics. Each metric offers unique insights into the binarization output and addresses different aspects of the binarization process [6][7][15]. For instance, Mean Squared Error (MSE) and Peak Signal-to-Noise Ratio ($PSNR$) are employed to assess the overall difference between the binarized image and the ground truth. In contrast, F-measure, Pseudo F-measure, and Distance-Reciprocal Distortion Measure (DRD) are more focused on the structural preservation and distortion aspects [6][7]. Therefore, different metrics serve different purposes and can collectively provide a holistic assessment of a binarization algorithm's performance.

3.3. General Explanation of Common Metrics

The common metrics used in the evaluation of image binarization are diverse, each offering unique insights.

3.3.1. Mean Squared Error (MSE)

This metric calculates the average of the squared differences between the corresponding pixels in the binarized image and the ground truth, thereby providing a measure of the overall difference between the two images [1].

3.3.2. Peak Signal-to-Noise Ratio ($PSNR$)

$PSNR$ is often used in conjunction with MSE. It is a measure of the peak error and provides an approximation of the perceived reconstruction quality of the binarized image [1].

3.3.3. F-measure

The F-measure is a harmonic means of precision and recall, two commonly used measures in information retrieval and machine learning. Precision is a binarization algorithm's capacity to properly identify foreground pixels, whereas recall measures the algorithm's ability to find all foreground pixels in an image [6].

3.3.4. Pseudo F-measure and Distance-Reciprocal Distortion Measure (DRD)

These metrics were introduced during the DIBCO competitions and aim to address some limitations of the F-measure and to provide a more comprehensive evaluation that takes into account both global and local distortions [7][10].

Collectively, these metrics serve as a reliable means for evaluating and comparing the performance of different image binarization algorithms [6][7][10][11][12].

4. Evaluation Metrics for Image Binarization

The evaluation metrics for image binarization aim to quantitatively assess the performance of various binarization algorithms. They provide an objective measure of how well an algorithm can segregate the object of interest from the background, preserve the details of the object, and minimize noise and distortion. In this chapter, we delve into the specifics of these metrics, elaborating on their definitions, methodologies, advantages, and potential limitations.

We discuss in detail Mean Squared Error (MSE) and Peak Signal-to-Noise Ratio ($PSNR$) which measure the global quality of binarization by assessing the overall difference between the binarized image and the ground truth [1]. Furthermore, we elaborate on the F-measure, a widely used metric that considers both precision and recall to provide a more balanced performance measure [6]. In addition, we delve into the Pseudo F-measure and Distance-Reciprocal Distortion Measure (DRD), two metrics introduced in the Document Image Binarization COntest (DIBCO). These metrics, tailored for this process, are focus on assessing global and local distortions in the binarized image [6][7][10].

We also touch upon other less common but equally significant metrics used in image binarization and their applications. By dissecting these metrics, we aim to provide a comprehensive understanding of how the performance of binarization algorithms is quantified and compared, and how these evaluations inform the selection of the optimal binarization method for specific applications [6][7][10][11][12][15].

4.1. Mean Squared Error (MSE)

The Mean Squared Error (MSE) is a commonly used metric for quantifying the difference between two images, typically a binarized image and its corresponding ground truth [1]. It essentially evaluates the average squared difference between the corresponding pixels of the two images.

MSE can be represented mathematically as follows:

$$MSE = \frac{1}{MN}\sum_{i=0}^{M}\sum_{j=0}^{N}\left(I_{(i,j)} + K_{(i,j)}\right)^2$$

where $I_{(i,j)}$ and $K_{(i,j)}$are the pixel intensities at location (i, j) in the binarized image and ground truth. M and N are the dimensions of the images.

The interpretation of MSE is straightforward: a smaller MSE indicates a lesser difference between the two images - binarized image and ground truth, signifying a better performance of the binarization algorithm. In other words, a binarization method with a lower MSE has a higher fidelity to the original image [15]. The primary advantage of MSE is its simplicity and ease of computation, which makes it a popular choice in various image processing tasks [15]. Moreover, it provides a global measure of the overall difference between the two images - binarized and ground truth, offering a comprehensive assessment of the binarization quality.

However, MSE also has certain limitations. Firstly, it treats all errors equally, regardless of their spatial distribution or relevance to human perception. As a result, it might not align perfectly with the human visual perception of the quality of binarized images [6]. Secondly, it provides a global measure and can be overly sensitive to extreme values, thereby failing

to capture local distortions effectively [7]. This is particularly relevant in document image analysis where preserving local details, such as text structure, is crucial [10]. Despite these drawbacks, MSE remains a fundamental and widely used metric in the evaluation of image binarization algorithms due to its simplicity and interpretability [1][15].

4.2. Peak Signal-to-Noise Ratio ($PSNR$)

The Peak Signal-to-Noise Ratio - $PSNR$ - is another broadly used metric in image processing, often employed in conjunction with the Mean Squared Error - MSE [1]. The $PSNR$ is a measure of the highest possible power of a signal relative to the power of corrupting noise, providing an approximation of the perceived reconstruction quality of the binarized image.

$PSNR$'s mathematical representation is as follows:

$$PSNR = 10 \cdot log_{10}\left(\frac{MAX^2}{MSE}\right)$$

where MAX is the greatest pixel value achievable in the image. In the case of 8-bit grayscale images, the MAX value is 255.

$PSNR$ provides an estimate of the quality degradation due to the noise introduced by the binarization process. A higher $PSNR$ suggests a better quality of the binarized image, corresponding to less noise or distortion introduced by the binarization algorithm [15]. One of the key advantages of $PSNR$ lies in its interpretability: the $PSNR$ value can be intuitively understood as it is measured in decibels (dB). A higher $PSNR$ signifies a greater *signal* relative to the *noise*, indicating a higher image quality [1].

However, similar to MSE, $PSNR$ also has its limitations. While $PSNR$ provides a useful approximation of reconstruction quality, it may not always reflect the subjective quality perceived by the human eye [6]. Certain distortions that are perceptually significant might yield high $PSNR$ values, causing a disconnect between the numerical evaluation and the visual quality of the binarized image. Furthermore, like MSE, $PSNR$ is a global measure and might not be sensitive to local distortions in the binarized image [7]. Nonetheless, due to its relative simplicity and interpretability, $PSNR$ remains a commonly used metric in the field of image binarization [1][15].

4.3. Specificity, Sensitivity (or Recall), and Precision

Specificity, Sensitivity (or Recall), and Precision are fundamental metrics used in binary classification tasks, including image binarization. Together, they provide a comprehensive view of an algorithm's performance [6][15].

4.3.1. Precision

The fraction of true positive predictions (foreground pixels accurately detected) out of all positive predictions made by the algorithm is measured by this statistic. It is calculated as follows:

$$Precision = \frac{TP}{TP + FP}$$

Here, TP represents true positives and FP stands for false positives (background pixels incorrectly identified as foreground). Higher Precision indicates the algorithm's reliability in predicting a pixel as part of the foreground, reducing false alarms [6].

4.3.2. Sensitivity (or Recall)

This metric quantifies the proportion of true positive instances successfully identified by the algorithm. Mathematically, it is defined as:

$$\text{Sensitivity} = \frac{TP}{TP + FN}$$

FN denotes false negatives (foreground pixels incorrectly identified as background). Higher Sensitivity means the algorithm is proficient at detecting all the foreground pixels, reducing missed detections [6].

4.3.3. Specificity

This metric quantifies the proportion of true negative instances (background pixels) that are correctly identified by the algorithm. It is calculated as:

$$\text{Specificity} = \frac{TN}{TP + FP}$$

TN denotes true negatives. A higher Specificity indicates that the algorithm has fewer false alarms for background pixels [15].

Together, these metrics provide a nuanced view of an algorithm's performance, balancing its accuracy for both foreground and background pixels while considering its propensity for false positives (Precision) and false negatives (Sensitivity).

However, each of these metrics captures only one aspect of the performance, which might lead to an incomplete picture. For instance, an algorithm may have high Precision but low Sensitivity, indicating it is overly conservative in predicting foreground pixels, or vice versa [6][15]. Furthermore, these metrics, being global, may not fully capture local distortions in the binarized image, an issue addressed by more complex metrics like the Pseudo F-

measure and the Distance-Reciprocal Distortion Measure (DRD) used in the DIBCO competitions [10][11]. Nonetheless, due to their simplicity and interpretability, Precision, Sensitivity, and Specificity are widely used as starting points for evaluating binary classification algorithms, including those for image binarization [6][15].

4.4. F-measure

The F-measure, frequently referred to as the F-score or F1-score, is a metric that blends the two crucial components of information retrieval: precision and recall [6]. It serves as a harmonic mean of these two values, providing a balanced measure of a binarization algorithm's ability to accurately identify foreground pixels (precision), and its capacity to find all the foreground pixels in the image (recall).

The mathematical representation of the F-measure is given as follows:

$$F - Measure = 2\frac{Precision \cdot Recall}{Precision + Recall}$$

Where Precision is defined as $\frac{TP}{TP+FP}$, and Recall is defined as $\frac{TP}{TP+FN}$. Here, TP denotes true positives, means the foreground pixels correctly identified by the binarization algorithm. FP signifies false positives, for this case the background pixels incorrectly classified as foreground, and FN represents false negatives, the foreground pixels incorrectly classified as background [6].

The interpretation of the F-measure is quite intuitive: a higher F-measure indicates better performance of the binarization algorithm. An F-measure of 1 denotes perfect precision and recall, whereas an F-measure of 0 implies complete failure in both aspects [6].

The primary advantage of the F-measure lies in its ability to provide a balanced evaluation of an algorithm's performance. It ensures that neither precision nor recall is disproportionately emphasized, mitigating the risk of an overly optimistic or pessimistic assessment [6].

However, the F-measure is not without its drawbacks. It assumes equal importance of precision and recall, which may not always be the case in certain applications. Furthermore, like the previously discussed metrics, the F-measure provides a global assessment and may not capture local distortions or structural details effectively [7]. In response to these limitations, metrics like the Pseudo F-measure and Distance-Reciprocal Distortion Measure (DRD) were introduced in the DIBCO competitions [10][11][12]. Despite these caveats, the F-measure remains a widely utilized metric in image binarization due to its interpretability and the balance it offers between precision and recall [6].

4.5. Pseudo F-measure as used in DIBCO

The Pseudo F-measure is a variant of the F-measure metric introduced in the Document Image Binarization COntest (DIBCO) to provide a more comprehensive evaluation of image binarization algorithms [10]. The traditional F-measure considers pixels individually and might not account for local structural distortions in the binarized image. The Pseudo F-measure addresses this by incorporating local pixel context into the metric, essentially measuring the degree to which the binarized image preserves the structure of the original image.

The calculation of the Pseudo F-measure involves the use of a pseudo recall and precision, defined by convolving the binary ground truth and binarization result images with a weighted circular window [10][12]. Then, the Pseudo F-measure is calculated in a similar manner to the traditional F-measure:

$$Pseudo\ F-Measure\ = 2\frac{Pseudo\ Precision\ \cdot Pseudo\ Recall}{Pseudo\ Precision\ + Pseudo\ Recall}$$

The Pseudo Precision and Pseudo Recall are integral components of the Pseudo F-measure and they are calculated using the concepts of convolution and a specific weighted circular window.

First, let's define a binary image B, where $B(i,j)$ represents the pixel at location (i,j). For a grayscale image, $B(i,j)\ = 1$ represents a foreground (or black) pixel, while $B(i,j)\ = 0$ represents a background (or white) pixel.

Now, the binary ground truth image and the binary result image obtained from a binarization algorithm are convolved with a weighted circular window W of radius r. The convolution operation is represented as:

$$C\ =\ B \otimes W$$

where $\otimes$ denotes the convolution operation. The weighted circular window W is defined as:

$$W(x,y) = \frac{1}{2\pi\sigma^2} e^{-\left(\frac{x^2+y^2}{2\sigma^2}\right)}$$

where (x, y) are coordinates in the window, and σ is a parameter related to the size of the window.

The Pseudo Precision and Pseudo Recall are then computed using these convolved images. The Pseudo Precision (PP) is calculated as:

$$PP = \frac{\sum_i \sum_j C_{Binarization(i,j)} \cdot G_{(i,j)}}{\sum_i \sum_j C_{Binarization(i,j)}}$$

where $C_{Binarization(i,j)}$ is the result of convolving the binarization result image with the window W, and $G_{(i,j)}$ is the ground truth binary image.

