A STEREOSCOPIC-BASED MOBILE AUGMENTED REALITY FRAMEWORK FOR DISASSEMBLY TRAINING

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KERANGKA KERJA AUGMENTASI REALITI MUDAH ALIH BERASASKAN-STEREOSKOPIK UNTUK LATIHAN PENYAHHIMPUN

MOHAMED JAFAR SADIK

DESERTASI YANG DIKEMUKAKAN UNTUK MEMENUHI SEBAHAGIAN DARIPADA SYARAT MEMPEROLEHI IJAZAH SARJANA TEKNOLOGI MAKLUMAT

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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ABSTRACT

Augmented Reality (AR) technology able to interweave the real world with virtual objects in real time. Conventional AR setups require the user to wear a big Head-Mounted Display (HMD) or use small device screens that provide a small perspective of view and come with the constrain of the user's movements and interaction. However, the rapid evolution of mobile technology has opened the opportunity to enhance the AR experience in learning of new skills. The lack of Mobile Augmented Reality (MAR) frameworks for assembly/disassembly training researches opens the opportunity to investigate more about the frameworks such as whether the frameworks have an influence on human memory especially the Long-Term Memory (LTM). The evaluation of LTM knowledge retention in previous researches was doubtful due to the short duration of time between the pre-test and post-test phase. Moreover, most of the previous AR frameworks were developed for a specific task and such frameworks are not suitable or difficult to be used for other tasks. Assembly/disassembly training is considered an essential process for individuals who undergo such types of tasks regardless of their previous knowledge. Thus, this research focuses on the exploring of the effectiveness of the MAR framework with stereoscopic technology in the assembly/disassembly training system on the information retention capability in LTM. Thus, this research developed a stereoscopic MAR framework for a disassembly training by attaching a mobile device to a head case to provide user a better visual assistance. The proposed stereoscopic MAR framework consists of two main parts; part one is the hardware part and part two is the AR environment. The hardware part consists of a mobile device with high computational power and headset case that permits a stereoscopic vision. Meanwhile, the AR elements consists of target tracking, 3d models, assembly animations, and an interaction method. An experiment consisting of pre-test and post-test phases has been conducted with 30 participants. The participants had been divided into two groups equally; one of the groups was assigned with stereoscopic MAR as an assistance tool while the other was assigned to a paper-based manual. A knowledge pre-test and post-test data, completion time, number of errors, and subjective data were collected in the experiment. The results showed that the MAR system group has an advantage over the traditional method group in the information retention and performance. Finally, the questionnaire results stated that the MAR system was more useful, easy to use and satisfactory, more than the paper-based manual.

ABSTRAK

Augmentasi Realiti (AR) merupakan satu teknologi yang dapat menjalinkan dunia nyata dengan objek maya pada masa nyata. AR konvensional memerlukan pengguna memakai satu paparan lekap kepala (HMD) yang besar atau menggunakan skrin peranti kecil membekalkan perspektif pandangan yang sempit dan mempunyai had dari segi pergerakan dan interaksi pengguna. Walau bagaimanapun, evolusi teknologi mudah alih yang pesat berkembang telah membuka peluang untuk meningkatkan pengalaman AR dalam pembelajaran kemahiran baru. Kekurangan rangka kerja Augmentasi Realiti Mudah Alih (MAR) untuk dalam latihan pemasangan/penceraian telah membuka peluang kepada penyelidik untuk menyiasat lebih lanjut mengenai rangka kerja seperti sama ada rangka kerja itu mempunyai pengaruh ke atas ingatan manusia terutamanya Memori Jangka Panjang (LTM). Penilaian simpanan pengetahuan LTM di kajian-kajian sebelum ini adalah diragui kerana jangka masa yang singkat antara pra-ujian dan pasca-ujian. Selain itu, kebanyakan rangka kerja AR sebelum ini dibangunkan untuk tugas tertentu dan menyebabkan rangka kerja tidak sesuai atau sukar untuk digunakan bagi tugas-tugas lain yang berbeza. Latihan pemasangan/penceraian dianggap sebagai satu proses yang penting untuk individu yang menjalani jenis-jenis tugas seperti ini tanpa mengira pengetahuan mereka sebelum ini. Penyelidikan ini bertumpu pada keberkesanan rangka kerja MAR dengan teknologi stereoskopik di dalam sistem latihan pemasangan/penceraian ke atas keupayaan pengekalan maklumat dalam LTM. Oleh itu, penyelidikan ini telah membangunkan suatu kerangka kerja MAR berjenis stereoskopik untuk latihan penceraian dengan melampirkan peranti mudah alih pada wadah kepala untuk memberi bantuan visual yang lebih baik kepada pengguna. Kerangka kerja MAR berjenis stereoskopik yang dicadangkan terdiri dari dua bahagian utama; bahagian pertama adalah bahagian perkakasan dan bahagian kedua adalah persekitaran AR. Bahagian perkakasan terdiri daripada peranti mudah alih dengan kuasa pengkomputeran yang tinggi dan wadah kepala yang membenarkan penglihatan stereoskopik. Sementara itu, elemen-elemen AR terdiri daripada penjejakan sasaran, model-model 3d, animasi pemasangan/penceraian, dan kaedah interaksi. Satu eksperimen yang terdiri dari fasa pra-ujian dan pasca-ujian telah dijalankan dengan 30 peserta. Peserta telah dibahagikan sama-rata kepada dua kumpulan; salah satu kumpulan telah diberi tugas dengan MAR stereoskopik sebagai alat bantuan manakala yang lain telah diberi manual berasaskan kertas. Data pengetahuan pra-ujian dan pasca-ujian, kadar kesilapan masa siap, dan data subjektif telah di kumpul dengan eksperimen tersebut. Hasil kajian menunjukkan bahawa kumpulan sistem MAR mempunyai kelebihan berbanding kumpulan kaedah tradisional dari segi pengekalan maklumat baru dan prestasi. Akhir sekali, keputusan soal selidik menunjukkan bahawa sistem MAR itu lebih berguna, mudah untuk digunakan dan memuaskan daripada manual berjenis kertas.

