A SURVEY ON AUGMENTED REALITY

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ABSTRACT

The aim of this paper is to present the concept of Augmented Reality (AR) and a summary of the approaches used for this technique. Augmented Reality is a technique that superimposes 3D virtual objects into the user's environment in real time. We analyze the technical requirements that are addressed in order to provide the user with the best AR experience of his surrounding context. We also take into account the specificity of certain domains and how AR systems interact with them. The purpose of this survey is to present the current state-of-the-art in augmented reality.

KEYWORDS: *Survey, Augmented Reality*

1. INTRODUCTION

Augmented reality is a technique that overlays some form of spatially registered augmentation onto the physical world. The user can see in real time the world around him, composited with virtual objects. These virtual objects are embedded into the user's world with the help of additional wearable devices. The difference between augmented reality (AR) and virtual reality (VR) is that the former is taking use of the real environment and overlays virtual objects onto it, whereas VR creates a totally artificial environment. In other words, AR adds virtual information to the real world, whereas VR completely replaces the real world with a virtual one.

The motivation for this technology varies from application to application, but mostly it provides the user with additional information that he cannot obtain using only his senses. Because AR has the potential to address different problems, reputed corporations such as Google, IBM, Sony, HP and many universities have put their efforts to develop it. Augmented Reality is suitable for applications in almost every subject, especially physics, chemistry, biology, mathematics, history, astronomy, medicine, and even music. These big companies are working to develop suitable technologic devices that can accommodate to any of these subjects and that can ultimately impact the user's life.

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AR also has a big impact in education and it is probable to change the way students will learn in the future. A study performed by [1] concluded that not only the students' understanding of a lesson increased when using augmented reality, but they were also more motivated and engaged into learning more.

The additional 3D virtual information will represent a powerful tool in the user's life, because it has the ability to support and improve their senses and their efficacy. It will impact the way the user learns, travels, talks, plays, treats some diseases and even the way he feels the food's smell or flavors.

The first part of this paper presents what Augmented Reality is and the motivation behind this technology. The second part focuses on what hardware and software has been developed for this technology and how it is best put to use and the last part focuses on some of the applications of this technology.

2. TECHNOLOGY

Hardware

The hardware components used for AR are the wearable devices that allow the user to see and interact with the system. These components are: displays, sensors, processors and input devices. The display offers the user an instant access to the AR environment and it is usually a form of lightweight see-through optical device. The sensors are usually MEMS (Micro-Electro-Mechanical Sensors) and they are useful in the tracking process. The processor is the one that analyzes the visual field and responds to it according to the AR's application. The input devices are consistent to the application's needs and represent the way the user interacts with the AR environment. Modern mobile devices like smartphones and tablet computers include these elements which makes them suitable for integrated Augmented Reality.

Display Devices

The user can see the virtual world through various display devices, such as: head-mounted display (HMD), hand held devices, monitors or any optical projection systems.

Figure 1. A closed-view head-mounted display. (Photo: [2])

The standard Head-Mounted Display (HMD), shown in Figure 1, is closed-view and it does not allow the user to see the real world directly. It is similar to a helmet, placed on the forehead and it is mostly used for aviation applications, but it can also be used in gaming, engineering and medicine. These closed-view displays use computer-generated imaginary superimposed on the real world view. They usually use one or two small video cameras and the display technology varies from cathode ray tubes (CRT), liquid crystal displays (LCDs) to organic light-emitting diodes (OLED) [3]. One disadvantage of these closed-view helmets is that in case the power is cut off, the user is unable to see.

The see-through HMDs allow light to pass through them and in case the power is cut off, they act like sunglasses. They are compact devices, lightweight, monocular or binocular and allow instant access to information either by optical system or video. As seen in Figure 2, semi-transparent mirrors reflect the computer-generated images into the user's eyes [4].