The Pseudo Recall (PR) is calculated as:

$$PR = \frac{\sum_i \sum_j C_{GroundTruth(i,j)} \cdot B_{(i,j)}}{\sum_i \sum_j C_{GroundTruth(i,j)}}$$

where $C_{GroundTruth(i,j)}$ is the result of convolving the ground truth image with the window W, and $B_{(i,j)}$ is the binarization result binary image [8,14].

These measures capture the degree to which the binarization result matches the local structure of the ground truth image, with a higher Pseudo Precision or Pseudo Recall suggesting a better match to the local structure. In the context of interpretation, a higher Pseudo F-measure indicates a better preservation of local structural information, leading to a higher quality binarized image [10]. One of the primary advantages of the Pseudo F-measure is its ability to evaluate both global and local distortions, making it a more sensitive and comprehensive measure for document image binarization [10][12].

However, the Pseudo F-measure is not without its drawbacks. The computation of Pseudo F-measure is more complex than traditional global metrics due to the requirement of convolving images with a weighted window. Moreover, as with any metric, the Pseudo F-measure might not capture all aspects of image quality and should ideally be used in conjunction with other metrics for a comprehensive evaluation of a binarization algorithm's performance [12]. Despite these limitations, the Pseudo F-measure has been widely adopted in the DIBCO evaluations due to its ability to provide a more detailed assessment of binarization quality, especially in preserving the structural integrity of document images [10][11][12].

4.6. Generalizations for F-measure and Pseudo F-measure

The F-measure or F-score is a popular metric in the field of information retrieval and machine learning, combining precision and recall into a single number. It is defined as the harmonic mean of precision and recall [7]. The F-measure and the Pseudo F-measure may be generalized by the introduction of a parameter, beta (β), to allow for differential weighting of precision and recall. The generic formula for F_β is as follows [11]:

$$F_\beta = \frac{(1+\beta^2)(Precision \cdot Recall)}{(\beta^2 \cdot Precision) + Recall}$$

The β parameter, in this context, regulates the degree of importance that is given to precision over recall [7]. If beta is set to 1, the F-measure becomes the F1-score, meaning that precision and recall are equally important [8]. However, by manipulating the beta parameter, one can adjust the F-measure to favor either precision or recall. A β greater than

1 gives more weight to recall, whereas a beta less than 1 gives more weight to precision [3]. The Pseudo F-measure, employed in the DIBCO competitions, is a variant of the F-measure and also incorporates the beta parameter to achieve a balance between precision and recall. However, unlike the traditional F-measure which utilizes pixel-based precision and recall, the Pseudo F-measure employs region-based precision and recall. The beta parameter plays the same role in the Pseudo F-measure as it does in the traditional F-measure, i.e., to give differential weighting to precision and recall [5].

In DIBCO, the beta parameter is usually set to 0.3, indicating that recall (or in the case of Pseudo F-measure, Pseudo Recall) is considered more important than precision (Pseudo Precision). This is a particularly suitable choice for document image binarization tasks where the priority is to retrieve as much text as possible from the image [15]. Nonetheless, the appropriate value of the beta parameter can differ based on the specific requirements of the task [2]. It should be noted that the selection of beta is critical, and it should reflect the relative importance of precision and recall for the particular problem or application under consideration [13].

4.7. Distance-Reciprocal Distortion Measure (DRD)

The Distance-Reciprocal Distortion Measure (DRD) is a metric specifically designed for document image binarization evaluation in the Document Image Binarization COntest (DIBCO) [11]. The DRD evaluates both the detection error (similar to F-measure) and the distortion error due to misclassification, making it more comprehensive than traditional metrics.

The DRD is defined as the average of the two terms: distortion of false negatives (D_{FN}) and distortion of false positives (D_{FP}).

$$D_{FN} = \sum \frac{\frac{D_{m(i,j)}}{1 + D_{m(i,j)}}}{N_{FN}} \qquad D_{FP} = \sum \frac{\frac{D_{m(i,j)}}{1 + D_{m(i,j)}}}{N_{FP}}$$

$$DRD = \frac{D_{FN} + D_{FP}}{2}$$

In these equations, $D_{m(i,j)}$ denotes the distance from a misclassified pixel at location (i, j) to the nearest correctly classified pixel. N_{FN} and N_{FP} represent the total numbers of false negative and false positive pixels, respectively. This distance measure is reciprocal, meaning that misclassifications far from correctly classified pixels are penalized more heavily [11][12].

A smaller DRD indicates better performance of the binarization algorithm, as it suggests fewer misclassifications and less distortion due to misclassifications. The DRD offers several advantages over traditional metrics. Firstly, it incorporates both detection and

distortion errors, providing a more complete picture of the binarization algorithm's performance. Secondly, by considering the distance of misclassified pixels, it gives a nuanced assessment that heavily penalizes gross misclassifications [11].

However, the DRD also has its limitations. The computation of the DRD is more complex than traditional metrics like MSE or $PSNR$, requiring the calculation of pixel distances. Moreover, DRD might be overly sensitive to minor distortions that have negligible impact on document readability. Lastly, like all other metrics, it might not fully align with human visual perception, necessitating the use of additional metrics for a comprehensive evaluation [12]. Despite these limitations, the DRD is extensively used in the DIBCO evaluations and is recognized for its ability to provide a detailed assessment of binarization quality, especially in the context of document images where both detection and distortion errors significantly affect the readability and subsequent processing of the documents [13,14].

4.8. Jaccard Index

Jaccard similarity coefficient or The Jaccard Index, is a measure used to compare sample set similarity and variety. It is used as an assessment metric in image binarization to quantify the agreement among the binarized output and the ground truth image [14].

The Jaccard Index is defined mathematically as the size of an intersection divided by the dimension of the union of the two groups. For a binarization task, it can be computed as:

$$Jaccard\ Index = \frac{TP}{TP + FP + FN}$$

where TP denotes true positives, FP represents false positives, and FN stands for false negatives. Essentially, this formula calculates the ratio of correctly identified foreground pixels (TP) to all pixels identified as foreground by either the ground truth or the binarization algorithm ($TP + FP + FN$) [14].

A higher Jaccard Index indicates a greater similarity comparing the binarized image and the ground truth, suggesting that the binarization technique is more effective.. The main advantage of the Jaccard Index lies in its simplicity and intuitiveness. It directly relates to the proportion of correctly classified pixels, providing a clear measure of the binarization algorithm's effectiveness [14]. However, the Jaccard Index also has certain limitations. As a global metric, it may overlook local distortions in the binarized image. Also, like any ratio-based metric, it can be sensitive to the class balance in the image. For instance, in an image with many background pixels, a few false positives may not significantly affect the Jaccard Index despite potentially causing noticeable visual artifacts [14].

Even of these limitations, the Jaccard Index is a useful metric that complements other metrics like the F-measure, Pseudo F-measure, and DRD, providing a comprehensive evaluation of the performance of image binarization algorithms [10][11][14].

4.9. Dice Coefficient

The Dice Coefficient is a statistic used to compare the similarity of two samples. It is also known as the Sørensen -Dice index or Dice Similarity Coefficient (DSC). It is used to analyze the agreement between the binarized picture and the ground truth in the context of image binarization [16]. The Dice Coefficient is computed by dividing the size of the intersection of the two sets by the total of their sizes. In terms of image binarization, it can be expressed as:

$$DSC = \frac{2TP}{2TP + FP + FN}$$

where TP represents true positives, FP denotes false positives, and FN stands for false negatives. Essentially, the Dice Coefficient calculates the proportion of correctly identified foreground pixels ($2TP$) against all pixels identified as foreground plus those incorrectly identified as background ($2TP + FP + FN$) [16].

A Dice Coefficient closer to 1 suggests a high similarity between the binarized image and the ground truth, indicating the superior performance of the binarization algorithm. The Dice Coefficient has its strengths in its straightforward interpretability and ease of calculation. It provides a balanced measure of the binarization algorithm's effectiveness by taking into account both the false positives and false negatives [16].

However, the Dice Coefficient, being a global measure, may not capture local errors in the binarized image effectively. Like other ratio-based measures, the Dice Coefficient can be sensitive to the class imbalance in the image. For example, in a predominantly background image, a few misclassified foreground pixels may not significantly affect the Dice Coefficient, despite potentially leading to noticeable visual artifacts [16]. Despite its limitations, the Dice Coefficient is a valuable measure that, alongside metrics like the F-measure, Pseudo F-measure, Jaccard Index, and DRD, provides a well-rounded evaluation of image binarization algorithms [10][11][14][16].

4.10. Matthews Correlation Coefficient (MCC)

The Matthews Correlation Coefficient - MCC, sometimes referred as the phi coefficient, is a binary classification measure that takes consider true and false positives and negatives. It is often considered as a harmonious measure that can be used even though the categories differ greatly distinctive in terms of size [12]. In essence, the MCC is a correlation coefficient between the discovered and anticipated binary classifications. It returns a value

within -1 and +1. In this case, +1 denotes flawless prediction, a coefficient of 0 denotes no better than an arbitrary estimation, and a coefficient of -1 denotes entire disagreement between forecast and observation. The MCC can be calculated based on the elements of a confusion matrix, which are the True Positives (TP), False Positives (FP), True Negatives (TN), and False Negatives (FN), as follows:

$$MCC = \frac{TP \cdot TN - FP \cdot FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}}$$

The main advantage of the MCC over other metrics like accuracy, F-score, or the area under the ROC curve (AUC), is that it is a more reliable statistical rate that only produces a high score if the prediction performs effectively in all four confusion matrix sections (TP, FP, TN, FN), as contrasted with other rates, which can yield misleading results even if TP, FP, TN and FN rates are imbalanced. In other words, the MCC considers both the over-prediction and under-prediction of each class and gives a balanced measure of the quality of binary classifications [12].

However, one of the limitations of the MCC is that it does not extend naturally to multiclass classification and does not have a clear interpretation in terms of probabilities or odds ratios. Also, while it does offer a more balanced perspective, it can be more difficult to interpret and explain than simpler statistics such as accuracy or F1 score [12]. Although with these drawbacks, the MCC is widely regarded as a reliable statistical accuracy measure in situations where the classes are imbalanced and provides a good complement to other evaluation metrics used in image binarization evaluations [12].

5. Evaluation Metrics in DIBCO Image Binarization Evaluations

5.1. Overview of DIBCO evaluations

Document Image Binarization Contest (DIBCO) is a benchmarking initiative that provides standard datasets and evaluation methodologies for the field of image binarization [3]. Since its inception in 2009, DIBCO has been instrumental in promoting innovative solutions for document image binarization, which is a crucial preprocessing step in many document image analysis and recognition systems [3].

5.2. Significance and Influence of DIBCO in the Image Processing Community

The significance of DIBCO in the image processing community is far-reaching. As an international competition, it brings together researchers worldwide, fostering a sense of collaboration and competition in advancing image binarization techniques. DIBCO datasets are composed of a wide variety of images, including handwritten and printed texts, historical documents, and texts under different noises and degradations. These diverse

datasets present challenges and opportunities, enabling researchers to develop and test robust binarization algorithms that can handle real-world situations [3].

5.3. Discussion of Metrics used in DIBCO

DIBCO evaluations employ a comprehensive set of metrics to evaluate the performance of binarization algorithms. The F-measure, Pseudo F-measure, DRD, $PSNR$, and MSE are all part of the evaluation toolkit. Furthermore, DIBCO also introduced other measures like the Negative/Positive Rate (NPR), Misclassification Penalty (MP), and Optical Character Recognition (OCR) error to evaluate the binarization results [2][3][5][13][15].

The F-measure used in DIBCO is a harmonic mean of precision and recall, while the Pseudo F-measure introduces weighted factors into the precision and recall calculation, making it more sensitive to certain types of errors [2][5]. DRD measures the average minimum distance between the boundary pixels in the binarized and reference images, providing a unique perspective into the quality of binarization [13]. $PSNR$ and MSE offer measures of the error between the binarized and reference images, each with its own strengths and weaknesses [4].

5.4. Comparison of DIBCO's Approach with Other Evaluation Methods

While other evaluation methods often rely on a single metric or a small set of metrics, DIBCO's approach stands out due to its wide-ranging and comprehensive evaluation using multiple metrics, which is designed to capture different aspects of binarization performance. This multi-metric evaluation approach presents a more complete picture of the binarization algorithm's performance, enabling researchers to identify the strengths and weaknesses of their algorithms and guide their improvements [3].