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AR	Augmented Reality
FOV	Field of View
HMD	Head-Mounted Display
HUD	Head-Up Display
LTM	Long-term Memory
MAR	Mobile Augmented Reality
SDK	Software Development Kit
UKM	Universiti Kebangsaan Malaysia

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Assembly today has been applied in different fields including manufacturing, construction, and biomedical (Groover 2002; Simpson & Durbin 2010; Tang et al. 2006). Manufacturing assembly, as one exemplary kind of assembly, exists in an extensive variety of mechanical merchandises that are inseparable from daily life, e.g. cars, aircraft, ships, and computers. In the construction area, the assembly also applies to the creation of construction materials, for example, Heating Ventilation Air Condition (HVAC) piping assembly, rebar assembly, prefabrication assembly and concrete formwork assembly.

Most of the assembly/disassembly training tasks use a two-dimensional (2D) paper-based sketch, in which contains a list of parts and instruct the user how to put these parts together to form the final handiwork. Those parts usually are numbered to be easy to recognize. Another type of paper-based manual for guiding product assembly/disassembly is the three-dimensional (3D) manual handbook, commonly used in guiding the regular operator in assembling modified merchandises. 3D is intuitive, simple to comprehend, and does not essentially need to hold complicated context, compared with 2D assembly/disassembly sketches (Hou & Wang 2013).

Furniture assembling or fixing a car engine, these categories of jobs are naturally in spatial interaction and can be hard to explain without observation assistance (Westerfield et al. 2013). Augmented Reality (AR) has the capability to provide practical drill where users can be given visual instructions in the context of the real-world objects. Instead of reading a paper manual, an individual could look at a car engine while the AR display demonstrates the parts that need to be adjusted and the order of steps required.

There are many concepts and paradigms for AR. The one proposed in this research utilizes a Mobile Augmented Reality (MAR) that supported by a stereoscopic vision to achieve its objectives. The concept of MAR developed around the mid-1990s. Since then and due to the rapid development of technology over the past years, lots of researches utilized this concept in their studies in different fields such as education (Redondo et al. 2013), training (Westerfield et al. 2015) and others.

1.2 PROBLEM STATEMENT

Training is a vital process in the industry, especially in the manufacturing industry. Regardless of previous experience that new employees may have from their previous jobs, it is almost certain that they need some level of training in company-specific tasks or operations. Normally the training is carried out by an experience senior responsible for transmitting the knowledge and skills to the trainee. This methodology has several drawbacks such as the extensive use of resources to begin with, requiring an experience trainer to be available at all times during the training, and keeping the machine and other resources engaged in a training process that does not directly generate value to the final products. Such methodologies make the training costly and time-consuming. In assembly tasks, the assembler is required to conduct a series of physical operations (observing, grasping, installing, etc.) and mentally manual-related processes (comprehending, translating and information retrieving) (Neumann, & Majoros, 1998). Using an assembly manual does not necessarily provide an assembler with the problem-solving skills that are often required when putting together components (Pastor & Ferrer, 2009)

Recent researches have presented AR frameworks to help the users in their jobs. However, each study framework was designed for a specific type of training. The presented AR frameworks were designed based on the researcher needs; it is not for general use, for example, the developed frameworks in (Akyeampong et al. 2014; M. M. L. Chang et al. 2017; Re et al. 2014; Westerfield et al. 2015). The previous framework did not include all the important components such as (Akyeampong et al. 2014; Westerfiel et al. 2015) frameworks which missing the portability trait due to the PC attached HMD. Framework in Re et al. (2014) study missing the free hand interaction due to the framework used device which requires one hand to hold it, and framework in Chang et al. (2017) study was missing the portability feature and AR environment interaction. A closer evaluation related to this research is the study of Westerfield et al. (2015). However, the evaluation method on the memory retention is questionable because they started the knowledge test right after participants finished the pre-test phase, according to Cammarota et al. (2007) study, the short term memory develops within few seconds or minutes and may last for several hours. However, the consolidation of long term memory proceeds slowly and it will be last long for 24 hours or more. Few studies in psychology have practice to test the long term memory after training in 24 hours or more as LTM takes several hours to stabilize (Nader & Hardt 2007).

Early AR was based on desktop computer and custom input-output device and backpack with HMD. The time passed, the trend of AR device has switched from the backpack with HMD to low-cost small handheld device such as PDA, Smartphone (Wagner & Schmalstieg, 2009). Other than that, recent rises of the headset cases such as “Samsung Gear VR” and “Zeiss VR One” for the smartphone devices that can be used to generate a 3D vision with a larger field of view. Given the growth of smartphone devices, the use of mobile AR platforms and the availability of headset case turning smartphones into a powerful platform. Thus, it is suitable for different tasks due to the features can be provided such as; the 3D stereoscopic display with depth judgment and larger field of view relatively to the small devices screen, such features give better visualization experience with virtual objects in the real world.

Thus, the focus of this research is to explore the effectiveness of the MAR technology with stereoscopic technology in the assembly/disassembly training system by testing how AR technology can help in retaining the information that learned by the developed MAR framework. The research question is whether the MAR based assembly/disassembly training system permits operators to absorb and recall assembly/disassembly abilities more effectively than traditional method which is the paper-based manual. A MAR based disassembly training framework for PlayStation3 console disassembly scenario will be developed as a platform to train the users to disassemble some of the PlayStation3 console components. The evaluation process will be designed to find out whether the user undergo MAR training is performing better than paper-based manual or not. A disassembly training system was selected because it recapitulates most cases and allegations made about the advantage of AR in different industrial areas, maintenance of gears and devices, and education.

1.3 RESEARCH QUESTION

The research question for this study:

1) Does the integration of augmented reality technology with stereoscopic view perspective has an effect on human long-term (LTM) memory registration process for the new information?

1.4 OBJECTIVES

The objectives of this research are:

1) Develop stereoscopic-based MAR framework for assembly/disassembly tasks.

2) Develop a stereoscopic-based MAR app based on the proposed framework.

3) Evaluate the knowledge retention in long term memory based on the completion time, number of error in disassembly task along with the usability of the proposed MAR stereoscopic system framework.

1.5 SCOPE

The scope of this research is about finding the effectiveness of the proposed MAR framework in the assembly/disassembly tasks and check the effect of integrating MAR technology with stereoscopic technology on Long-Term Memory. It will be using an single user android application installed on Samsung Note 5 smartphone as a mobile device with Samsung Gear VR which provides the user with stereoscopic view perspective. The application contains 3D models which is PlayStation 3 console and also contains an animation that shows how to disassemble that PlayStation 3 console.