Figure 2. See-through HMD (Photo: [5])

There are two main techniques that exist for see-through HMD: curved combiner and waveguide. The curved combiner diverge light rays for a wider field-of-view (FOV). The diverged rays need to travel to a single point, the user's eye, for a clear and focused image [6]. This technique is used by Vuzix's personal display devices (Figure 2) in applications for 3D gaming, manufacturing training and military tactical equipment [7]. It is also used by Laster Technologies products that combine the eyewear with interaction functions such as: gesture recognition, voice recognition and digital image correlation [8]. The waveguide or light-guide technique includes diffraction optics, holographic, polarized optics, reflective optics and projection. This technique is used in many applications and many companies such as Sony, Epson, Konica Minolta, Lumus, etc. have chosen it as a suitable technology for their devices.

Figure 1. Google Glass (Photo: [9])

Head-up display (HUD) is a transparent display, lightweight and compact that can show additional data and information and enables the user to remain focus on his task, without taking out too much of his field of view. It was firstly used by pilots to show basic navigation and flight information. Google Glass, shown in Figure 3, is one of the most well-known HUD devices that have a touchpad, a camera and a display. This device allows the user to take pictures, go through old photos and events, offers information about weather and different news. The device benefits from a high resolution display that is the equivalent of a 25 inch HD screen, it can take photos up to 5MP and shoot videos using 720p resolution [10]. It also comes with a dual-core processor, 2GB of RAM, 12GB of usable memory, a 570 mAh internal battery, Wi-Fi and Bluetooth and its own operating system, Glass OS. Google provides APIs for Google Glass, available for PHP, Java and Python [11].

Figure 4. Microsoft Hololens (Photo: [12])

Another HUD device is Microsoft HoloLens, shown in Figure 4, device that allows the user to interact with the colorful virtual objects, project different objects onto the floor and even manufacture objects. It is Microsoft's revolutionary AR device and packs some interesting hardware. It has see-through holographic lenses (waveguides), 2 HD 16:9 light engines, automatic pupillary distance calibration and holographic resolution, 2.3M total light points. It comes with four environment understanding cameras, one depth camera, one 2MP photo/ HD video camera, four microphones and one ambient light sensor [13]. Microsoft Hololens uses 32bit architecture processors with a custom built Microsoft Holographic Processing Unit (HPU 1.0) and benefits from 2GB RAM and 64GB of flash memory. As OS uses Microsoft 10 and it comes with APIs for Visual Studio 2015 and Unity.

Another AR device is the virtual retinal display (VRD), a personal display device under development at the University of Washington's Human Interface Technology Laboratory. This technology allows for the capture of real world to be directly scanned onto the retina of a viewer's eye. The viewer sees what appears to be a conventional display floating in space in front of them.

EyeTap, presented by [14], also known as Generation-2 Glass, captures rays of light that would otherwise pass through the center of the user's lens, and substitutes synthetic computer-controlled light for each ray of real light. The Generation-4 Glass (Laser EyeTap) is similar to the VRD (i.e. it uses a computer controlled laser light source) except that it also has infinite depth of focus and causes the eye itself to, in effect, function as both a camera and a display, by way of exact alignment with the eye and resynthesis (in laser light) of rays of light entering the eye.

Because mobile devices are really powerful and can act as small computers, they are great to display AR application. Not only do they offer the display technology, with big enough LCD screens, but they also offer cameras, GPS, processors and other sensors. Usually, the phone's camera is used to capture the real world and with the help of AR application, the virtual objects are superimposed in real time onto the phone's display, as shown in Figure 5.

Figure 5. Augumented reality displayed onto a handheld device. (Photo: [15])

Tracking devices

In augmented registration, tracking devices are used for registration. By registration, virtual objects generated by a computer are merged into the real world image. The computer needs to have a powerful CPU and great amount of RAM in order to be able to process the images and interact accordingly with the user. In [16] it was identified that for AR, the tracking devices should be: mechanical, magnetic sensing, GPS (Global Positioning System), ultrasonic, inertia and/ or optics. These devices have different ranges, resolution, time response and setup that combined can generate different levels of accuracy and precision [7].