DIBCO's datasets, evaluation metrics, and methodologies have become a benchmark in the field of image binarization. They have significantly contributed to the development of more effective and efficient image binarization techniques, leading to improved performance in various applications such as document image analysis, OCR, and historical document digitization [1][3][6][7]. The influence and significance of DIBCO in the image processing community continues to grow, with its datasets and evaluation methodologies being widely used and cited in related research [3].

6. Comparative Analysis of Metrics

6.1. Discussion on How Different Metrics Relate to Each Other

In the evaluation of image binarization algorithms, different metrics provide different perspectives on the performance of the algorithms. MSE and $PSNR$, for example, are both

error metrics that quantify the difference between the image binarized and the original one. MSE calculates the mean squared difference between pixel intensities, while $PSNR$ is based on "the ratio between the maximum possible power of a signal and the power of corrupting noise" [4]. As such, they are inversely related; a lower MSE indicates a higher $PSNR$.

Similarly, the notions of True Positives (TP), False Positives (FP), and False Negatives (FN) underpin Precision, Recall, and the F-measure. Precision is the proportion of properly recognized positives in comparison to all identified positives (TP and FP), whereas recall is the proportion of correctly identified positives in comparison to all real positives (TP and FN) [12]. The F-measure is the harmonic mean of Precision and Recall with the goal of balancing these two measures [2]. The Pseudo F-measure, as employed in DIBCO, changes these calculations by taking weights into account [5].

6.2. Comparison of Metrics in Terms of Their Effectiveness, Accuracy, and Usability

In terms of efficacy, accuracy, and usefulness, each measure has advantages and disadvantages. MSE and $PSNR$ are easy to calculate and understand but may not always reflect the perceptual quality of the binarized image [4]. The F-measure and Pseudo F-measure, while they provide a balanced measure, can be sensitive to the choice of the beta parameter [2][5]. DRD, on the other hand, measures the average minimum distance between the boundary pixels in the binarized and reference images and can be useful in situations where boundary preservation is of importance, such as in text recognition tasks. However, the calculation of DRD can be computationally intensive [13].

The usability of these metrics can depend on the specific requirements of the application. In some cases, a simple, easily interpretable metric like MSE or $PSNR$ might suffice, while in other cases, a more sophisticated measure like the Pseudo F-measure or DRD may be necessary [3][2][13].

6.3. Case Studies Demonstrating Different Metrics' Performances in Different Scenarios

Several case studies have illustrated the performance of these metrics in different scenarios. For example, in the DIBCO evaluations, the Pseudo F-measure was found to be particularly effective in identifying algorithms that performed well in preserving text stroke width, an essential feature for text readability and subsequent OCR processing [3][5]. On the other hand, measures like MSE and $PSNR$ have been found to be less effective in this context, as they do not directly consider structural aspects like stroke width [4].

In another study involving historical document image binarization, the F-measure was found to be more effective than $PSNR$ in assessing the quality of the binarization [10]. This shows that the choice of the evaluation metric can significantly impact the perceived

performance of binarization algorithms, and the choice of metric should consider the specific characteristics and requirements of the application domain [10][5][14].

7. Limitations and Challenges in Current Evaluation Metrics

7.1. Identification of Gaps in Current Evaluation Methods

Despite the range of available evaluation metrics for image binarization, there are still gaps in current methods. One of the significant challenges is the lack of consensus on a universal metric that can cater to all types of images and applications [8]. While metrics such as MSE and $PSNR$ are good for quantifying the overall difference between binarized and reference images, they may not capture certain aspects like structural preservation [4]. Conversely, more specialized metrics like DRD and the Pseudo F-measure are sensitive to certain features like boundaries and stroke width but may not be suitable for all types of images [4,9]. Another gap is the heavy reliance on ground truth or reference images for the computation of most of these metrics [8]. While this approach is ideal for benchmarking purposes, it is not always feasible in practical applications where ground truth images may not be available.

7.2. Challenges and Issues in Implementing and Interpreting the Metrics

Implementing and interpreting the metrics presents its own set of challenges. The computation of some metrics, such as the DRD, can be complex and computationally intensive, which may not be practical in some situations [13]. In addition, the interpretation of results can sometimes be ambiguous due to the trade-off nature of certain metrics like Precision and Recall, and their derived metrics such as the F-measure and Pseudo F-measure [2][5].

For metrics like the MSE and $PSNR$, while they provide a straightforward numerical measure of the error, their interpretation in terms of perceptual quality can be non-intuitive [4]. High $PSNR$ or low MSE does not necessarily correlate with a high-quality binarized image, especially when the noise is non-uniform or structured.

7.3. Discussion on How These Challenges Might Be Overcome

To overcome these challenges, future research could focus on developing more sophisticated metrics that balance the trade-off between complexity and effectiveness, as well as developing methods for metric computation that do not heavily rely on ground truth images [8]. One potential approach could be to incorporate machine learning techniques to predict the quality of binarized images based on features learned from a large set of training images [9].

In terms of interpretation, it might be beneficial to provide guidelines or frameworks for interpreting different metrics in different contexts. For instance, a guide on when to use $PSNR$ versus the F-measure based on the specific requirements of the image binarization task could be useful.

Additionally, to address the challenges of interpreting metrics like Precision and Recall, future work could focus on developing more intuitive visualizations and explanations of these metrics to aid in their understanding and use [11][14]. It's also crucial that future research work towards identifying an optimal set of metrics that can be used to evaluate binarization algorithms effectively across a wide range of scenarios.

8. Future Directions and Conclusions

8.1. Suggestions for New Evaluation Metrics or Improvements on Existing Ones

The field of image binarization evaluation metrics is ripe for innovative advancements. While current metrics offer valuable insights, further improvements and new metrics could enhance the precision and practicality of these evaluations [14]. As we grapple with the trade-off between simplicity and sensitivity, one recommendation is the integration of machine learning techniques to enhance metrics [9]. This could potentially lead to metrics that can better adapt to various types of images and binarization tasks.

An alternate approach might be the development of meta-metrics that incorporate multiple existing metrics into a single score [8]. This approach could leverage the strengths of individual metrics while mitigating their limitations. Similarly, current metrics could be refined to be more perceptually relevant. For instance, advancements could be made on MSE and $PSNR$ to make their interpretation more intuitively linked to perceived image quality [4].

8.2. Discussion on the Potential Future of Image Binarization Evaluation

The future of image binarization evaluation holds much potential. As machine learning and AI continue to permeate image processing, we expect these technologies to play a substantial role in enhancing image binarization evaluation [9]. New methodologies could emerge that learn from a diverse range of image data to predict binarization quality, leading to more reliable and adaptive evaluation processes.

Furthermore, as the image binarization field continues to evolve, we anticipate a growing interest in specialized metrics tailored to specific applications, such as document analysis or medical imaging. The continuing development and expansion of benchmark datasets and competitions, like DIBCO, will also be instrumental in driving this research forward [7].

8.3. Summary of Key Findings and Conclusions

In summary, this paper has provided an in-depth review of various evaluation metrics for image binarization, highlighting their respective strengths and weaknesses. The necessity for a balanced evaluation strategy that considers both general and task-specific attributes of the image binarization problem has been stressed.

The paper discussed the significant role of DIBCO in shaping the current understanding and application of these metrics [7]. We examined the limitations and challenges of current metrics and proposed potential directions for future research [13][8]. By combining traditional metric-based evaluations with emerging technologies and methodologies, the field can move towards more accurate, adaptive, and application-specific evaluations of image binarization algorithms [9].

As we move forward, it's vital to continue questioning and refining our approaches to ensure we are effectively evaluating and improving image binarization techniques.

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THE QUALITY OF FINANCIAL-ACCOUNTING INFORMATION IN THE CREATIVE ACCOUNTING EQUATION – FROM EXACT RELEVANCE AND REPRESENTATION TO UNCERTAINTY AND AMBIGUITY

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Abstract

At the national, European, and international levels, there is a need for quality financial information, and accounting standards have imposed several fundamental and enhancing features to make sure that users can profit from the data from annual financial statements. The current research, however, shows that as innovative accounting techniques are employed, the quality of financial accounting information is impacted, losing its utility, and shifting from being relevant and accurately represented to being uncertain and ambiguous. The management of the entity assumes a few risks as a result of the implications of creative accounting on the annual accounts. These risks can be minimized by putting strategies in place to identify and restrict the mechanisms used to manipulate financial accounting information. If we consider the fact that managers largely consent to the use of creative accounting, acting under the guise of its legality, this is challenging to accomplish.

Keywords*:* financial-accounting information, quality, creative accounting, relevance, financial position, financial performance, manipulation of financial-accounting information

JEL Classification: M41

1. Introduction

Financial accounting information serves as the foundation for decision-making within an economic entity. Its role is to provide competitive advantages to its users, both internal and external, for them to make and justify optimal decisions. Thus, in order to serve its purpose, accounting information must be of high quality, that is, it must possess certain characteristics that ensure its usefulness to all those interested in the entity's economic life.

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Although it has always been a stated goal of accounting to provide reliable financial accounting information, recent years have brought to light the urgency of this goal considering the rise in bankruptcies brought on by the falsification and embellishment of annual accounts. The need to regulate how accounting information is defined led standardization bodies to establish some qualitative requirements that accounting information presented in financial reports must adhere to. Depending on the laws passed at the national, European, or international levels, different standards are used to define the quality concept of financial accounting information.

Given that this new branch of accounting, creative accounting, involves the transformation of financial statements as a result of the existence of the choice of accounting treatments, estimates and forecasts, and other permitted practices by the accounting regulations in force, the emergence of creativity in accounting has put and will continue to put the quality of accounting information in doubt.

2. Literature review

After the 1929 financial crisis, there was discussion in the USA regarding the definition of the problem of the quality of financial accounting information and the voices that signaled the inadequateness of the information provided by businesses and the absence of standards for evaluating the quality of financial accounting information.

Over time, American standardization bodies were concerned with defining the qualitative criteria of financial-accounting information, which later became a critical component of any conceptual framework, whether American, British, or international. A brief list of the accounting staff members who emphasized the quality of financial-accounting information is provided below:

• FASB publishes in 1980 - the qualitative characteristics of accounting information

• IASC publishes in 1989 the requirements for obtaining high-quality information, along with the qualitative characteristics of financial statements;

• The British standardizer's perceptions of the qualities of financial information are published by the ASB in 1991.

Regarding the definition (Stefan D., Sărămăt O., 2011) [1] of the qualitative characteristics of accounting information, the standardization bodies starting from: defining user groups, identifying information needs, determining the objectives of financial reporting, have shared points of view with regards to the highlighting of certain characteristics (relevance, reliability, intelligibility, and comparability), but at the same time they have divergent views regarding the other characteristics.

The qualitative characteristics of the financial-accounting information that have been recognized by the aforementioned standardization bodies are rendered (Minu, M., 2002) [2] and are the subject of a ranking scheme (Vilaia D., Pietraru A., Popa I., 2008) [3] that is developed in 2008.

The CNC did not take into account the definition of qualitative characteristics of accounting information in France, so only certain qualities of accounting information were listed in the French plan. Along with the debates and proposals about the need for a French conceptual framework, the professional organization of accounting experts developed its own conceptual framework, which included aspects about the concept of accounting information quality.

Celine Michailesco (Michailesco C., 2000) [4] considers that there are certain similarities between the characteristics of the accounting information retained by the CNC and those provided in the Anglo-Saxon conceptual frameworks:

- adequate or adjusted refers to relevance;
- clarity refers to intelligibility;
- loyalty can only be linked to reliability.

Several time periods were examined in order to define the quality of accounting information in national regulations. The findings of the research highlight the following elements:

- because the state as a user caused an asymmetry in the demand and supply of accounting information in comparison to other users, and because the faithful image can be obtained if the rules of patrimony evaluation and other accounting standards are followed, emphasis was not placed on these qualitative characteristics of accounting information in the framework of the first regulations from 1991 to 1999.
- the emergence of normative acts (OMFP 403/1999, OMFP 94/2001) through which the Romanian legislation is harmonized with the IV EC Directive and the International Accounting Standards marks the second stage of the accounting reform in that country, which began in 1999. The national framework that characterizes the development of the accounting system is fixed through these normative acts, and at the same time, the beneficial influences regarding the qualitative aspects of the accounting information are assumed.
- the primary qualitative characteristics of the annual financial statements are specified precisely and succinctly in the third stage of the national accounting system's development, which was started in 2006 by the normative acts OMFP 1752/2006, OMFP 3055/2009, and OMFP 1802/2014. They align with IFRS' characteristics, demonstrating once more how Romanian accounting has become

more accessible to those who need accounting information in order to make wise decisions or investments.