1.6 SIGNIFICANCE OF STUDY

The lack of the AR framework studies gives the opportunity to present a MAR framework that has the advantage of improving the user abilities in assembly/disassembly training tasks. This research presents a mobile AR framework that has the ability to enhance the user's performance in the assembly/disassembly tasks by improving the learning process. Furthermore, the training's content generation and the repeatability of the MAR training system in the proposed framework can reduce the costs of hiring an expert or using expensive systems for training purposes. In other words, such significance can contribute in enhancing Industry 4.0 by providing a flexible, resource efficient, and short development periods framework.

1.7 ORGANIZATION OF THESIS

This research consisted of six chapters, each one of these chapters discuss what has been done by researchers, as following:

Chapter one:

This chapter gives a brief explanation of the research background, problem statement, research question, research objective, research scope and the significance of this study.

Chapter two:

This chapter will define the aspects of this research and shows its related work, and the proposed work explained in the last section of this chapter.

Chapter three:

This chapter will explain the methodology of this research by defining the used materials and components, which includes the design phase.

Chapter four:

This chapter will go through the development steps of the MAR prototype system, the paper-based manual, and the questionnaire.

Chapter five:

This chapter will discuss and evaluate the collected data from the implementation phase.

Chapter six:

A final conclusion and future work stated in this chapter.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Assembly today has been applied in different fields. Manufacturing Assembly considered an example for such tasks, and it can be seen inspirable from our daily life, e.g. cars engine, computer hardware and so on. Based on that the process of manufacturing a product used to be a one-time activity which can be summarized as once the product was manufactured and sold, it rarely came back to the manufacturing plant. Instead, it ended up in a landfill at the end of its useful life. The disassembly process for the manufactured product can be useful by taking back the product to a disassembly plant in which the disassembled components can be resold or reused in the assembly plant or recycled at a separate recycling plant. AR has proven its usability in different domains, and that is why it will be utilized in this research to do a disassembly task by integrating it with other devices and technologies to present a mobile framework. The idea behind designing a framework is to put down together the most and frequent used AR related devices and technologies together and make it easier for the developer to choose what AR feature, device, display type, and so on, is more suitable and serve his/her needs.

Thus, this literature review focus on the topics regards the assembly/disassembly tasks, augmented reality, MAR, augmented reality and human memory, human view perspective, augmented reality framework.

2.2 ASSEMBLY/DISASSEMBLY PROCESS

According to the Oxford dictionary, the assembly process defined as the activity of putting together the different parts or components of a machine or certain object (Oxford dictionary). Assembly process should have a plan or structure that organized in order, the planning considered as an important step in the manufacturing process because it contains the assembly sequence steps and the used tools. Good planning can raise the productivity and goodness and also reduce the manufacturing cost and process time (Wang et al. 2009).

Radkowski, Herrema & Oliver (2015) mentioned that manual assembly is a process that involves using various tasks such as alignment and fastening for multiple pieces or parts to come up with the final product, this process also known as the manufacturing process. They stated that any manual assembly operation might lead to final product or sub-product and in both cases, there are several actions that the operator must go through it which are; identification, handling, alignment, joining, adjustment and checking. Falck, Örtengren & Rosenqvist, (2012) study investigated in assembly tasks ergonomics and complexity, the research result for the manual assembly complexity indicates a high error rate when the complexity of the assembly task increased.

Disassembly process is the contrary task of the assembly process which can be defined as the process of systematic removal of desirable constituent parts from an assembly while ensuring that there is no impairment of the parts due to the process (Brennan et al. 1994). Separation of the constituent components provides the opportunity to recover and isolate valuable components and/or materials from scrap using manual or automatic separation processes (P. Veerakamolmal 1999). According to Veerakamolmal (1999), the main purpose of a manufacturing disassembly process is to preserve resources by reusing or recycling the disassembled parts. Thus, the disassembly process must make sure a maximum number of components are reusable after it retrieved and the rest of the components are good to recycle. Disassembly and retrieval of reusable components are the most crucial elements of the recovery system. Since these operations are typically manual, they tend to be the most expensive. The major cost of disassembly attributed to the requirement of trained personnel. Nowadays, consumers are also prone to do a disassembly tasks when they want to replace their outdated products even though they are still working such as electronic products, home appliances, and so on.

2.3 AUGMENTED REALITY

The term Augmented Reality first employed in 1992 by Caudell and Mizell who used it to describe the process of overlaying digital content on a view of the real world. The digital content typically associated with AR includes images, text, animations, 3D models, and sound. Generally speaking, the content overlaid on a direct, real-time view of the world.

AR which is a variation of virtual reality (VR) and it is a growing research area (Azuma 1997). AR enhances the user's perception of the real world by showing some additional virtual information. AR combines a live view of a physical environment for real-world with computer-generated sensory inputs which are interactive in actual time and registers in three-dimension. Also it allows an individual to become fully engaged within a real environment while being simultaneously engaged with associated augmented virtual items such as; people, images, videos, websites, avatars, and/or 3-D objects (Dunleavy et al. 2009; Klopfer & Squire 2008; O'Shea et al. 2009; Yuen et al. 2011). AR is not restricted by display technologies nor limited to the sense of sight and can virtually remove or occlude real objects with virtual ones (Azuma 1997; Van Krevelen & Poelman 2010). AR systems have explored in many domains of applications including entertainment, military training, medical, robotics, and so on. Kipper, & Rampolla (2012) reported that AR uses digital information such as images, audio, video, or touch sensations and overlays them in a real-time environment to enhance all five senses and its most common use is visual. L. B. Rosenberg, (1992) demonstrated AR's benefits to human performance in 1992 at the Armstrong U.S. air force research laboratory while testing virtual fixtures which considered one of the first functioning AR systems. The AR application did well for providing a hands-on experience working with statistical data.

To experience AR, three key components are required: a camera with a display screen, a computer processor, and the appropriate software. Today, almost everyone already has a device with the combination of these technologies in his or her possession (International Telecommunications Union, 2010). Craig (2013) Mentioned that three specific components must work together to make an AR software work properly. First, a sensor is utilized to determine the location of the physical world where to deploy the application. Secondly, a processor evaluates the sensor data and then generates the signals needed to drive the display. Finally, creating a display that allows the participant to feel like the virtual world and the real world coexist.

2.3.1 Display Method

Craig (2013) noted there are two basic ways to combine the digital world with the physical world. The first mode is to collect information from the physical world, create the digital information on the computer, and merge those two worlds together in a computer to be displayed. The second way is to project the augmentations onto the physical world using projection devices. Projection on objects can be used to create deception about the position, orientation, and depth of an object. In such case, a consideration of the object structure should be studied in depth. The object's distance from the projection should be calculated, and the projection light sequence is then designed carefully to deceive the viewer's mind (Figure 2.1).