Input and interaction

According to [7], the interaction between the user and AR world can obtained by: tangible interfaces, collaborative interfaces, hybrid interfaces or emerging multimodal interfaces.

Tangible interfaces allow the user to interact with real world objects. VOMAR application, developed by [17], allows users to rearrange the furniture inside a room. The user's gestures represent intuitive commands and he can select, move or hide different pieces of furniture. Another input for the AR environment can be sensing gloves that provides tactile feedback. These gloves can use a range of sensors to provide the hand's position or can use vibration motors to simulate different surfaces. Senso Devices is a company that produces Senso Gloves especially for virtual reality, shown Figure 6. Mark Zuckerberg, CEO of Facebook, announced that gloves will be used in the near future to draw, type on a virtual keyboard and even play games.

Figure 6. Tactile data glove SensAble's CyberTouch (Photo: [18])

Collaborative interfaces allow multiple users to connect and share the same virtual objects. This enhances teleconferences by sharing between participants the same 3D-windows, display platforms, documents, etc. The application presented in [19] allows remote videoconferencing and can be integrated in the medical field, where multiple users can access the same patient and discuss the diagnosis and treatment course.

Hybrid interfaces allow the user to interact with the system through different interaction devices. A mixed reality system can be configured for the user's desire and it can adapt accordingly.

Multimodal interfaces combine real object with speech, touch, hand gestures or gaze. A sixth sense wearable gestural interface that allows the user to interact with the projected information onto any uniform surface was proposed in [20]. Another method is presented by [21] and it allows the user to interact with the system by gazing or blinking. It is a robust, efficient, expressive and easily integrated method that is currently receiving a lot of attention from the research labs.

Software

The software used for AR is mostly focused on the application specificity. It uses real world coordinates offered by the tracking devices and camera images. Augmented Reality Markup Language (ARML) developed within the Open Geospatial Consotium (OGC) is used to create XML from the coordinates in order to obtain the location information. By image registration, the captured images are analyzed. This process belongs to the computer vision field and it is mostly based on video tracking methods and algorithms. There are some software development kits (SDK) for AR offered by Vuforia, ARToolKit, Layer, Wikitude, Blippar and Meta that enables developers to build their own AR environment.

Usually these methods consist of two parts. The first stage detects the interest points, fiducial markers or optical flow in camera images. This step can use feature detection methods like corner detection, blob detection, edge detection or thresholding and/ or other image processing methods. The second stage restores real world coordinate systems from the data obtained in the first page. Some methods assume objects with known geometry are presented in the scene (Vuforia). In some of those cases the scene 3D structure should be pre-calculated. If part of the scene is unknown simultaneous localization and mapping (SLAM) can map relative positions as mentioned by [22]. If no information about scene geometry is available, structure from motion methods like bundle adjustment are used. Mathematical methods used in the second stage include projective (epipolar) geometry, geometric algebra, and rotation representation with exponential map, Kalman and particle filters, nonlinear optimization and robust statistics.

3. APPLICATIONS

AR is a technology suitable for innovative and creative solutions for many problems. The user's perception of life can be enhanced by bringing virtual information to his immediate or indirect real surrounding. Although some research, such as [23] considers that AR is limited to the display technology, AR systems can be developed to apply not only to the sight sense but also to touch, smell, hearing or any combination of them. Because of this reason, AR has a wide range of applicability.

Navigation

One of the first AR applications and probably the most used one is in navigation. With the help of GPS data, an AR system can overlay the best route to get from point A to point B. Wikitude Drive, shown in Figure 7, is an application that uses GPS data and with the help of the user's mobile phone, the selected route is displayed over the image in front of him.