Against the backdrop of accounting rules' flexibility and the availability of alternative options and treatments, creative accounting adheres to the letter of the law but not to its spirit. Thus, specialized literature confirms the legality of creative accounting practices while emphasizing the negative consequences for entities and users of financial-accounting information.

Naser K., in the work Creative accounting: its nature and use, defines creative accounting from an academic perspective as "the process by which, due to the flexibility and existence of gaps in the rules, the figures in the annual accounts are manipulated, the result of the choice of measurement practices and information being the transformation of summary documents from what they should be to what managers want" (Naser K., 1993)[5] and draws attention that "the manipulation of accounts is an old accounting problem that has appeared since the 1920s".

Even though it first appeared more than a century ago, creative accounting practices are still relevant and of interest, particularly to managers who use accounting earnings to meet investors' growing expectations of economic returns (Beneish M. D., Nichols C., 2005) [6].

In his book Comptabilité générale, Colasse B. mentions the possibility of creative accounting techniques being illegal due to the deviation of accounting rules: "accounting information practices that are often at the limit of the legal are used by certain entities that take advantage of the limits of regulation and normalization in order to embellish the image of the financial position and the reported economic performances." (Colasse B.,1997) [7].

Creative accounting techniques are described by Stolowy H. in his book Comptabilité créative as "a set of procedures that aim either to modify the result, in the sense of maximizing or minimizing it, or to modify the presentation of the annual financial statements, but without the two objectives being mutually exclusive" (Stolowy H., 2000) [8]. These aspects are a significant part of the theme addressed in this scientific research.

McEnroe J.E. addressed the issue of financial scandals caused by the use of creative accounting techniques in the study Individual Investors' Perceptions Involving the Quality and Usefulness of Audited Financial Statements and highlights the negative effect they had on trust in the reported financial-accounting information. (McEnroe J.E, 2007) [9].

According to the subject of this scientific research, we also observe some interest in the national specialized literature, implying that the concerns of recent years have been concretized in new writings, perspectives, and visions regarding creative accounting.

The late professor Niculae Feleagă was the first author to dare to write about creative accounting in our nation. In his book Accounting Controversies, Conceptual Difficulties,

and the Credibility of Accounting (Feleagă N., 1996) [10], published in 1996, he discusses the techniques used in this type of accounting as well as the dangers associated with using them in actual accounting practice.

Three years later, Liliana Malciu presents in detail her mentor's ideas from the above-mentioned work, addressing conceptual aspects such as the motivational complex of the development of creative accounting techniques, practices arising from the choice of accounting policies, or the accounting profession's reaction to the emergence of this phenomenon. (Malciu L., 1999) [11].

Diaconu P., in the work How do accountants make money? Tax evasion, tax havens, creative accounting analyzes the role of creative accounting in maximizing the performance of the economic entity (Diaconu P., 2004) [12].

Munteanu V. and Zuca M. consider creative accounting as a tool to support the manager, a tool used to present the desired image of the entity that leads in pursuit of one's own interests, in the article Considerations regarding the use of creative accounting in distorting information from financial statements and "maximizing" the company's performance. (Munteanu V., Zuca M., 2011) [13].

Groșanu A. examines the relationship between creative accounting and other concepts such as true image, accounting fraud, and corporate governance in the work Creative accounting. It also highlights a series of empirical studies aimed at assisting users of annual financial statements in understanding creative accounting techniques and their impact in the Romanian economic environment. (Groșanu A., 2013) [14].

Creative Accounting. From idea to money, written by A. S. Dumitrescu, proposes the search for positivism and negativism in the analysis of creative accounting. The author's point of view is unequivocal: "creative accounting, in a positive sense, is capable of emitting an objective truth and message." But let us not lose sight of the fact that the truth revealed by creative accounting is only a filter that cannot distinguish between the constructed and desired truths, between innovation and manipulation. (Dumitrescu A. S., 2014) [15].

3. Research methodology

The objective of the current scientific research was to develop and deepen our understanding of the quality of financial accounting information and how creative accounting affects it. To accomplish this, the research was conducted in a systematic manner from both theoretical and practical perspectives.

The basic research reflected in this paper was based on theorizing the specific concepts of the chosen theme, namely: the quality of financial-accounting information, the qualitative characteristics of financial-accounting information, and the impact of creative accounting

on the information presented in annual financial statements. Furthermore, they are analyzed from a theoretical standpoint, aspects concerning:

- The quality of financial accounting information in relation to the regulatory frameworks of the United Kingdom, France, and Romania;
- The fundamental and enhancing qualitative characteristics of financial accounting information in the context of IFRS financial reporting requirements;
- Model for assessing the quality of financial accounting information at Romanian businesses;
- The impact of financial-accounting information quality on the entity's value dimension;
- Influences and effects of creative accounting on the accuracy of financial accounting data;
- Methods for identifying and preventing mechanisms that manipulate financial accounting data.

Additionally, this paper's content successfully combines elements of qualitative research with those that call for quantitative analysis. We continued our review of the specialized literature with the idea that the more bibliographic resources are based on them, the more reliable and convincing our scientific findings will be in terms of qualitative or interpretive research (Yin R.K., 1994) [16]. As a result, we used deductive reasoning to document the investigated phenomenon, and among the analyzed sources we discovered: specialized books, articles published in magazines and economic journals indexed in international databases, accounting standards and norms, and normative acts. We paid equal attention to writings in English, French, and Romanian because we took a more complex approach to the field under study. We conducted an in-depth, specialized investigation of the effects accounting engineering has on the quality of information provided by the annual financial statements of Romanian economic entities in the pharmaceutical industry. The sources cited throughout the paper revealed opinions and analyses of foreign and domestic authors regarding the quality of financial accounting information and the phenomenon of creative accounting that manifests both internationally and nationally.

The design and presentation of a model for evaluating the quality of financial-accounting information in the Romanian context, based on the examination of the entity's financial statements, constitutes the quantitative or positivist research presented in this article.

4. The demand for high-quality financial accounting data at the international, European, and national levels

4.1. Definition of the quality concept for accounting and financial data

Given the growing emphasis on providing quality accounting information through financial statements in academic and professional environments, the idea of the quality of financial-accounting information is regarded as a contemporary one.

Regulatory organizations that operate at the national, European, and international levels establish various criteria for evaluating the quality of financial accounting information. These qualitative requirements must be met for the information provided by the economic entity's financial statements to be credible and useful.

Defining the quality characteristics of financial-accounting information has become a fundamental component of any Anglo-Saxon or international conceptual framework that proposes their identification and ranking. In contrast to this approach, French accounting places little emphasis on the concept of financial-accounting information quality but insists that it must provide a useful representation of the economic entity's reality. In terms of the Romanian accounting standard, OMFP no. 1802/2014 fully adopts the provisions of the IASB's General Conceptual Framework on the qualitative characteristics of financial-accounting information.

Analytical reasoning is used to test and classify the financial accounting data under the conditions of compliance with specific limitations, and then validate the quality criteria that the data must meet. Making such an analysis is challenging, and in this regard, we observe the varying viewpoints that have existed over time regarding the ranking of the qualities required to generate reliable financial accounting information. However, in order to highlight the similarities and differences that currently exist at the level of the accounting system, we believe it is appropriate to present a comparative presentation of these characteristics as defined and ranked in national and international legal texts.

4.2. The quality of financial accounting information in relation to the regulatory frameworks of the United Kingdom and France

The quantity and, most importantly, the quality of accounting information ensure the usefulness of financial reports. Accounting standardization and regulatory bodies in the United States, the United Kingdom, and France all had different concerns about defining the quality characteristics of financial-accounting information.

The Financial Accounting Standards Board (FASB), an American standardization body, published a series of qualitative characteristics of accounting information in 1980, organised in decreasing importance, as follows: intelligibility, reliability, relevance, and comparability. If the costs of producing the information are less than the benefits of using

it, and the information presented in the financial statements is significant, these characteristics achieve qualitative competence.

Figure 1 shows, schematically, the qualitative characteristics of financial accounting information according to the FASB.

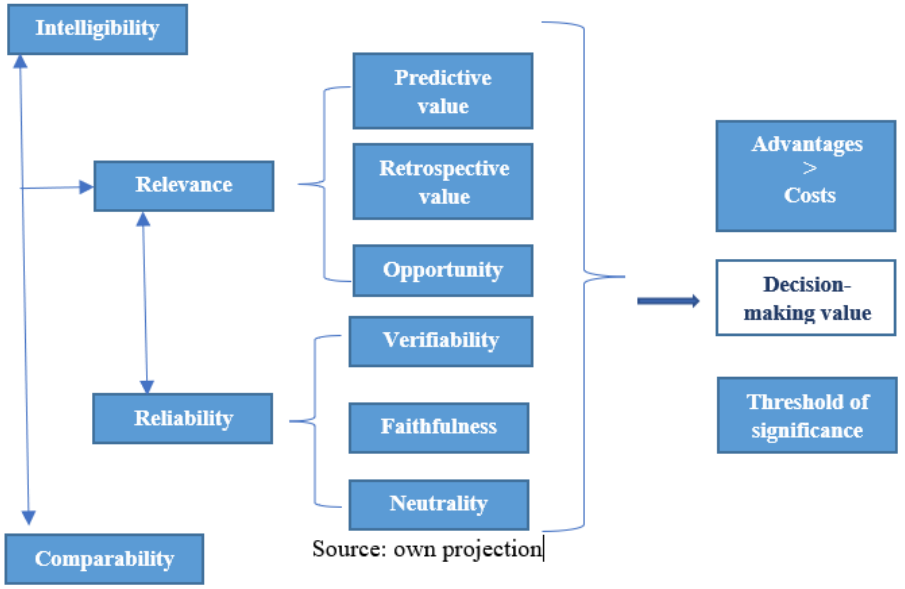


Figure no. 1: Qualitative characteristics of accounting information according to FASB

The primary quality of financial information must be relative importance, followed by the main qualities of relevance (relevance) and reliability, and the secondary qualities of comparability and intelligibility. This is according to the UK's accounting standard-setter, the Accounting Standards Board (ASB), which published its own opinion on the quality of accounting information in 1991. *(*Figure no. 2). Opportunity, the cost-benefit analysis, and the imbalance between the quality characteristics may all act as barriers to achieving the quality of accounting information.

The ASB's perspective on the main qualities of information reveals the following relationship: more of one quality means less of the other, in other words, information that focuses more on relevance is less reliable, which is why achieving a balance between the two qualities is necessary. Another feature unique to British accounting is that information reliability refers to the absence of errors or elements that could lead to erroneous interpretations; meeting this quality criterion requires the following requirements: credible representation (substance before form), neutrality, exhaustiveness, and prudence.

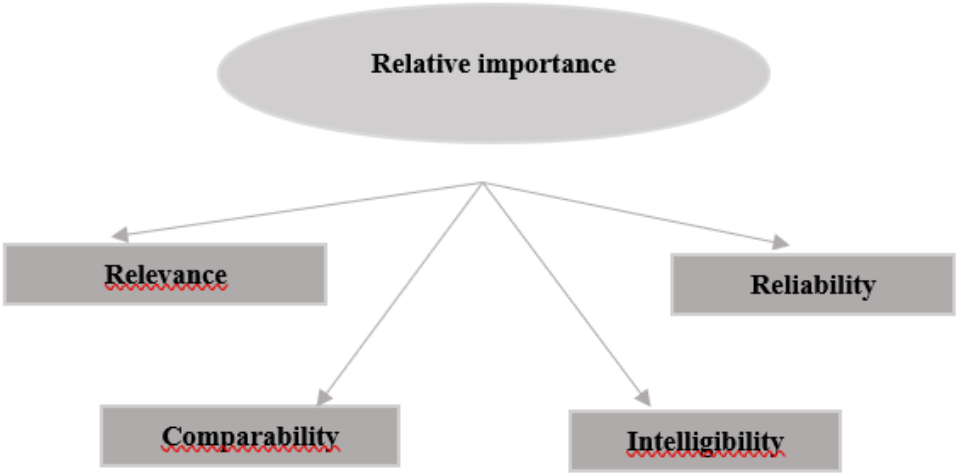


Figure no. 2: The ASB's guidelines for the quality of accounting information

Source: own projection

In France, the national accounting regulatory body has not taken the definition of the quality characteristics of financial-accounting information into account. Rather, the French General Chart of Accounts (PCG) requires that accounting information provide users with an adequate, fair, clear, precise, and complete presentation of economic transactions and operations. In addition, in order to obtain an accurate picture of the accounts, the French normalizers imposed three principles: regularity, honesty, and prudence.