Figure 2.1 Projection-Based Augmented Reality

Source: Perbadanan Putrajaya.

2.3.2 Tracking Method

AR is available in many forms such as location-aware AR, vision-based AR, and others. Augmented virtual information with the location-aware type AR are via a GPS supporting device users can have access to digital media as they move around to the physical world as shown in Figure 2.2.

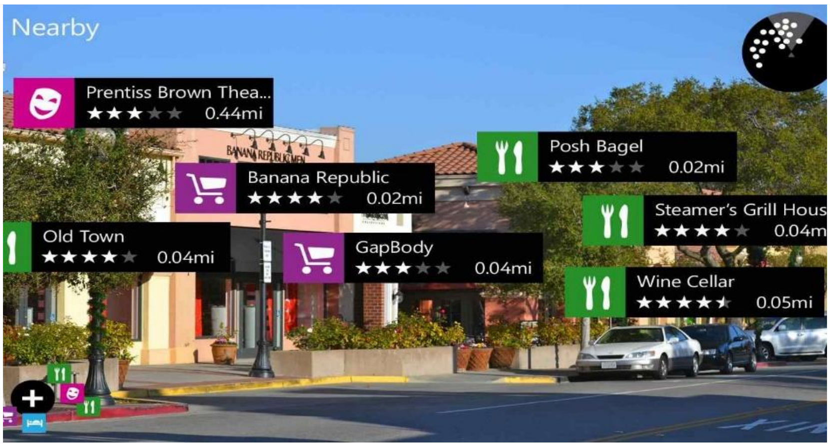


Figure 2.2 Location-Aware Augmented Reality

Source: Nokia.

On the other hand, with vision-based type AR a device with a built-in camera can be used for presenting AR content material. According to Johnson et al., (2011) AR has two predominant ways of gathering data. The first mode depends on a visual metaphor, and the second relies on spatial positioning as shown in Figure 2.3. For the visual metaphor, markers are seen by a computer or mobile device after the user has pointed the device at an object (image) that linked to a digital information (Figure 2.4).

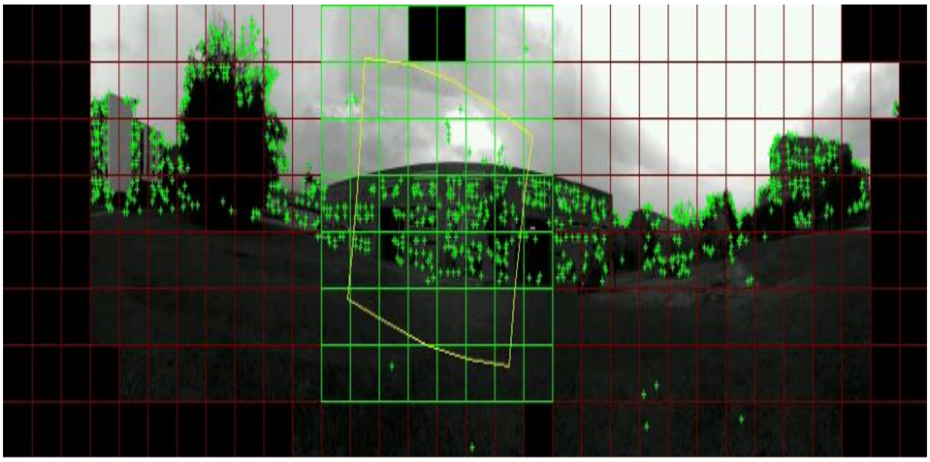


Figure 2.3 SLAM spatial aware augmented reality application.

Source: Reitmayr et al. (2010)

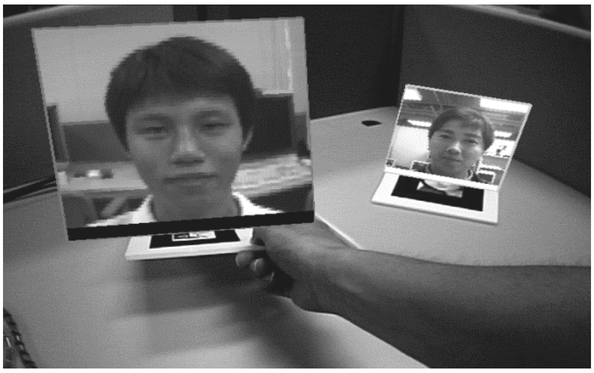


Figure 2.4 Marker based augmented reality application

Source: Kato & BIllinghurst (1999)

2.3.3 Evaluation and AR Hardware

In 1968 Ivan Sutherland, the father of computer graphics invented the head-mounted display (HMD) as shown in Figure 2.5, as a practical window to the virtual world (Sutherland 1968). Steve Mann built upon Sutherland's HMD in 1980 to create the first wearable computer vision system, integrating text and graphics onto photographically mediated reality calling it Augmented Reality (Mann & Moffat 1980).

Figure 2.5 First head-mounted display (HMD)

Source: Sutherland (1968).

Initially, users experienced AR by wearing a complex optical see-through head mounted display hooked up to a computer (Sutherland 1968). Today, sophisticated wireless mobile devices (WMDs) such as Microsoft HoloLens, CastAR, Epson Moverio BT-300 and others are capable of delivering AR content without causing the user to carry a cumbersome amount of expensive equipment. WMD hardware and software components are used to provide access to AR content. For example, the AR content triggered when the device's camera identifies a marker or when the device's accelerometer and GPS system recognize a specific location.

MAR is a quickly rising domain which elucidates many potentials for shore both entertainment and beneficial equipment. The main defiance nowadays for MAR is to supply the operators with more practical features as possible without overfilling the computational capacity for most mobile appliances. This equilibrium is made a lot simpler by the latest growth in mobile computing capacity, but it remains the one that should consider so that such applications do not overconsume the processing power when running several applications at the same period. This domain is still rising, and now there are various current cases of how to apply MAR. Moreover, even the use of the AR technology is not widespread for the public yet, but nowadays it is employed in different areas because of the tangible use of such technology.

2.4 THE APPLICATION OF AUGMENTED REALITY

Previous studies showed that AR has been employed in a many and different areas (medical, marketing and sales, entertainment, games, manufacturing, etc.). This study will specifically focus on disassembly tasks learning. Hence, the following literature will discuss the application of AR that closes to the learning purpose such as AR in training and assembly/disassembly and education.