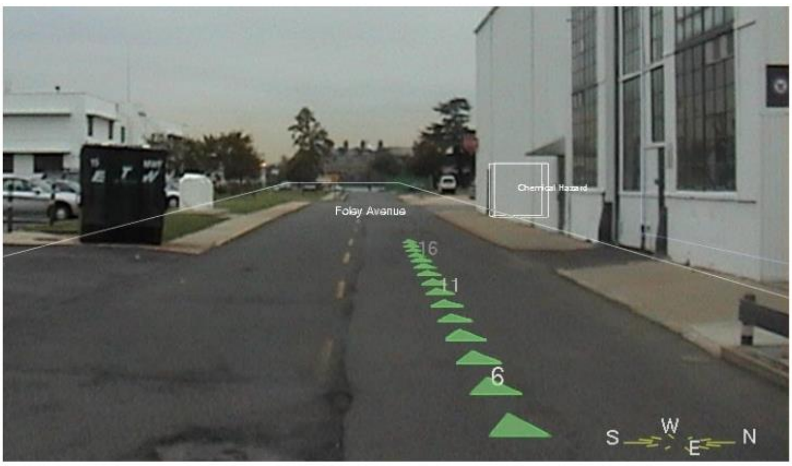

Figure 7. Navigation: Wikitude Drive (Photo: [24])

Medical environment

In medicine, doctors can use AR to diagnose, treat and even perform surgery. By using endoscopic cameras inside the patient's body, the doctors can see in 3D the region of interest and can perform image guided surgery, as suggested by [25]. This endoscopic augmentation can be applied in brain surgery, liver surgery, cardiac surgery and transbronchial biopsy as suggested by [26], [27] and [28]. This type of augmentation is obtained by using tracking system and a virtual penetrating mirror that can visualize at least one virtual object, as presented in Figure 8.

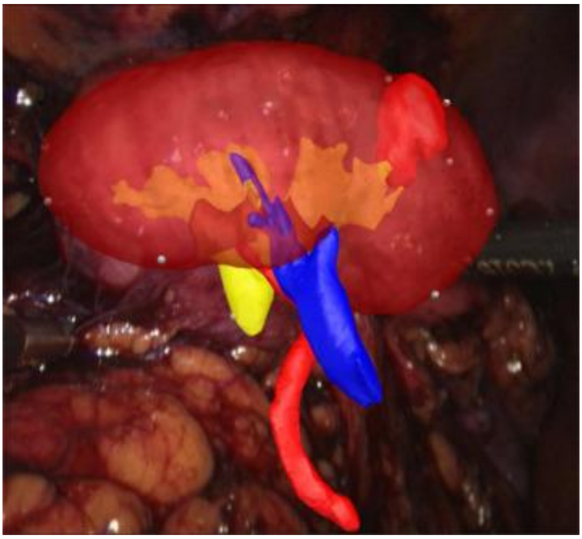

Figure 8. The 3D image of a cancer suffering kidney (Photo: [29])

Another practical application of AR in medicine include training and educating doctors in a more immersive manner, as shown in Figure 9. ARnatomy is an application that wants to replace the use of textbooks, flash-cards and charts and wants to present the student with virtual 3D image of the human's skeleton. AccuVein is another application that projects the circulatory system onto the patient's body in order to make it easier for the nurse to drain blood. AR can be used also in plastic surgery, where the patient can have an intuitive sight of the reconstruction results.

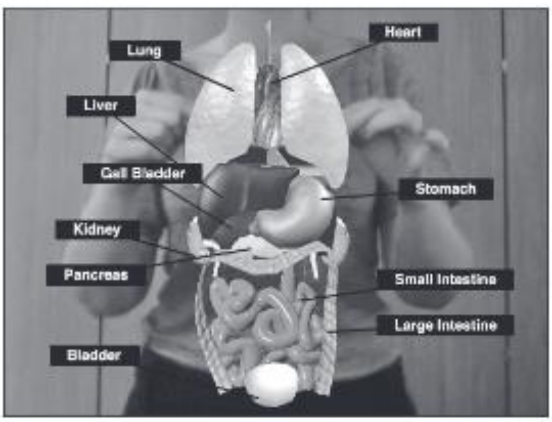

Figure 9. A model of human's organs for a Biology class (Photo: [30])

AR can also be used in patient's treatment and therapies. Patients suffering from depression, anxiety, addiction or mental health conditions can be treated using different AR environments. It can also be treated to cure different phobias. For example, patients suffering from fear of heights can be treated by making them used to walking on virtual glass floor in tower buildings. The same can be done for patients suffering from arachnophobia and they can be put in an environment where they have to get used to spiders, as shown in Figure 10.