Regardless of the provisions of various conceptual frameworks or accounting regulatory texts, it is crucial to make clear that financial-accounting information does not completely meet the proposed sets of quality characteristics, but that they must at least partially possess all of them in order to be useful in the decision-making process (Feleagă N., 1996) [17]. In order for the accounting information to best meet the qualitative requirements specified by the adopted reference, compromises are frequently made in the processing and presentation of the accounting information.

4.3. The fundamental and enhancing qualitative characteristics of financial accounting information in the context of IFRS financial reporting requirements

In the public interest, the International Accounting Standards Board (IASB) has developed a set of globally agreed financial reporting standards known as International Financial Reporting Standards (IFRS). The goal of implementing these standards is to provide users with quality, transparent, and comparable financial-accounting information that they can use to make economic decisions.

The conceptual accounting framework is a document that contains the concepts, objectives, and fundamental principles required to create a reference system for the preparation and presentation of the financial statements of an economic entity.

The development of such a reference material took place after several attempts. Thus in 1989, the IASC developed the first conceptual framework that contained rules regarding the preparation and presentation of financial statements. In 2010, the IASB issued a new conceptual framework that clarifies the objectives of financial reporting: the information provided by annual accounts must meet the common needs of the majority of users. Following an extensive revision and addition process, the most recent conceptual framework was published in 2018. This resulted in a new IASB international reference, structured in eight chapters, with the role of guiding the accounting professional in formulating the reasoning required for financial statement preparation and presentation (***Figure no. 3***).

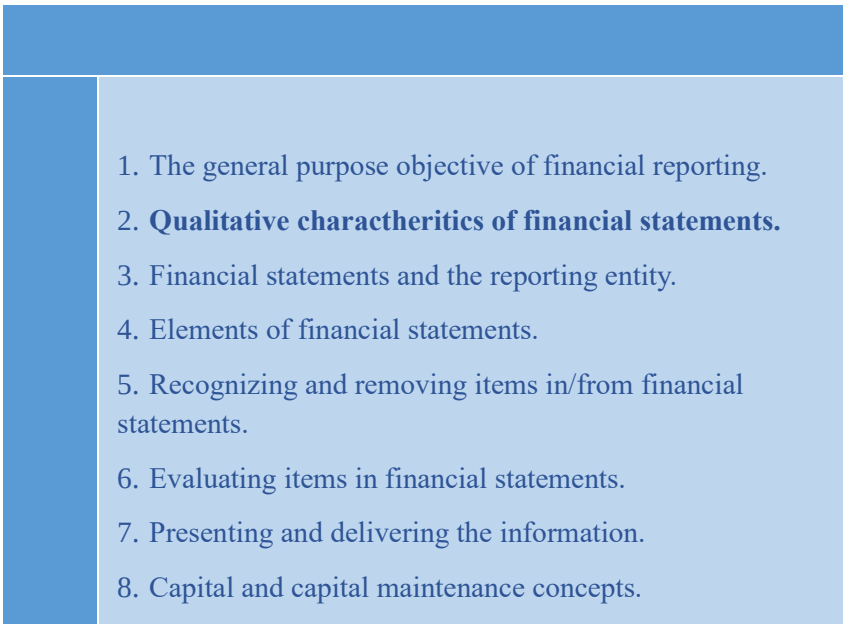


Figure no. 3: The conceptual accountanting framework (IASB, 2018)

Source: own projection

The relevance of the events and transactions recorded and accurately represented in the accounting, according to the current international accounting regulations, determines the usefulness of the information provided by financial statements.

One of the most crucial qualitative traits of financial accounting information is ***relevance.*** Information is generally considered relevant if it has an impact on the beneficiaries' financial decisions. ***Relevance*** gives meaning to the data in financial reports, enables users

to assess past, present, and future operations and transactions, and supports or contradicts earlier projections and estimates (Ristea M., Dumitru C.G., 2012) [18].

Relevance assumes that the information presented prior to the current fiscal year about the entity's financial position and performance has a predictive or forecasting role for the subsequent periods. At the same time, relevant information serves as an evaluating or confirmatory function by highlighting the truth about the entity's financial situation. As can be seen from ***Figure no. 4***, there is a close relationship between the two roles played by relevant information*:*

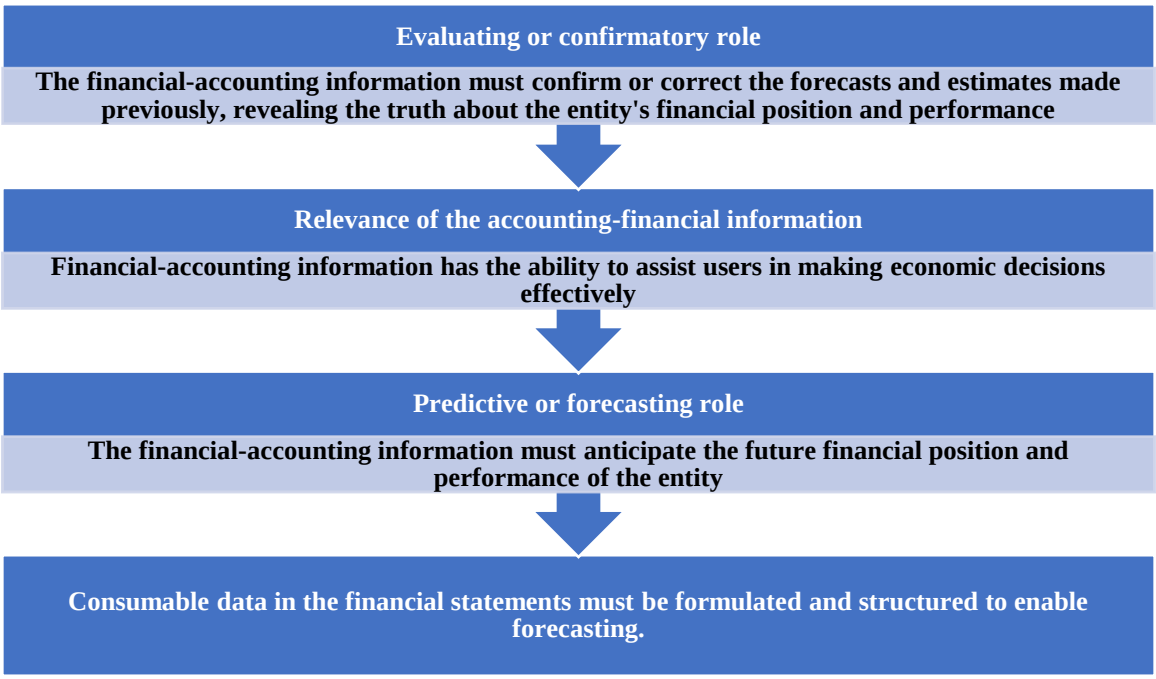


Figure no.4: The relevance of financial-accounting information

Source: own projection

Accounting should entail more than just providing historical information in financial statements. Accounting must periodically offer, through forecast accounts, predicative data on assets, equity and liabilities, income, and expenses in order to demonstrate its value as a tool for financial management and analysis. The financial accounting information included in the preliminary financial statements must therefore be relevant.

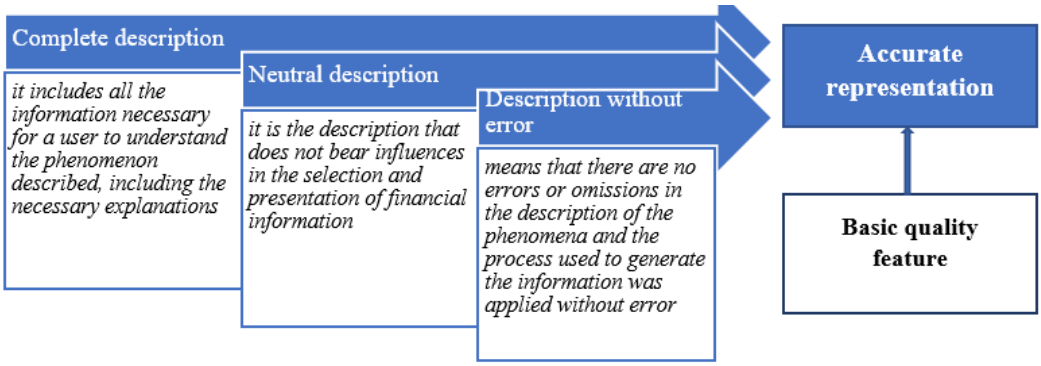
The controversies surrounding financial accounting information arise from the controversies surrounding its nature and materiality or significance. The nature of the information is usually sufficient to determine its relevance. However, there are times when the relevance of the information must be determined after considering its materiality.

The materiality of accounting information refers to the threshold of significance, or the point beyond which decisions made based on incomplete or incorrect information in financial statements are influenced. As a result, information is only relevant if it is significant.

Another aspect of relevance is the selection and processing of information based on the needs of users, as well as the provision of a sufficient volume of data to avoid over- or under-informing the beneficiaries. In addition, when it comes to the perishability of information, relevance includes promptness and punctuality.

Financial accounting data is relevant if it meets all the criteria listed above. Furthermore, the General Conceptual Framework emphasizes that for information to be useful, it must be both relevant and accurately represent the events it claims to represent.

Financial-accounting ***information must be accurate***, free from influence, distortion, or manipulation in any way, and without errors or omissions to be understood. Accurate representation is one of the fundamental qualitative requirements that financial-accounting information must meet, along with relevance. In other words, a complete, unbiased, and error-free description of the events, transactions, and accounting phenomena specific to the entity's economic activity is necessary for the accurate representation of financial-accounting information. (***Figure no. 5***).



Source: own projection

Figure no. 5: Accurate representation of financial and accounting information

4.4. The quality of financial accounting information in Romania, according to the reference accountant

The problem of defining and evaluating the quality of the information presented in the financial statements was hesitantly addressed by the accounting reform that was initiated in Romania immediately following the 1989 revolution. Because the Romanian normalizers saw accounting as a control tool, they imposed reliability and truthfulness as

the primary qualities of accounting information. Under these circumstances, the state, acting as the legislator, also acquired the privilege of using accounting data, which gave the appearance of informational asymmetry when compared to the other user categories.

Accounting was transformed into an information tool and decision support after 1999, when legislative texts became more coherent than they were during the first stage of reform (1991-1994). Accounting was oriented towards its external users through an economic approach to the acquisition and processing of accounting information at the expense of the legal approach. As a result, the degree of capitalization of accounting information increased proportionally to their number, requiring the introduction of quality criteria required in financial statement preparation and communication.

Romanian accounting must address the issue of the quality of accounting information, considering the specific transformations that have generated a developing economy. (Minu M., 2002) [2]:

- redefining and remodeling the business as a producer of accounting information;
- redefining and remodeling the message sent through financial statements;
- defining and recognizing the categories of users of financial information, as receivers of accounting message.

However, we note the influences that international accounting benchmarks have on the accounting system in our country. Defining the quality of accounting information was a concept taken over, translated, and transposed in Romanian accounting. The lack of a personal point of view of the Romanian standardizers regarding the quality of accounting information also emerges from the literal adoption of the quality criteria used in the international accounting standards.

Currently, accounting regulations for individual annual financial statements and consolidated annual financial statements are in effect in Romania, as approved by Order of the Minister of Public Finance No. 1802 of December 29, 2014.

The qualitative attributes of the data provided by the economic entity's financial statements are enumerated and described in section 2.3 of OMFP no. 1802/2014. We emphasize that the IASB General Conceptual Framework's requirements for these qualities in financial accounting information have been adopted by local accounting legislation, resulting in the following provisions in the Romanian accounting regulations currently in effect:

For financial information to be useful, it must be relevant and represent exactly what it is intended to represent. The usefulness of accounting information is enhanced if it is comparable, verifiable, timely and comprehensible.

The technical literature also suggests additional quality requirements—transparency, responsibility, confidentiality, and correctness—that the information presented in financial

reports must meet in addition to those specified in the rules (Ristea M., Dumitru C.G., 2012) [18]. Credibility, however, is a mega-characteristic that gives utility to accounting information, thus the other qualities, except relevance, are incorporated by it:

- The user must possess specialized knowledge in order to understand accounting information; otherwise, the message conveyed by financial reports will be distorted;
- Although it is necessary to apply qualitative criteria to accounting information, doing so does not ensure its quality (Minu M., 2002) [2];
- To assess the quality of accounting data, tools are required.