2.4.1 AR and MAR in Education

One of the advantages of AR is it gives students the chance to manipulate virtual objects or representations of real objects that would normally be unattainable to them such as a running engine or engine block. AR on mobile devices can encourage the transfer of learning which considered as a challenge for many educators (Klopfer & Squire 2008). Blagg (2009) reported another benefit of incorporating AR into the curriculum is that it increases student participation and motivation to learn.

A team of researchers explored the affordances of AR for data collection in a similar context. The Ecosystems Mobile Outdoor Blended Immersive Learning

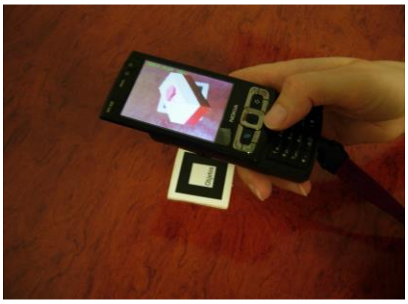
Environment (EcoMOBILE) project was designed to augment and supplement an elementary school environmental science field trip (Kamarainen et al. 2013). While visiting a local pond, a group of sixth graders collected data to identify different biological qualities found in the ecosystem. The students used smartphones to view virtual information from strategically placed AR targets positioned at the field trip location. By using the smartphones, the students were able to view information that normally would not be available without some form of technology (Figure 2.6).

Figure 2.6 EcoMOBILE application

Source: Kamarainen et al. (2013).

At the conclusion of the field trip, the researchers measured engagement and collaboration. According to these measures, they documented positive benefits of using AR and mobile technology. The researchers concluded that students were more engaged in the immersive experience and showed improved learning gains overall.

Juan et al. (2011) developed a mobile AR game called ARGreenet, the aim of that developed game was to increase the awareness of how important of recycling is to the people and how to do it. A comparison for recycling topic has been conducted as an experiment for this study between the developed ARGreenet game with a basic mobile phone game as shown in Figure 2.7 a,b. 38 children have been participated in this study, all of the participants have an enough knowledge about both of the games but in different order. In the evaluation, the level of engagement, easy to use and fun related to the participants perceived knowledge of recycling was evaluated, and the level of readiness to change attitude and judgement to AR and non-AR games. The results of this study showed that there is no statistically significant difference between the two games. However, 69.4% of the participants favored the ARGreenet game which they alleged it as easy to use and more engaging and fun than basic mobile phone game. Furthermore, a positive effect for the games was noticed when it comes to participants intention to change. behaviors and also suggest that the mobile phone is a good platform to change the individual's behavior as well as enhance their learning (Juan et al., 2011)



(a)

(b)

Figure 2.7 a: ARGreenet player is picking up a residue. b: ARGreenet player has correctly placed a residue

Source: Juan et al. (2011)

Recently, a team from Spain studied the possibility of teaching human history with AR. The whole approach was called REENACT and it is based on the exploitation of AR for improving the understanding of several historical events. Results were evaluated as extremely good since the participants were able to recall and most important is they can understand more aspects of events like the Battle of Thermopylae. AR provided new experiences that could be generalized in all school courses (Blanco-fernández et al., 2014).

A project called The CONNECT uses MAR technology; the purpose behind the development of such project was to help the students to learn science in formal and informal learning environment. This project needs the student to wear a head mounted display (HMD) that connected to laptop as a learning platform to visualize the learning environment and allows physical and intellect interaction with that environment. The interaction deals with guidance elements through hands-on experimentation and minds on reflection (Figure 2.8). Furthermore, students could conduct trials that can't be done at school. An evaluation for the CONNECT project has been conducted in terms of usability and effectiveness, in which it has been done by involving students with physical disabilities like Arthrogryposis, Muscular Dystrophy and Cerebral Palsy (Arvanitis et al., 2009). The interesting part of this study was the researchers found that the normal students and the disabled student got almost the same results after comparing their tests. The conceptual idea of the CONNECT project has been supported by the results of this research experiment, in which shows that the CONNECT project has a positive influence towards education domains particularly for students with disabilities.

Figure 2.8 CONNECT wearable system

Source: Arvanitis et al. (2009)

A study by Fleck et al. (2015) present an instructional design environment by using AR technology which named AIBLE-HELIOS to help student understating science classes. The result confirms that mixing virtual objects with the physical world would lower abstraction level for learners because of the spatial and explicit information that provided and also indicates that the interaction possibility increased. According to these results, the developed system in this study used AR to get the best results as this study needs the participants to understand and learn what they are doing (Figure 2.9).

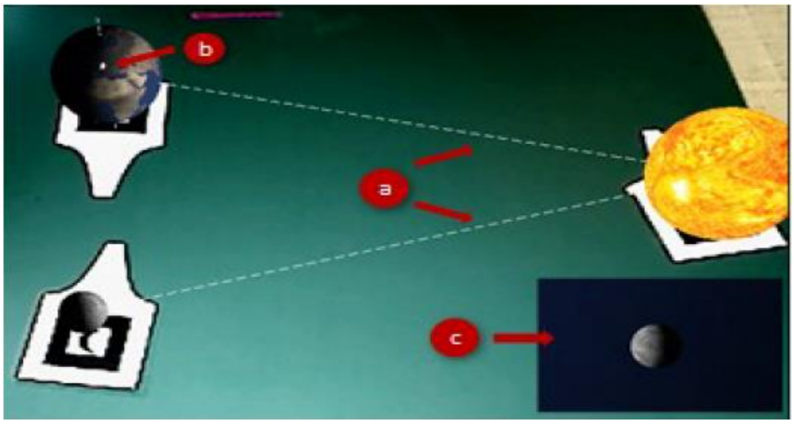


Figure 2.9 HELIOS first person perspective visual guides support learners: (a) dashed-lines between bodies' centers (b) a terrestrial observer (c) Viewport showing the terrestrial observer's view in real-time

Source: Fleck et al. (2015).

Another AR tool that has been tested in 2014 was related to teaching chemistry at a junior high school in Shenzhen of China. Students were able to control, combine and interact with a 3D model of micro-particles with the use of markers. They were able to conduct a series of inquiry-based experiments. Researchers concluded that the AR tool had a significant supplemental learning effect as a computer-assisted learning tool. The AR tool was more effective for low-achieving students, students presented positive attitudes towards AR, and these attitudes linked to their evaluation of the software (Cai, Wang & Chiang, 2014).