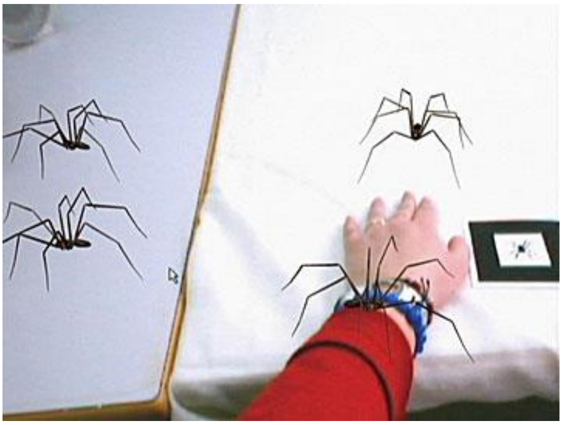

Figure 10. An example of AR application used for treating arachnophobia (Photo: [31])

Education

Besides the already mentioned tools in which a student can learn medicine, there are also other fields that improve the way a person studies. 3D models can appear from a textbook that gives a better perspective over the subject of study. Elements 4D is an application that allows students to trigger chemistry elements into images. Arloon Plants is another application that students can use for biology lessons and they can learn about structures and parts of plants. Math alive is based on marker cards that trigger some exercises of counting and numeracy skills.

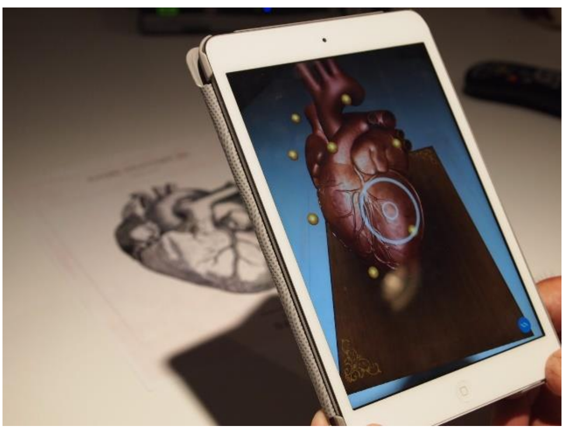

Figure 11. Example of a biology textbook using Augmented Reality (Photo: [32])

A survey completed by [33] presents the way students can interact with their lessons and also how the teaching methods can improve by using AR. The teacher can use AR to display different annotation that can help him with his course as presented in [34].

Entertainment

There are a lot of AR applications that exist for entertainment. From cultural apps, with sightseeing and museum guidance, to gaming and many smart-phone apps, AR can enhance the user's experience. While visiting a museum, the user can use a mobile phone to project a multimedia presentation about what he is seeing. Or as presented by [35] the user can virtually see the reconstruction of ancient ruins and have an intuitive feeling about how the ruins looked back in the time, as shown in Figure 12. Wikitude World Browser is an app that overlays information about stores, hotels, scenery and touristic locations in real time.

Figure 12. Example of a view with the reconstruction of the Dashuifa's ruins (Photo: [7])

For gaming, the AR can offer more than the other physical board game by introducing animation and other multimedia objects. Pokemon Go is an example of AR app, in which the player needs to walk as much as possible and look for pokemons. Other games are marker-based and with the help of some cards the user can see 3D objects. Piclings is an iOS game in which the iPhone's user takes a picture, redefines it digitally and incorporates it into the actual game. Junio Browser is a famous German app in which the user needed to point the smart-phone to the TV and answer a quiz. This games was nationwide spread and a lot of users started to compute against each other for the big prize. Zoombie ShootAR from Metaio is an AR game where the players need to shoot the zombies that are superimposed into the real world through their mobile device. Lego's offers the possibility to see Lego products by simply scanning some cards from their website. Once a webcam is put in front of the computer screen, a 3D Lego object will appear.