4.5. Measuring instrument for the quality of financial-accounting information at Romanian economic entities

According to the IASB conceptual framework, which maintains the following qualitative characteristics, the quality of financial accounting information is evaluated in Romanian accounting in accordance with relevance and exact representation, comparability, verifiability, timeliness, and intelligibility. The quality of the accounting information is determined by whether the aforementioned criteria are met; the definition of the concept is achieved by ranking these six characteristics according to their significance to users. However, measuring the quality of accounting information is just as crucial as defining it. This is challenging to do because there is subjectivity involved in how the qualitative characteristics of the information are interpreted.

In this regard, we offer a model for evaluating the accuracy of accounting information that is based on creating a set of inquiries whose goal is to confirm or, on the other hand, refute the existence of the quality standards specified in the rules in the company's financial statements (***Table no.1***).

Users who are familiar with the particular language must honestly respond to the pertinent questions in the proposed model for evaluating the quality of accounting information after reviewing the reporting entity's financial statements. The questions are set up so that a "YES" response indicates that the standards of excellence were adhered to in the creation and presentation of the annual financial statements. The realization of this model was based on the Romanian standardizers' belief that accounting information is of high quality if it satisfies the qualitative standards outlined in the applicable legal texts. To measure and determine the quality of accounting information in the Romanian environment, we used the quality characteristics listed and defined in OMFP no. 1802/2014. We also developed questions whose answers led to this measurement and determination.

RELEVANCE (basic quality characteristic)			
Questions	**Answers**		**Observations**
	Yes	**No**	
1. Do accounting information have predictive value? (can they be used to predict future results of the entity?)			
2. The annual reports also contain non-financial information necessary to identify risks or opportunities for business development?			
3. Historical cost is used as the main basis for evaluating the items presented in the financial statements?			
4. What accounting information is detailed in the financial statement notes?			
5. Accounting information informs users about significant events or transactions affecting the company?			
ACCURATE REPRESENTATION (basic quality characteristic)			
Questions	**Answers**		**Observations**
	Yes	**No**	
1. Are the informations regarding accounting options and estimates detailed in the financial statements?			
2. Have there been detected in previous periods significant errors and were they corrected?			
3.Do financial statements present positive events as well as negative ones that affect the activity of the entity?			

4. The entity's financial statements have been audited in the past?			
5. Do the financial statements of the entity include information on corporate governance?			
COMPARABILITY (amplifier quality characteristic)			
Questions	**Answers**		**Observations**
	Yes	**No**	
1. Are the accounting policies used and their changes explained in detail?			
2. Are statutory adjustments made when an accounting policy is changed, or an accounting estimate is revised?			
3. Are the results obtained in the current period comparable to those obtained in previous years?			
4. Is the information in the financial statements comparable to that presented by other entities?			
RELIABILITY (amplifying quality characteristic)			
Questions	**Answers**		**Observations**
	Yes	**No**	
1. Is the accounting information presented in the financial statements based on data that can be verified from other sources?			
2. Are the accounting methods and treatments used by the entity listed and/or explained?			
3. Are specific indicators calculated and presented in the financial statements?			
4. Are the annual reports published in full?			

OPPORTUNITY (amplifying quality characteristic)			
Questions	**Answers**		**Observations**
	Yes	**No**	
1. Are the deadlines for drawing up and presenting the financial statements respected?			
2. Are quarterly financial reports with temporary results published?			
3. Are all users able to access financial reports that were created and published in previous years?			
4. Does the organisation publish temporary financial reports on a frequently updated website?			
INTELLIGILIBITY (amplifying quality characteristic)			
Questions	**Answers**		**Observations**
	Yes	**No**	
1. Are the financial statements well organized?			
2. Is the information in the financial statements also explained with the help of tables and graphs?			
3. Do the explanatory notes include specific information about the position and performance of the company?			
4. Does the accounting information presented in the financial statements include the explanations required by any user with even a basic understanding of accounting to decode and comprehend the accounting language?			

Table no. 1: Measuring instrument of accounting information in Romanian environment.

Source: by authors

The proposed model's limitations are related to the professional knowledge of the accounting information user, as well as the subjectivity of accounting professionals who analyze the entity's financial reports.

4.6. The effect of financial-accounting information quality on the entity's value dimension

Accounting is described in the specialized literature as an information system that allows for the creation and distribution of data in order to make decisions (Ionașcu I., 2003)[19]. Through accounting, the quantitative and qualitative expression of the management of its patrimony is realized. The accounting reports contain supporting information for the analysis of the financial position and performance of the entity (Cristea H., 2021) [20]. Accounting is the primary source of information for parties interested in the economic entity's activity. The accounting records' role in representing the entity's economic reality is assumed as a result of the performance of specific accounting functions, which are highlighted in ***figure no. 6***.

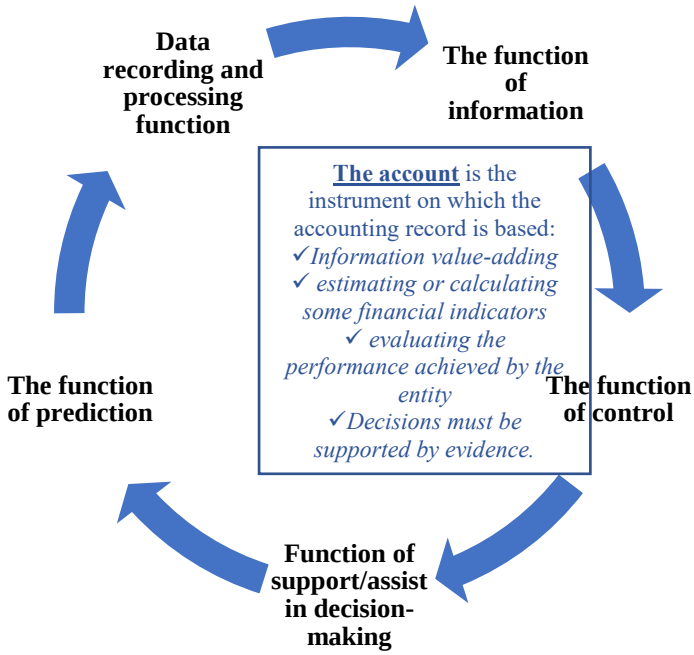


Figure no. 6: The functions of accounting, premises of the representation of the economic reality of the entity

Source: adaptation after Cristea H, (2021), *Quality and quantity in accounting,* CECCAR Business Review, Nr. 4, pp. 3-8.

For their users to have the option of supporting the choices made, the financial-accounting information must be current and accurately reflect the economic reality of the entity. Because this information serves as the foundation for the mathematical model that accounting uses to measure and assess the financial position, financial performance, and cash flows, the quality and quantity of financial-accounting information has a significant impact on the analysis of the value dimension of the entity. Any type of financial report manipulation involves the dissemination of cosmeticized, unreliable information, which encourages incorrect economic judgements with potentially catastrophic results.

5. Creative accounting – influences and effects on the quality of financial and accounting information

To achieve the desired results, ***creative accounting*** employs accounting techniques or assumptions that are permitted by the legal framework. In this instance, financial accounting data is modelled to affect financial decisions. If the information provided by accounting is of poor quality, the interests of users of financial reports cannot be met. The quality of summary documents is negatively impacted by creative accounting, particularly the information provided by the balance sheet and the profit and loss account.

The parties interested in the activity of the entity must identify the mechanisms for manipulating the annual accounts in order to lessen the impact of inventive accounting techniques on financial information and, implicitly, on economic decisions. Once these mechanisms have been identified, it is critical to use clearly defined limiting strategies to avoid the pitfalls of creative accounting.

5.1. Creative accounting and the quality of financial-accounting information

The science of accounting has developed the tools required to ensure, on the one hand, the recording and processing of data pertaining to the activity of the economic entity and, on the other hand, the communication of information to interested parties.

New paradigms are added to the definition of accounting as a science of organization and communication through symbols (Cristea H., 2021) [20] to highlight the creative, artistic nature of the accounting technique.

The professional accountant is the one who puts these clearly defined rules, standards, and principles into practice. In these circumstances, it's critical that the accountant's professional reasoning considers not only the applicable laws but also the ethical norms that demand adherence to the values of morality, equality, and justice.

Creative accounting is based on the technical prowess of dishonest accountants who take advantage of legal loopholes or the potential to manipulate financial accounting data using alternative accounting treatments. As a result of the faulty accounting data processing, the

annual accounts are impacted, and the information provided on the market to those interested in the entity's activity is no longer accurate or relevant. Given that financial accounting information serves as the foundation for economic decision-making, it is clear that financial report manipulation or embellishment can have serious negative consequences.

Accounting as both a science and an art allows the accountant to be creative in the preparation and presentation of annual financial statements. The quality of financial-accounting information is being questioned, and its users are suffering as a result of the use of creative accounting techniques. As a result, we believe it is necessary to examine the quality of accounting information from the standpoint of the professional accountant's morality (***Figure no. 7***).

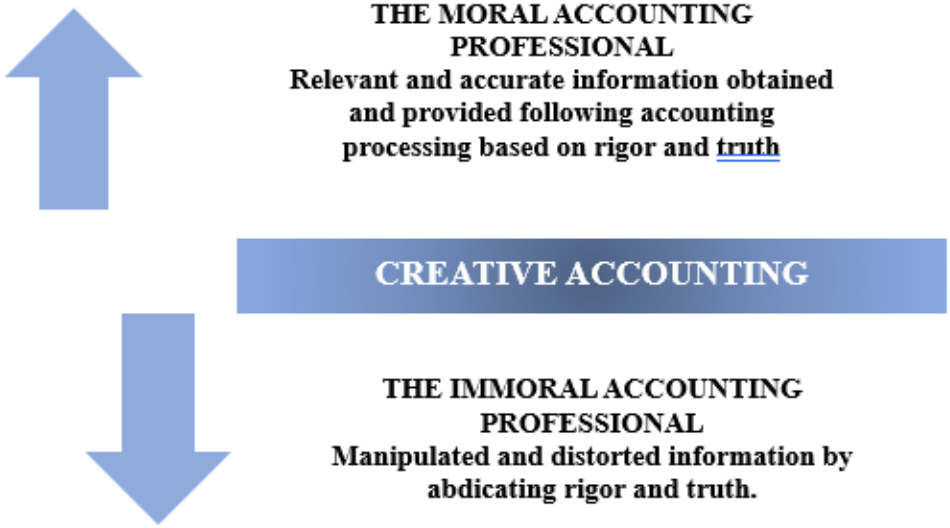


Figure no. 7: Creative accounting and the quality of financial-accounting information

Source: own projection

Because accounting rules are flexible, creative accounting techniques can be used in the legal sphere, but their application frequently results in a distorted representation of the entity's economic reality. It has been discovered that the fundamental quality characteristics that accounting information must possess to be useful in decision-making are relevance and accuracy. In this context, we can conclude that the use of creative accounting techniques results in the preparation and presentation of embellished financial statements that mislead accounting information users.

5.2. Effects of creative accounting on financial accounting information

The goal of ***creative accounting*** is to alter the accounts to better reflect the economic entity's financial situation. These modifications lead to the distorting of financial-accounting data from reports, which has an immediate effect on the decision-making process.

The information provided through the annual financial statements is subject to a variety of effects from creative accounting, including changes in the value and structure of revenues, expenses, and equity as well as changes in the value of assets and liabilities.

Creative accounting methods are employed to "beautify" the financial position and performance in accordance with the strategic and financial interests of the entity. For instance, the entity may use alternative accounting treatments permitted by the applicable rules if it wants to improve the result or, on the contrary, decrease it.

Another factor to consider when analyzing the effects of creative accounting is the manipulation of the information presented in the financial statements' appendices. This explanatory information, which is primarily narrative in nature, has become increasingly important in recent decades as parties interested in the entity's activity, particularly investors, use it more and more frequently in the decision-making process.

5.3. The impact of creative accounting on the information presented in annual financial statements

The laxness of accounting rules is used in ***creative accounting*** to present the entity's financial situation in a way that differs from the actual one. The preparation and presentation of reports that embellish economic reality are creative accounting tools available to the entity's management to achieve their own interests at the expense of those of the stakeholders.