Chang et al. (2011) implemented an AR learning system for English vocabulary learning (Figure 2.10). They investigated learner's satisfaction and behavioral intention as well as the achievement of the AR-learning system. This study shows that system quality was a critical factor affecting perceived satisfaction, perceived usefulness, and AR-learning achievement. Furthermore, the design of system function and operation process must be more straightforward for learners when adopting new technology in the learning system.

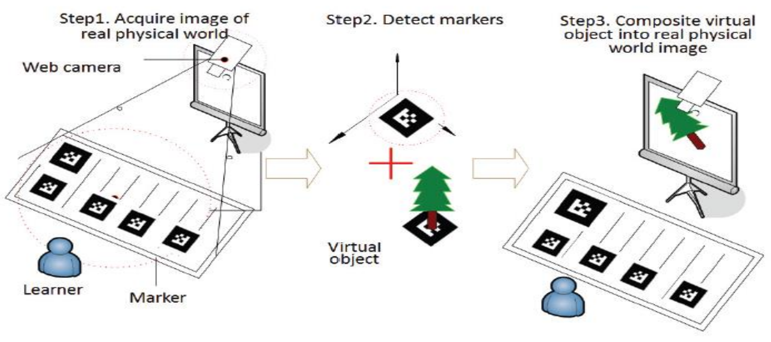


Figure 2.10 Composition of virtual objects and the real physical world.

Source: Chang et al. (2011)

Santoso et al. (2012) from Institute of Ambient Intelligence (IAI) alongside with Sungsan Elementary School (SES) by developing a Digital Edutainment Content based on Tangram toy as an existed edutainment media (Figure 2.11a). The tangram toy edutainment content adopted due to its capability of enhancing student spatial cognitive ability. An iPad was used for the developed application, when the user selected the AR session the iPad built-in camera will be automatically activated. Then, the user must point at a colorful marker on the book using the camera. After that, the software will display the virtual objects for each tracked marker (Figure 2.11b). The result indicates that the usages of AR in mobile devices have two benefits which were mobility and easiness-to-use.

(a)

(b)

Figure 2.11 a: Tangram toy. b: The used scenario

Source: Santoso et al. (2012)

In 2013, A. Di Serio, M.B. Ibáñez and C.D. Kloos studied the effects of AR on the motivation of students on a visual art course at a middle school in Madrid, Spain. The presented material was relevant to the Italian Renaissance Art, and it consisted of images and information of this period's paintings. The experiment included two situations one with traditional teaching material and one with AR material. Results led to the conclusions that though AR is not mature enough for broad application in education due to the usability issues back then, but this study also concludes that the positive impact of AR on motivation leads students to achieve higher levels of engagement in learning activities with less cognitive effort (Di Serio et al. 2013).

Science domains, mobile devices have been used as tools for learning in informal learning spaces. These informal learning environments included: gardens, butterfly farms, arboretums, museums, science centers, forests, playgrounds, lakes, and watersheds (Halpern et al. 2011; Klopfer et al. 2002; S M Land & Zimmerman 2014; Susan M. Land et al. 2011; S Yoon et al. 2011; SA Yoon et al. 2012; H T Zimmerman et al. 2013; Heather Toomey Zimmerman & Land 2014). These studies indicated that AR promotes high levels of engagement, supports collaboration, allows students to engage in higher-order thinking skills, and permits students to take on roles during gameplay (Dunleavy et al. 2009; Halpern et al. 2011; S Yoon et al. 2011; SA Yoon et al. 2012).

AR is one way that educators can provide new, meaningful and strong learning experiences for their students (The EDUCAUSE Learning Initiative 2005). The EDUCAUSE Learning Initiative (2005) also acknowledged that the use of AR in the educational setting could make the learning experience much richer. Based on the result students who use AR are more likely to comprehend what they are learning and retain that knowledge longer. One aspect of AR that is attractive to many educators is the fact that students have the ability to capture and record their thoughts or impressions when working with artifacts during an AR experience. Move it to the end of this sub-paragraph

Based on that, the researchers proposed the following set of best practices for effectively integrating the emerging technologies of AR with mobile devices:

- Create virtual experiences that mirror the real world
- Constrain extraneous information

- Provide appropriate feedback
- Provide context throughout the experience

2.4.2 AR and MAR in Training and Assembly

There are many ways for people to traine themselves regarding specific skills they need. These methods include workshops with textbooks, computers, handheld devices and other electronic appliances. The choice of learning innovation is dependent on an individual's access to various technologies and the infrastructure environment of a person's surrounding.

AR can deliver hands-on training where users receive visual instructions in the context of the real-world objects. Instead of reading a paper manual a person could look at a car engine while the AR display shows the parts that need to be adjusted and the sequence of steps required. AR has been applied to a variety of assembly operations by numerous researchers and is used to fulfill the same roles as paper instruction manuals and other instructional methods to guide users through an assembly sequence. One of these roles is identifying the assembly components and tools that a user should be interacting with at a given time while the other role is indicating where components and tools should placed and how they should be oriented or manipulated.

Significant advancements in purchaser equipment and PC vision contributes to the first academic AR prototypes in the 1990s. Earlier research in this area has largely involved procedural tasks, where the user follows visual cues to perform a series of steps with the focus on maximizing the user's efficiency while using the AR system (Caudell & Mizell 1992). In which assisted with assembling aircraft wire bundles with the goal of improving worker efficiency and lowering costs. Some studies investigated the AR area throughout this time, and in 1997 R. Azuma directed a point of interest review of earlier research and introduced the generally acknowledged meaning of AR, AR systems consolidate genuine and virtual scenes which interface progressively and spatially enlisted in 3D (Azuma 1997). In the following year, J. Rekimoto made an essential leap forward with his (Matrix) technique for object identification and registration (Rekimoto, 1998). This was the primary significant execution of a posture estimation framework using 2D square-formed marker that encodes unique recognizable data also called marker tracking. H. Kato and M. Billinghurst developed the ARToolkit tracking library in 1999 which further refined Rekimoto's approach (Kato, & Billinghurst 1999). ARToolkit was soon released to the general population as an open-source extend and turned out to be broadly mainstream among AR researchers, business endeavors and private people alike. This significantly expanded the introduction and notoriety of AR and provoked the investigation of new interdisciplinary applications. ARToolkit and other tracking libraries lately applied for mobile and web platforms which have formed new avenues for research and commercial adoption such as outdoor AR and web-based AR advertising. The AR area has developed exponentially and is acquiring its place as an prominent frontier of current innovative improvement.