Another application for AR is in advertising and commercial, as shown in Figure 13. Most techniques are marker-based in which the user needs to point to the advertising card that will trigger an animation or a presentation of a product.

Figure 13. Example of a 3D virtual model of MINI car. This 3D object appeared as the user pointed to the marker trigger (Photo: [7])

Military

From navigation to combat and simulation, AR has applicability also in military field. The first head-mounted display gave pilots information about velocity, positioning and other navigation information. Afterwards, AR was used to offer a better visualization of targets and point of interest in combats. AR can also offer extra information to the soldiers by using IR (infrared) cameras for night vision or cameras sensible to heat that can show if someone is hidden nearby.

AR can be used also for battle planning, where more soldiers are connected to the same interface and they can see in 3D the plan of the battle and decide the best way to take action, as shown in Figure 14.

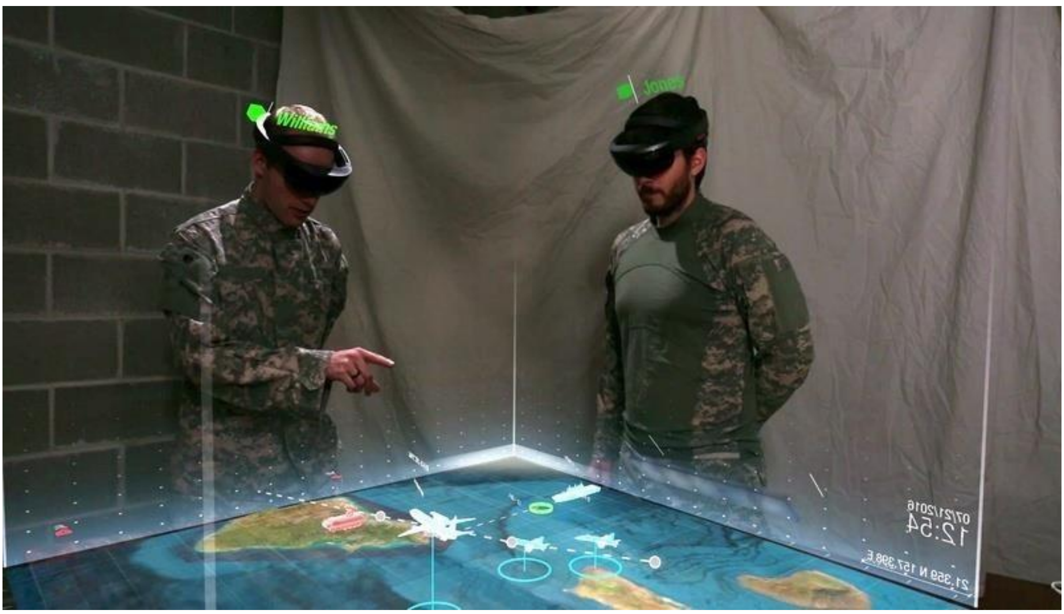

Figure 14. Example of AR application with the help of Hololens. In the picture, the two soldiers share the same environment, a map on which they can make battle presumptions (Photo: [36])

Assembly and manufacturing

In order for a product to come to life, there are many steps through which it needs to go: planning, design, ergonomics assessment, etc. A survey done by [37] on the AR application in assembly. Boeing used the first AR assembly system for guiding technicians in building the airplane's electrical system. Another comprehensive survey was performed by [38] and [39] about the use of augmented reality in manufacturing industry, in which graphical assembly instruction and animation can be shown and [40] wrote about the use of AR in design and manufacturing. State-of-the-art methods for developing CAD (computer-aided designs) models from digital data acquisition, motion capture, assembly modeling and human-computer interaction were presented by [41]. Figure 15 shows an example of a CAD assembly in AR.