The negative impact of creative accounting on annual financial statements is a decrease in user confidence in financial-accounting information. The application of creative accounting techniques affects the true picture of the annual accounts, and therefore indicators calculated to reflect profitability, liquidity, or solvency are irrelevant because they do not accurately represent the reality faced by the economic entity.

According to specialized literature, more than 90% of embellished financial reports are the result of the use of creative accounting techniques. Managers use these techniques because of their legal character, which stems from the flexibility of accounting regulations. The shaping of the entity's results and financial position is the result of management incompetence or, on the contrary, greed.

The elements of the financial statements are manipulated as a result of the option of selecting a more convenient accounting treatment for achieving the entity's objectives. The

impact on the annual accounts may differ depending on the creative accounting practices used:

- Increasing or decreasing expenses and/or revenue;
- decreasing or increasing the value of assets, liabilities and/or equity.

Regardless of the predominance of creative accounting techniques on the balance sheet and profit and loss account, we note that the cosmeticized financial-accounting information fails to fulfil the functions for which it is produced, and the numerous financial scandals that have hit the international financial markets support this assertion.

5.4. Strategies for detecting and limiting financial-accounting information manipulation mechanisms

Creativity in accounting provided knowledge in solving problems that the standards did not have an answer to, but also opened the way to manipulations of the information provided by the annual financial statements and this has a direct impact on the economic decision-making process.

The irrational and immoral use of creative accounting techniques has resulted in the emergence of massive international bankruptcies, prompting specialists to seek strategies to limit or diminish the mechanisms of financial accounting information manipulation. A summary of these measures to limit accounting creativity is provided in ***figure no. 8.***

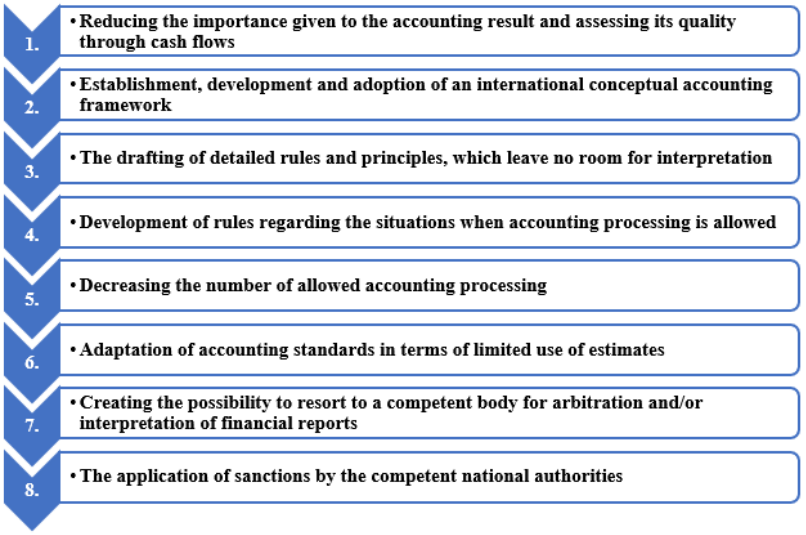


Figure no. 8: Strategies for Limiting Creative Accounting Techniques

Source: own projection

6. Conclusions

Specific informational needs exist depending on how an economic entity interacts with both its internal and external environments. The provision of pertinent, correct, and unbiased financial accounting information is necessary to meet their needs.

In recent decades, international regulations, including those in our country, have adopted the idea of the quality of financial-accounting information as a central component of the global conceptual framework.

By using clearly defined criteria that enable the creation of a measurement tool with the aim of enhancing the accounting communication process, the quality of the financial accounting information is evaluated.

The foundation of accounting is a set of rules and principles that are secondary to the requirement to deliver high-quality information. The observance of some fundamental and amplifying characteristics required by international standards and national referential, characteristics that give it utility and credibility, is a precondition for the quality of the financial accounting information.

However, the use of innovative accounting techniques has an impact on the usefulness of financial reporting and the accuracy of accounting information, and information asymmetry is one of the disadvantages that users of embellished financial statements must deal with. In this sense, strategies for detecting and limiting financial accounting information manipulation must be put into practice at the same time as disclosing the influences and effects that creative accounting has on the financial position and performance reported by the economic entity.

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INTERNET LITERACY – CYBERCRIME FUNDAMENTALS

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Abstract

During the last years the term "literacy" began to apply more and more to much complex and newer things than its old, consecrated, meaning of "knowing to read and write". Nowadays true literacy means one is able to use a computer at least for office work, to understand basic concepts about computers and computing in general, to be able to safely use social media platforms and to have basic knowledge about cyber-threats.

This topic became even more stringent since children of very young age are also exposed to the internet through various devices. Even though the use of such devices is usually a positive thing, quite a lot of them being introduced officially in formal and informal academic programs and curricula, their intrinsic capabilities and features can transform them into potentially harmful devices.

The ideal thing would be to create and implement mass-programs, in all countries, in order to dramatically increase the level of awareness regarding the possible (basic) threats that could very easily be encountered when using the "Swiss knife" of the current era – the internet. The more one knows about the potential dangers, the more one is able to counter its effects, as well as educate others in the same topic.

Keywords: computer literacy, basic cybersecurity, cybercrimes

JEL Classification: I21, L86, M15

1. Introduction

During the last years the term "literacy" began to apply more and more to much complex and newer things than its old, consecrated, meaning of "knowing to read and write". Nowadays true literacy means one is able to use a computer at least for office work, to understand basic concepts about computers and computing in general, to be able to safely use social media platforms and to have basic knowledge about cyber-threats.

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This topic became even more stringent since children of very young age are also exposed to the internet through various devices. Even though the use of such devices is usually a positive thing, quite a lot of them being introduced officially in formal and informal academic programs and curricula, their intrinsic capabilities and features can transform them into potentially harmful devices.

The use of a home-device like a webcam is basically a positive action, the use of a modern IoT device to help supervise the perimeter or the activity taking place there. On the other hand, the same device can become a threat in case its internet connection access is flawed, and a malevolent actor can get access (either through a backdoor, a programming error or a connection protocol one) to the webcam. This situation can have very important negative repercussions, from privacy issues to plain theft, robbery, or other crimes.

The ideal thing would be to create and implement mass-programs, in all countries, in order to dramatically increase the level of awareness regarding the possible (basic) threats that could very easily be encountered when using the "Swiss knife" of the current era – the internet. The more one knows about the potential dangers, the more one is able to counter its effects, as well as educate others in the same topic.

2. Literature Review

The new paradigm of "digital literacy", in our opinion, has two most important approaches – two slightly different points of view. The first one would be the understanding of the term from the point of view of the employers, while the second one would be the term's understanding from the general public side.

While a potential employer would emphasize the knowledge regarding "job skills", comprising of course at least basic cyber-security knowledge but mostly focusing on IT skills to help in day-to-day tasks (e.g., Office-like skills, basic database usage, search algorithms understanding etc.), the general public (the overall society) would focus more on the basic cyber-security knowledge, in order to primary and foremostly protect the individual and not a company/employer.

The employer would favor more specific skills (even linked to different specific areas), while the general public would favor more general-knowledge items, being relevant regardless of a specific job area.

Fig. 1. Different terms within the digital literacy umbrella[3]

2.1 Digital Literacy from the Employer Point of View

Looking at the paradigm of "digital literacy" from the employer/company position, Joaquim Miro[4] considers that the concept is based on four main pillars, centered around different skills that the employees should have:

- Employees should be able to stay up to date with the evolving technology.
- Employees should be able to properly communicate and make use of the specific tools within the online environment.
- Employees should be able to manage their ideas in the online environment.
- Employees should be able to manage their teams by leveraging the current technology available to them.

Another actor in the field, Matt Dunne[5], considers the term under the following informal definition:

"*Digital literacy refers to someone's ability to use IT and digital technology to find, evaluate, create and communicate information. If an applicant claims to have digital literacy skills, I'd expect them to be able to conduct thorough online research, which they can then analyze and evaluate. I would also expect them to be capable of creating a range of different digital documents and to use digital communication systems.*"

[3] Source: https://www.eschoolnews.com/featured/2018/08/08/8-essential-qualities-of-a-digital-literacy-curriculum/
[4] Founding Partner, Hoppin' World, https://hoppin.world/
[5] Hiring Manager, https://www.healingholidays.com/

We should also mention that in today's business environment there are some elementary knowledge, such as web browsing, search engines or social media platforms, that cannot actually count as "skills" anymore. These things are nowadays considered as almost a given and they bring no advantage to a potential employee, but they become a huge disadvantage in case they are missing.

Of course, the concept of digital literacy from the point of view of the employers is also biased based on the specific field of activity. For example, in creative roles (digital marketing, audio-video production etc.) digital literacy would comprise knowledge on operating at proficiency levels with dedicated software like Adobe Creative Suite or Corel Draw Graphics Suite. In research activities positions one would be considered as digitally literate when one is able to evaluate legitimacy and truthfulness of different online data sources, when one can put together a research-study based on a methodology etc.

Nonetheless, after studying vast amounts of literature in the field, we can map out a set of general skills that (most) companies/employers agree on to be part of the digital literacy concept. These general knowledge items are listed below:

Independent-led research capabilities

Much of the digital literacy concept is actually based on self-research and self-teaching. Even with a formal background in technology, keeping up-to-date means you must always check new things, read, test and apply new concepts and approaches. An employee is expected to figure out how to work with new, updated, technologies, by doing independent research on the topic, solving at least the basic problems related to it and becoming adapted to the new technology. Such a skill would be very high on the employers' lists, because besides the pure technical quality it also shows a general pattern of critical thinking and problem-solving skills that are extremely valuable for all fields of activity.

Experience with common IT&C terms and online platforms

Employers do not expect everyone to be able to write code/programs, configure hardware equipment or install operating systems. Being able to cope with most of the terms encountered by an average user of the internet is an expected skill. Also, capabilities to work with office-like applications (either the original Microsoft version, or Google Suite or any other similar counterpart) are expected from a "good" employee.

Collaborative work capabilities

Quite contrary to the movie-like approach of the lonely computer genius, the vast majority of today's technology users are expected to be able to work collaboratively. Most of the

employees will be part of a team, which will conduct its activities at least partly based on remote cooperative platforms and/or project management and supervision tools.

Even if the employee discovers a new collaborative platform in use at the new workplace, his prior knowledge and experience in the field will help immensely in becoming adept with it very soon.

Adaptability to new technologies

Another very important element of the digital literacy paradigm, for employers, is the capability of the employee to adapt quickly to new technologies. Although we humans appreciate attaining a certain level of comfort in our daily work and the related processes, it is crucial to recognize the continuous evolution of technology around us. As new tools, technologies, and software emerge, being adaptable and comfortable with making adjustments in our work/personal routines becomes essential.

Capability to explain your use of technology tools

Such a capability would be a big plus for the digital literacy pack of an employee, perhaps saving time and resources for the company. If one is adept not only at using technology for the job, but also at explaining and even teaching others about this, he might be of tremendous help to the employer. He might cover, at least partially, different learning processes for newly hired personnel, processes that would require the allocation of dedicated resources (money, time, work-force, spaces etc.).

Most of the digital literacy skills mentioned above are not solely confined to "pure" IT&C technology. However, when utilized in the digital environment, they become invaluable assets for today's workforce. One of the most thrilling aspects of digital literacy for future employees is its lack of limitation to particular technologies or systems. The proficiency to embrace new technology is a in itself a skill that improves with each mastery of a new platform, software, or service, and it can be carried over to any future new job environment.

2.2 Digital Literacy from the General Population Point of View

Switching back to a broader view, the most widely accepted, though informal, definition for the "digital literacy" is the ability to use a computing device and digital technologies effectively. As the internet access became a "given" in modern societies, something that was pioneered as a public service since the start of the current century – with Estonia passing a law that declared the Internet access as a fundamental human right in 2000 and with Finland stating broadband Internet access is a civil right starting on July 1st of 2010

[1], the literacy in the field of IT&C became more and more relevant for the productive citizen of the 21st century.

In order to better understand the concept of digital literacy we must mention that the idea in itself, the "specialized literacy" related to a field that becomes very present in people's lives at a certain historic moment, is not new. By reviewing the historical information, we can see in Table 1 (below) different characteristics underpinned within a "specialized literacy" umbrella.