AR systems have proposed as arrangements in numerous areas including medical, entertainment, military training, engineering design, robotics and teleoperation and so on. As the objective of this research is to investigate the application in the industrial training domain, we will highlight some of the proposed applications in this domain.

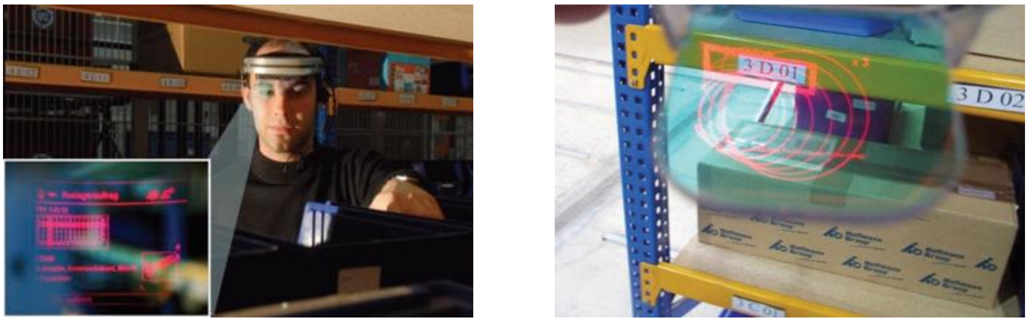
There has been much earlier research investigating the utilization of AR for manual assembly tasks. In the industrial domain, P. Caudell and D. Mizell at Boeing created one of the principal point of interest models which helped with putting the aircraft wire bundles together (Caudell & Mizell 1992). Their objective was to enhance operative competence and lower costs by diminishing dependence on the conventional methods, form board charts and concealing gadgets regularly utilized in the assembly procedure. The display utilized basic wireframe vector illustrations to demonstrate the way of the link to be added to the package and along these lines did not utilize 3D graphics equipment. The system was later assessed by Curtis et al. (1999) who raised an assortment of commonsense concerns in regards to the model and its distribution in a real aircraft plant (Curtis et al., 1999). Baird & Barfield (1999) studied the assembly of components on a computer motherboard. Participants were asked to perform the task using printed materials, slides presented on a computer monitor or screen-fixed textual instructions on opaque and see-through HMDs. The test subjects completed the assembly task significantly faster and with fewer errors when using the HMD displays with AR support. Another early examination included the formation of a head-mounted monocular AR display to help with auto entryway bolt assembly (Reiner et al. 1998). This system utilized 3D CAD models of the auto entryway and inner locking instrument which gave enhanced spatial mindfulness over the 2D designs in the previously mentioned Boeing wire package system. The system guided clients through the assembly process in a well-ordered manner reacting to voice orders to move between the steps. In the assessment of Reiner et al. (1998), they found that the model was not sufficiently steady for totally new operators whose activities were frequently not inside the expected working parameters. The researchers concluded that some basic preparation was required to increase any unmistakable advantage from the AR system.

These early investigations soon prompted the arrangement of a few research groups devoted to investigating the utilization of AR applications in industrial domain. ARVIKA was a group based in Germany whose assignment was to utilize AR to carry out user-oriented and application-driven support for working procedures in the development, production, and servicing of complex technical items and systems (Friedrich 2002). They got financing from the German Federal Ministry of Education and Research and additionally different corporate patrons to investigate a few areas including vehicle and aircraft assembling and power plant overhauling. Their emphasis was on reasonableness and appropriateness since most past AR models were too awkward to ever be coordinated effectively into industrial environments. The researchers led convenience tests to assess ergonomic aspects of AR equipment and programming the time-cost and quality impacts of the utilization of AR in the work procedure and the advantage of AR telepresence which enables experts to give remote help to operators in the field. The study found that the use of AR in industrial development contexts can be tremendously valuable and that the expensive nature of AR systems is often offset by reduced the development time and enhanced product quality. For example, design could quickly assess ergonomic aspects of various flying machine cockpit models by overlaying virtual format components over genuine cockpit mockups which essentially streamlined the outline procedure.

AR has been used to teach a variety of procedural tasks. In several studies (De Crescenzio et al. 2011; Haritos, & Macchiarella 2005; S. J. Henderson, & Feiner 2009; S. Henderson, & Feiner 2011a; S. Henderson, & Feiner 2011b; Neumann, & Majoros 1998; Tang et al. 2003), AR was used to train participants to complete maintenance or assembly tasks in which a specific set of procedures followed. In two studies (Liao et al., 2010; Yeo et al., 2011), AR instruction was used to train specialized medical professionals to perform complex surgical procedures.

Haritos and Macchiarella denote two benefits for AR training that it could reduce errors, thus increasing passenger safety and minimizing incidents and accidents. The first one is that AR allows an efficient method of retrieving information. The second way is that AR could compliment human information processing by facilitating a transition to expert levels of knowledge in a shorter span of time (Haritos & Macchiarella 2005). Thus, the information retrieved could be the equivalent to an expert's recall from long-term memory.

Researchers from Germany (Reif et al., 2010) developed an AR system that instructed factory workers to select specific items from warehouse storage shelves (Figure 2.12 a,b), that AR system attempted to enhance the productivity of workers by allowing them to complete item selection quicker and more accurately. The Pick-A-Vision system required workers to wear a HMD and small portable computer. As they navigated a factory floor, the system displayed text information indicating the aisle for next stock location and as the worker approached the correct storage compartment, an identifying arrow overlaid on their field of vision changed colors when identifying the correct storage compartment. By using the ability to overlay text and images as a means to guide workers to a specific location, the Pick-A-Vision system was able to lower the selection error rate as compared to workers using a traditional paper list (Reif et al., 2010).



(a) (b)

Figure 2.12 (a) The used system in this setup: a Micro-vision Nomad HMD, a head-set for the speech input and a possible visualization. (b) Tunnel becoming transparent if the right storage compartment is recognized and a frame around the right stock location

Source: Reif et al. (2010)

De Crescenzio et al. (2011) used an AR system to help workers maintain airplanes. This system was designed to deliver instructions that would reduce errors due to procedure violations, misinterpretation of facts or insufficient training. While the study did not use the terms cognitive phase and psychomotor phase, the AR system tried to assist with tasks related to both phases. Cognitive phase assistance came in the form of overlaid 2D arrows that directed worker attention to specific parts of the plane. Psychomotor assistance came in the form of a 3D animation that showed how an oil cap should twisted during removal (Figure 2.13). Participants were asked to fill out a NASA-TLX (Task Load Index) form and result indicated that the AR system led to low ratings for mental workload and effort and high ratings for user satisfaction. Such ratings suggest that the cognitive and psychomotor techniques used in the AR delivery were successful.