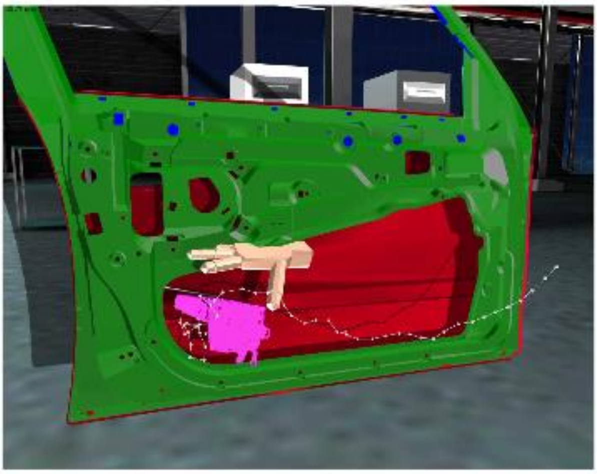

Figure 15. Example of virtual door lock assembly (Photo: [28])

Robot path planning

Teleoperation is the process in which an assembly is controlled from distance. A robot can be controlled from long distance and it can execute tasks already programmed. But, because there might exist long distance communication problems, it may be better to control a virtual version of the robot. AR allows for this to happen and the user can see in real time the results of his manipulations, as shown in Figure 16. These virtual manipulations can predict some errors that might appear in reality and improve their performance. Robot Programming using AR (RPAR) is a form of offline programming that uses a video-tracking method from ARToolKit to eliminate a lot of calibration issues.

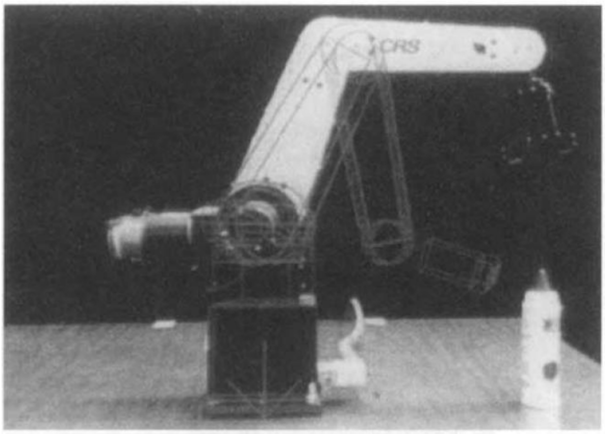

Figure 16. Virtual lines that show the planned motion of a robot arm (Photo: [34])

Pervasive Augmented Reality

A survey was concluded by [42] about the future goal of augmented reality, pervasive augmented reality (PAR). PAR aims to offer a continuous AR experience to the user, with as little interaction as possible. If standard AR was a context-aware experience, PAR's purpose would be to sense the current context of the user and adapt accordingly. So far, most of AR applications are developed to address one problem, with a specific solution, for a specific domain. PAR systems aims for an AR technology that can learn from the user's experience and context and adapt to it, without the user's interaction. But PAR, being a continuous AR experience, has some hardware challenges and also of ethics. From the hardware point of view, the system needs to be able to collect and process a lot of data in real time, in order to offer a reliable solution to whatever the current context and situation might be. Also, the collected data needs to be safe to use and respect the privacy of others.

CONCLUSION

Throughout this survey, the AR technology was presented, taking into account both the technology behind it and its applicability. A lot of work was already developed for this method, but taking into account its evolution and its possibilities, a lot more will be developed in the future years. Just as personal computers and smartphones changed the life of all the users, it is expected that all the wearable devices with AR technology will also have a huge impact. The future expectancy of this technology is PAR, the continuous AR experience and an easy-to-use technology.

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