Specialized literacy concept	*Coverage of the concept*
Literacy	It is the traditional, basic, understanding of the term and it covers one's ability to read and write.
Mathematical literacy	It is the second oldest understanding of the term, relating to one's ability to understand/solve/make use of basic algebra and mathematical analysis elements, equations, logics, data analysis.
Financial Literacy	It relates to one's ability to understand basic and medium level financial operations, to create/maintain a basic budgetary structure, to understand the investment/capital concepts.
Cultural Literacy	It is one the modern forms of literacy, covering the ability of an individual to see/understand further than basic literacy level. It means one can understand and from a text more than it meets the eye, being able to make connections with other elements, put information into different contexts, understand rules of etiquette and place a set of information within correct/different historical setups.
Healthcare Literacy	It covers the ability of an individual to understand health consequences and basic medication, to effectively communicate relevant information about a health

	situation (symptoms, background information etc.), to understand and be able to use the local healthcare environment.
Mass-media Literacy	It is the newest form of "specialization" for the public, being in fact quite difficult to master – especially in front of the huge amounts of information available in today's media. It relates to the ability of evaluating the information published in different media channels, as well as to the ability of understanding the inner workings of the current media industry.

Table 1. Specialized Literacy Concepts

The digital literacy factor is not directly linked to field of work or age. Of course, there is an indirect relation between those elements, but it mostly relates to the skills one has or aims to master during the current times, skills related to the digital tools at his disposal. From the literature review we can point out a series of such elements which are present in the majority of the cases when talking about digital literacy:

- The ability to make use of different devices, with different OS[6]s (e.g., Windows, MacOS, iOS, Android, Linux flavors etc.).
- The ability to use the most widespread online platforms.
- A general understanding of the current digital environment as a whole (basic concepts, basic security issues etc.).
- The capability to make use of technology in order to solve real problems.
- The capability to research and identify relevant information by making use of the extensive media categories at one's disposal today (mostly online access).
- The capability to apply critical thinking for evaluation of digital information.
- The ability to recognize and mitigate (at least) basic digital threats today.
- The use of digital tools at one's disposal by taking into account the safety and ethical issues.
- The ability to create new information and disseminate it with effectiveness throughout the entire online environment.

[6] OS – operating system, the software that manages the device's hardware and software resources.

3. Relevant views in the field of digital literacy

One of the most complete, even holistic, approaches in the area of digital literacy concepts is the one introduced by Doug Belshaw [2]. According to him, there are eight elements comprised within his understanding of the digital literacy term. The synthesis of his research in the field brought the following pattern elements for covering the definition of the term:

- Cultural
- Cognitive
- Constructive
- Communicative
- Confidence
- Creative
- Critical
- Civic

Synthesizing the description of each element in Belshaw's view can be found below:

- Cultural - it provides guideline elements for behavior in the online environment; it covers both the respect for network etiquette as well as online privacy protection elements.
- Cognitive - it provides the body of knowledge in the field, it relates to one's ability to make use of technology efficiently and also recognizing today's common digital tools, platforms, and capabilities.
- Constructive - it relates to one's understanding on how to effectively reuse electronic materials abiding by the relevant laws and regulations (copyright, public usage etc.).
- Communicative - the element covers the regulations and guidelines of online communication and the reasonable expectations from different publishing/social-media tools.
- Confidence - it comprises the knowledge related to the belonging to a community (online/electronic one) and understanding of the differences between real-life and online communities.
- Creative - covers the ability to create new and innovative content under the rules and regulations of a digital environment.
- Critical – it comprises the necessary skills one should have in order to be able to analyze and evaluate digital information and its context, by making use of different other means of information verification.

- Civic – it represents the understanding different digital environments with the view of being ready to become part of social manifestations started from/within the digital environment.

4. Results and Discussions

Based on the above-mentioned syntheses, we can easily argue for the really vast content that one would need to master in order to be considered "digitally literate" by all views and approaches.

Having quite an amount of data/information to process and master, and also because of the today's reality of immersive digital environments being available to younger and younger people, we consider that the training for digital literacy should start from a very young age.

The children, in a vast majority percentage, are already exposed to the digital environment today. It would be a excellent idea for them to also start developing their "real" digital literacy skills in the same time. Having useful skills and requested abilities since childhood brings them a distinctive advantage over their peers, which were also immersed in the same digital environment but only for recreational, social-media and gaming activities.

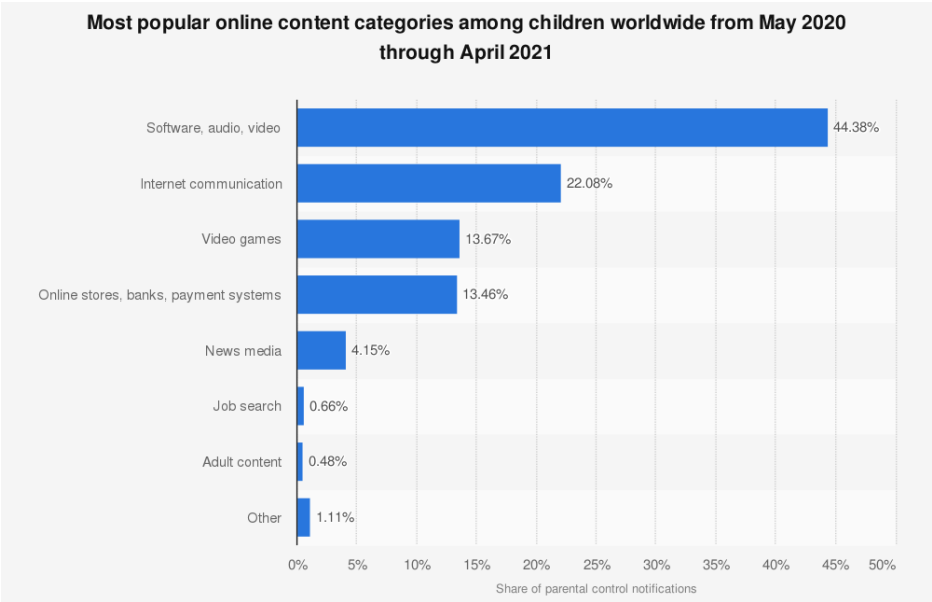

Fig.1 Most popular online content for children – May 2020 to April 2021[7]

[7] Figure from Kaspersky Lab, Statista 2021

Correlating the above numbers with the fact that around 1 in 50 children navigation the digital environment is considered to become a victim of a cybercrime (identity theft, schemes, etc.), we can safely assume that there is a huge number of children at risk.

Cybercriminals are not only targeting high-stake actors, nations, world-wide spread multinationals, but also the average internet user – which would cover the children also.

The children can be taught, both by direct but also by indirect means, about basic cybersecurity skills. With proper guidance, they can quickly accumulate knowledge that would greatly benefit the entire society. First, because they will be better prepared and will grow up with an already capable set of abilities and skills, and secondly because they can be an important dissemination vector: both their colleagues/friends as well as their families might take advantage of their updated body of knowledge in the field.

As we can see below, in Fig.2, an ITU[8] research [3] shows that the skills usually included in the "digital literacy" index can be at different levels for the same individual, with the safety values (defense against potential cybercrimes) among the lowest.

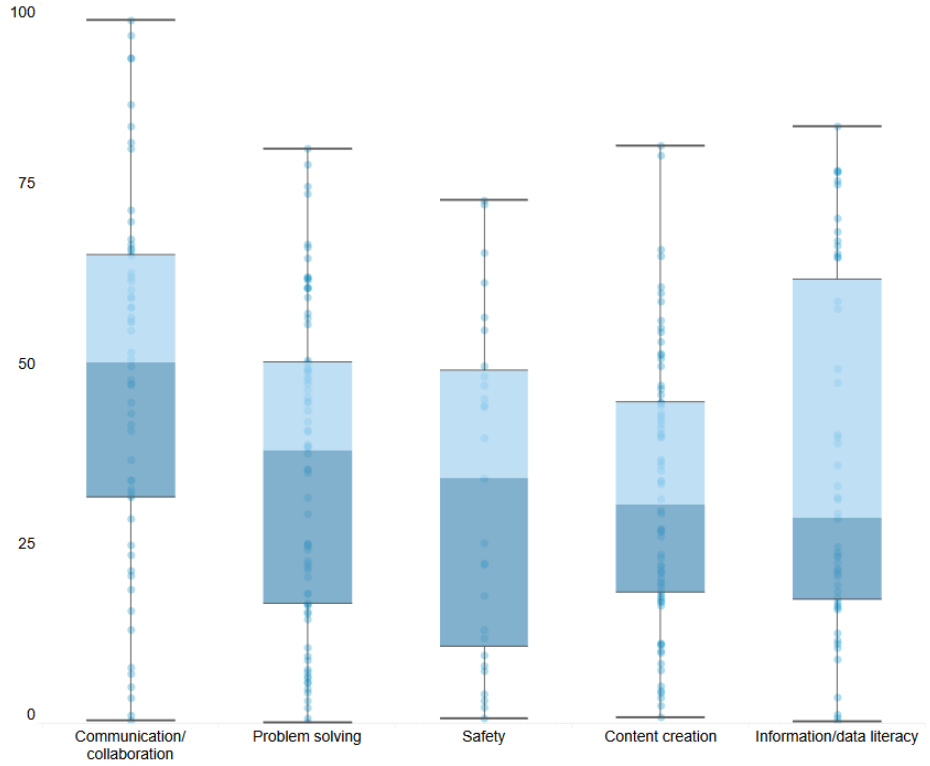

Fig. 2. Percentage of individuals with ICT skills by type of skill (2019-2021)[9]

[8] ITU – International Telecommunication Union, www.itu.int

[9] Source: https://www.itu.int/dms_pub/itu-d/opb/ind/d-ind-ict_mdd-2022-pdf-e.pdf, p.15

5. Conclusions and Recommendations

There is no exact path, 100% route to go, in order to reach a certain degree of digital literacy. As each individual is different, the type of knowledge involved in this aspect cannot be made to exactly fit everybody's needs. Taking into account these facts, we recommend a sustainable approach related to the digital literacy index increase. Such an approach would entail cooperative work from different perspectives – both private and public, family and education system, plus inner and societal motivation.

The first element which determines the index of digital literacy is public motivation. The level of digital literacy is not something attained mostly through formal training and schooling, but mainly by self-study, borrowing good practices, and practicing continuously. The general-public motivation towards increasing their literacy index in the field should mainly take into account the risk related to the digital environment. Among the most widely found risks for everyday user of the digital world we mention:

- Identity theft
- Cyberbullying
- Malware infestation
- Social engineering

Another important element to help increase the index of digital literacy is the governmental approach, their policies, and regulations. Cybersecurity, as part of digital literacy, needs legislative support. Of course, formal laws and regulations cannot always be updated with the latest technologies, as they advance at a very rapid pace. Nevertheless, communities require stable, dependable, and sustainable government policies for supporting digital literacy.

The educational system is another critical element for digital literacy [4]. Both formal and informal/vocational education systems could greatly benefit from teaching their students elements of cybersecurity first [5]. First levels school can also focus, with their younger body of students, on digital literacy as a whole, without technical elements. Higher level schools should focus more on the elements of digital literacy that would entail more technical knowledge.

An indirect but crucial element is represented by the labor market. As in many other cases, the labor market has a decisive role for guiding the development path of the individuals before actually comprising them. Young people prepare for what are the labor market requirements usually and a bigger emphasis of the employers' majority on a certain topic would greatly help that topic's expansion in the near and mid-term future. In case the labor market continues to focus on requesting or recompensating higher degrees of digital literacy (general public meaning), the young people and their guardians will emphasize acquiring skills in this specific area. The situation has greatly improved in this view after

the pandemic, as more and more employees were working from home - almost 100% based on digital equipment and tools, and the employing companies (the base of the labor market) understood that an increased level general knowledge related to the digital environment, especially regarding cybersecurity basics, would hugely benefit them directly. Such employees, with a higher level of digital literacy obtained previously to their current employment place, mean that the company can save a lot of resources that would have been otherwise required in order to bring them up-to-date with different requirements of the digital environment. A lot of money, time, skilled personnel, and trainers are required to cover this area in case the majority of the workforce is not digitally literate at an adequate level.

The overall conclusion is that the level of digital literacy, as sum of different ICT skills, is very directly correlated with the intrinsic level of cybersecurity that the digital environment users are able to expose, without specific training in the field. The higher the level of digital literacy, the higher the level of mass-protection against cybercrimes, thus the lower the spendings (in different units of measurement, not only strictly monetary) needed to mitigate and recover from cybercrimes (both at individual and employing companies' levels).

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