Figure 2.13 The display window and steps for the oil check procedure

Source: De Crescenzio et al. (2011)

S. J. Henderson, & Feiner (2011a) explain that activities related to procedural learning can be classified as cognitive or psychomotor and offer evidence that AR can assist with both aspects. S. J. Henderson, & Feiner (2011a) explain that cognitive phase activities include directing attention, comprehending instructions, and transposing information from the instructions to the actual task environment. Psychomotor phase activities are said to include performing physical manipulations such as comparing, aligning, and adjusting. Essentially, the two components involve the learner determining an effective course of action and then acting upon it (Figure 2.14).

Figure 2.14 AR assistance for the psychomotor phase of a procedural task

Source: S. J. Henderson, & Feiner (2011a)

Yeo et al. (2011) attempted to determine if AR could assist medical trainees in learning the correct placement of a needle for a very specific type of joint injection that had to be done in an exact spot at an exact depth, a task that involved both cognitive and psychomotor demands. The researchers selected 40 volunteers and randomized them into treatment and control group. The control group participated in a training session that included six freehand insertions into a synthetic model spine, and the treatment group received a training session that included guidance from an AR experience. To offer support for cognitive phase activities, the AR treatment overlaid a guiding image on the model spine and for psychomotor support, used a digital marker to indicate the proper insertion point of the needle (Figure 2.15). After training, each member made two insertions on a spine phantom. Researchers recorded data related to total procedure time, the time inside the phantom, the path inside the phantom, and potential tissue damage, (Yeo et al. 2011). The results were strongly in support of the AR training method suggesting that the cognitive and psychomotor support was effective. While the time of the total procedure and the time inside the phantom spine were not significantly different between the two groups, the treatment group had a larger number of successful placements and took a significantly more efficient path inside the phantom and also had a lower amount of potential tissue damage.

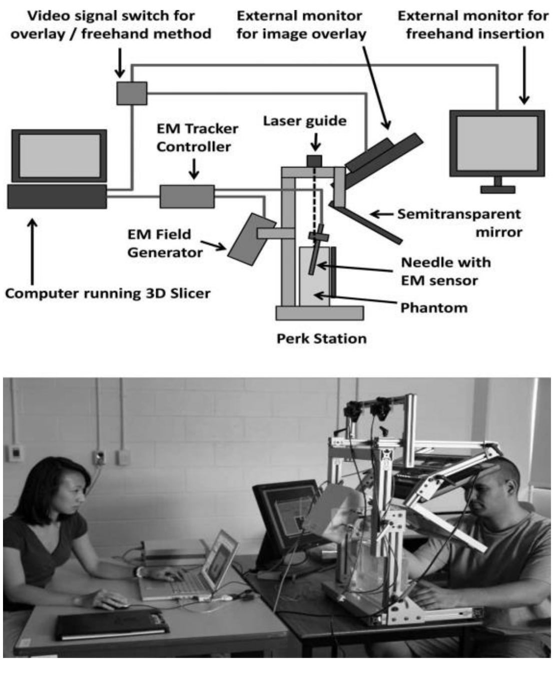


Figure 2.15 Simulator setup

Source: Yeo et al. (2011)

S. Henderson, & Feiner (2011b) conducted a study that illustrated how AR could assist with the psychomotor aspect of procedural learning (Figure 2.16). In the study, a wearable AR display was used to overlay instructions related to the assembly of an airplane engine. This AR system provided cognitive phase support in the form of 2D text that communicated the desired action. Three specific techniques were used to provide support for the psychomotor phase including 3D arrows that provided feedback about the correct orientation of an object, highlighting effects that helped users connect and align two objects, and dynamic labels that responded to the motion of the user and the labeled objects. Findings indicated that the AR system was able to help users perform the psychomotor aspects of the engine assembly more quickly than when using a more traditional (LCD monitor) delivery method. Also, a statistically significant number of participants preferred the AR treatment and indicated that it was more intuitive than the LCD treatment. The AR system also allowed participants to complete alignment tasks more accurately that the LCD treatment. Essentially, the AR system was found to be more accurate and faster for the psychomotor phase activities and was overwhelmingly preferred by participants.

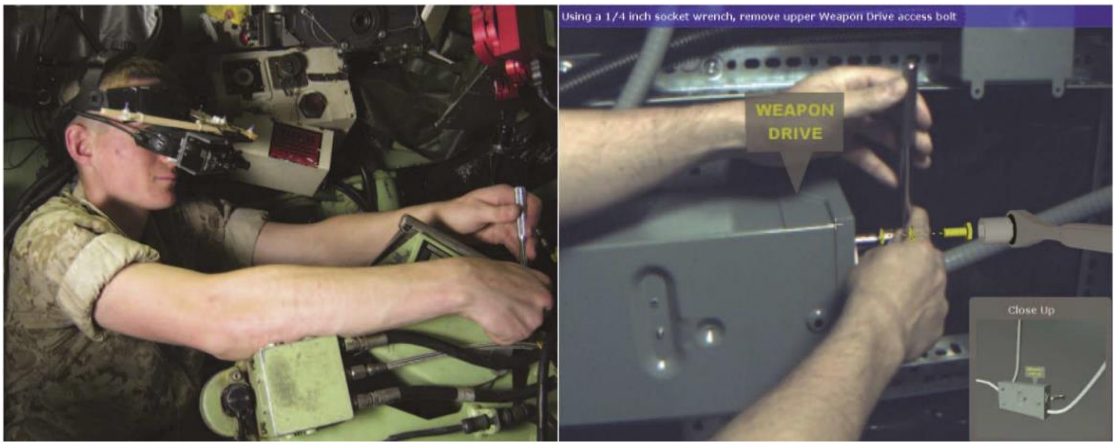


Figure 2.16 A mechanic wearing a tracked head-worn display and performing maintenance task

Source: S. J. Henderson, & Feiner (2011b).

Henderson and Feiner (2011a, 2011b) provided specific examples of AR design elements that were used to assist with both the cognitive and psychomotor phases. The design elements are summarized below: