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Stereoscopic Vision Mobile Augmented Reality System Architecture in Assembly Tasks

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Abstract: Augmented Reality (AR) technology has great potential to be applied in different fields like education, medical surgeries, manufacturing, etc. Assembly process is an important process in manufacturing field and it is happening in our daily life too such as put furniture's pieces together. Therefore, an assembly training is essential for a person who has no or simple knowledge about the product assembly process. Conventionally, the assembly task training is conducted through paper-based manual to guide and train the participant to understand the assembly steps. This traditional method is costly and time consuming. Stereoscopic vision has shown to be more beneficial over the monocular vision which it can provide depth information to the users. AR could combine with the stereoscopic vision to present the virtual object in a better way for the users to judge the distance of the virtual object in assembly system. Thus, it will be more closely to the real assembly situation. This study proposed a new system architecture which consists of the necessary components that are needed for stereoscopic-based mobile augmented reality system. It can be a reference for others who want to create a mobile type augmented reality with stereoscopic vision applications for assembly processes. The components of the system architecture include the hardware, different type of target and the AR environment part. Various interaction modes have shown and explained in the AR environment part to allow users to interact with the system. At the end of the study, a mobile augmented reality assembly system for PlayStation 3 console was successfully developed according to the proposed stereoscopic-based mobile AR assembly system architecture.

Key words: Mobile augmented reality, augmented reality system architecture, stereoscopic, human computer interactive assembly task, PlayStation

INTRODUCTION

Assembly process is needed and important in different fields including manufacturing, construction and biomedical (Groover, 2002; Simpson and Durbin, 2010; Tang *et al*., 2006). Computers, ships, aircrafts and cars considered as an example for manufacturing assembly which can be seen in our daily life. In construction, it can be seen in the piping assembly of some certain materials like the Heating Ventilation Air Condition (HVAC), prefabrication assembly, concrete formwork assembly and rebar assembly.

In the assembly task, the person who assembles a machine or its parts is required to make a sequence of numbers of physical operations (observing, grasping, installing, etc.) and mentally manually operated procedures (mentally grasping, interpreting and information retrieving) (Neumann and Majoros, 1998). In the industry, training is an essential process in spite of the previous experience for the fresh workers that they might have in their previous jobs. It is almost sure that they need some level of preparation in company-specific tasks or operations. In the usual method of training, the training is accomplished by persons who have the knowledge or skills in a particular field which they are responsible for transmitting that knowledge and skills to the new trainee. A sketch normally used in assembly training to guide the users through the assembly steps. The sketches usually come in a two dimensional study based (2D) that contain a list of portions; these portions are labeled and numbered according to its corresponding position and the sketch show how to gather them, even though that 2D sketches usually more effective in assembly tasks that do not contain complex drawing but still not contextual enough. While another type of study-based manual which is the three dimensional picture (3D), it is also used to guide the users through the assembly/disassembly process and it is more contextual in assembly tasks than the 2D sketches (Tanaka *et al*., 2004). Humans can recognize 3D objects easier than 2D

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objects due to the more details that 3D objects have specially the depth cues while 2D vision requires more time to process the information, 3D vision considered more intuitive and requires less cognitive details and also proved that its enhance user performance (Blavier *et al*., 2006).

This type of training has some downsides. The resources will be extensively used when conduct the training, like calling for skilled trainer commonly a technician or even an engineer to be available at all times throughout the preparation and keeping the machine and other resources involved in a training that does not straight forward produce the final products. Thus, the traditional methods is costly and time consuming to conduct a training (Peniche *et al*., 2012).

The technology of Augmented Reality (AR) is one of computer science exploration areas which interweave the real world with virtual objects in real time. AR can be used as an assistant tool in manual assembly and maintenance processes. For example, an individual is assembling a furniture or fixing a car engine in which these kind of jobs are naturally spatial in nature and it could be so hard to explain the process with no guidance (Westerfield *et al*., 2013). The early setup of AR was on desktop computers with custom input and output device and a backpack with HMD. The time passed and the computing technology is rapidly evolved which allows utilizing AR on small handheld devices (smartphones, PDA's, etc.) (Wagner and Schmalstieg, 2009). AR has the capability to provide practical drill where the virtual information can be given to the users in the context of the real world objects as an alternative way of looking and reading a study-based manual. A user can look at a car engine while in the same time; the AR display shows the virtual information about the portions that need to be regulated and the order of the required steps. Augmented reality has the ability to deliver beneficial assembly guidelines in the user's field of view in an actually existing environment. AR technology prevent time wasting and suitable to retrieve the information and sending it back to back-up the user's in their assembly procedures (Yuan *et al*., 2005). The notion of applying AR in mobile settings was developed around the mid-1990s then it's known as Mobile Augmented Reality (MAR). However, only a limited studies have applied the stereoscopic technology with AR technology and these studies did not mention about the stereoscopic mobile augmented reality system architecture such as (Cirulis and Brigmanis, 2013; Gorbunov, 2014; Kytak *et al*., 2014; Li, 2016; Wojciechowski and Cellary, 2013). Thus, this study aims to develop a system architecture specific in stereoscopic MAR assembly system.

Literature review: Caudell and Mizell (1992) described a successful AR system that used in aircraft manufacturing to reduce cost and improve individual efficiency in their hands-on tasks. Rosenberg (1992) demonstrated AR's benefits to human performance in 1992 at the Armstrong US air force research laboratory while testing virtual fixtures, one of the first functioning AR systems that AR application did well for providing a hands-on experience working with statistical data. AR combines virtual objects with the real world and permits the user to interact with virtual object in the real time. AR is not restricted by display technologies nor limited to the sense of sight. It can use different type of display devices such as projected based, large screen or mobile based to augment the virtual information on the real environment (Azuma, 1997; Krevelen and Poelman, 2010). Three key components are required for this technology: a camera with display screen, a computer processor and appropriate software. Now a days, almost everyone has a smart phone that contains all these components.

Augmented reality in training or assembly: Augmented reality has the advantages in supporting individuals in their tasks in terms of cognitive and psychomotor aspects according to the studies that done by Henderson and Feiner (2011), Yeo *et al*. (2011). Results of both studies showed that using AR technology in some certain task or training that requires the users to be aware of what surrounded them in their environment has significance in facilitating their tasks. The results showed the task done faster and more accurate for the group who use AR system in Henderson and Feiner (2011) study. Even though, results in Yeo *et al*. (2011) study showed no significant differences in completion time between the AR user group and non-AR user group but all participants agreed and prefer using AR systems and they feel it is more effective than using traditional way.

Augmented reality proved its usefulness when compared to other methods such as virtual reality (Gavish *et al*., 2015) and when applied in monitor setting (Chen *et al*., 2015; Fleck *et al*., 2015; Radkowski *et al*., 2015) and other different fields. Gavish *et al*. (2015) presented a study to evaluate between augmented reality and virtual reality; the results indicate that using augmented reality technology as a tool for training have a good influence in reducing errors less than who did not use augmented reality. The evaluation in studies that used monitor setting AR showed an increasing in user confidence (Radkowski *et al*., 2015), increased interaction possibility (Fleck *et al*., 2015) and increased the task accuracy (Chen *et al*., 2015).

Westerfield *et al.* (2015) developed an intelligent tutoring system in an augmented reality computer motherboard assembly and has performed an evaluation between using the intelligent AR tutor and without the intelligent support and the result shows that the AR intelligent tutoring system is faster in completing the assembly tasks and improves the overall test scores. Westerfield *et al.* (2015) suggested using stereoscopic setup for better performance. However, it needs experimental study to confirm the performance of the stereoscopic-based AR. This study will suggest stereoscopic-based mobile augmented reality assembly system. It could be a reference for researchers whom interested in developing mobile AR systems that support 3D vision with depth information.

Binocular vision has shown some advantages in the physical environment. It visional impacts obviously, it mesmerizes large number of people when their eyes lay down on 3D image. Further, than the appealing nature of stereoscopic 3D images, it delivers the following advantages over monocular vision:

- The ability to make the right decision about scene depth. The locative relationship of objects in depth from the observer can form an opinion directly by utilizing binocular vision
- Spatial localization. The brain has the ability to concentrate on object that exist in certain depth and ignore other objects that exist in other depths using binocular vision
- Recognize disguised objects. The capability to select disguised objects in a scene is possibly one of the developmental causes for utilizing binocular vision
- Physical surface awareness. For example, glitter, shimmering gems and gleaming metals are in part seen as such because of the different shining reflexion noticed by the left and right eyes (Helmholtz, 1867)

These advantages make stereo image display of significant benefit in particular professional implementations where depth decision is vital for reaching positive outcomes. In addition, the impact of stereopsis is convincing enough that stereoscopic images have created the foundation of numerous entertainment systems.

Czerwinski *et al.* (1999) stated that 3D visualization techniques have a significant influence on the user memory, especially the place that stored the most frequent used information. Also, there is evidence that 3D visualization enhanced spatial memory. Robertson *et al.* (1998) presented that the task duration and error rates were lower when using 3D data mountain than when using the standard 2D mechanism of internet explorer in retrieving web pages.

MATERIALS AND METHODS

The proposed stereoscopic-based mobile augmented reality assembly system architecture consists of two parts, part one is the hardware part and part two is the AR environment as shown in Fig. 1 and the explanation of each part of the system architecture can be seen below which will start by explaining the physical components and ends by explaining the virtual components and how to interact with it.

Hardware: Two main components in hardware part required in this system architecture are a mobile device and a Head-Mounted Display (HMD). For mobile devices, lots of devices can be used in the proposed system architecture as long as they have enough computational power to run AR technology. In the proposed system architecture, a mobile device is plugged into HMD that HMD permits stereoscopic video-see through by using the mobile device camera.

Target: There are many types of targets can be used as targets in augmented reality system. Three types of the target tracking have identified for the stereoscopic MAR assembly system. The three of it are indoor based tracking. Location based tracking are not suitable for the training because most of the training are indoor and location based tracking mainly use for outdoor tracking. Below are the three type tracking suggested for the assembly system:

- Image: this type of target is a 2D type tracking and it is mostly used in AR tracking because it is easy to use, stable to be tracked, divergence of its types and sizes. The option for the images include a fiducial marker (Kato and Billinghurst, 1999; Nuanmeesri *et al*., 2016) or a normal images with a rich features that could detected by the image tracking algorithm (Neumann and You, 1999)
- Environment: this technique can be used for applying AR in an unknown environment. An example for that is using SLAM (Simulation Localization and Mapping) to map an unknown environment to get the location of it, so that a virtual object can be well aligned on top of physical environment. Although, this technique shows a fast and robust performance but it requires a high computational power which also will be costly

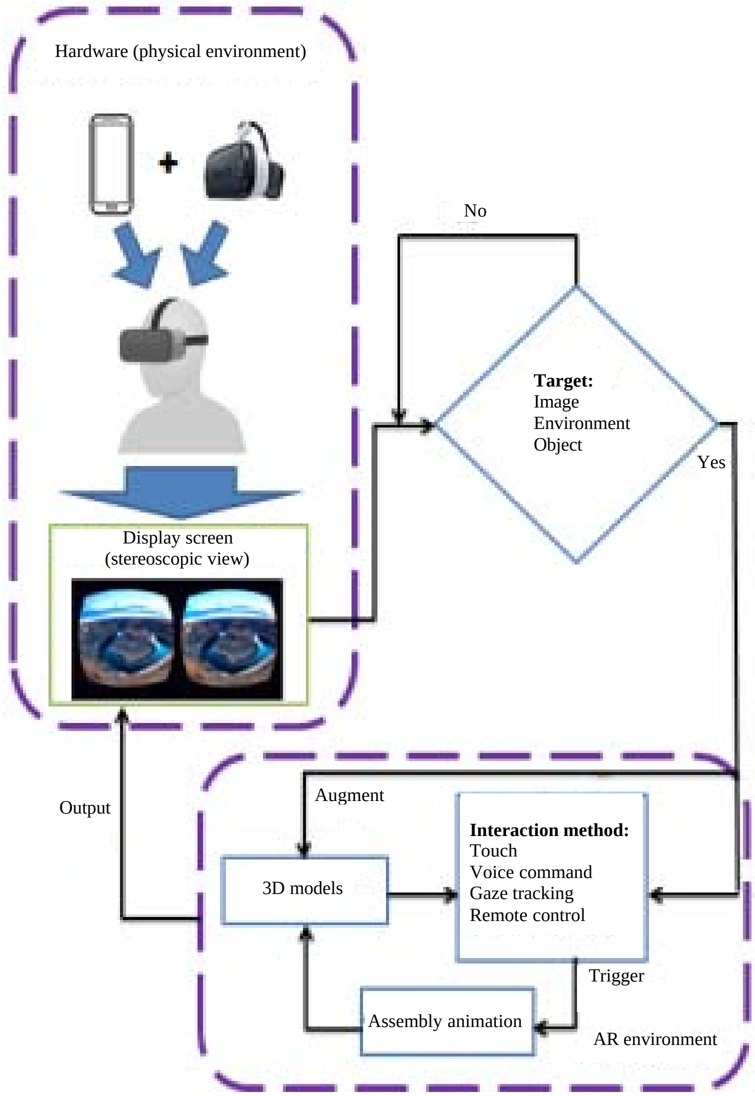

Fig. 1: System architecture

- Objects: object in the physical environment can be a target for an AR system. It could be tracked by detecting the images on each phase of the object which make the tracking process more efficient. Thus, a virtual object can render beside the physical object without the penetration or occlusion problem (Park *et al*., 2008; Selvam *et al*., 2016)

Augmented reality environment: The AR environment in this system architecture is consisted of three components:

- 3D Model: this component refers to the superimposition of the 3D models in the real world. In AR assembly system, the 3D object is the 3D Model of the product that allows users to view the appearance of the product
- Assembly animation: in order to show the assembly step of the product, animations were needed such as animation on how to fasten/unfasten the screws in the product. Animation will be triggered by the users according to their selection to show them the assembly process
- Interaction method: this component refers to how the user will interact with the virtual objects by using one of these methods (touch, voice command, gaze tracking and remote control)
    - Touch: the most commonly method that used to interact with any interface is done by a touchpad for augmented reality users can use touchpad that positioned on the HMD to select the proper interaction in the virtual world (Thomas *et al*., 2002)

- Voice command: users can use the mobile device microphone to select the suitable interaction they wish to initiate vocally in the virtual world (Kollee *et al*., 2014)
- Gaze tracking: in this method, users can make use of their head movement and use their gaze to interact with virtual world (Porta and Turina, 2008)
- Remote control: there are different types of devices that can be used by the users to interact with the virtual world remotely, these devices may use wireless or Bluetooth connection and also devices such as smartphones could be used for same purpose by using the proper software (Chen *et al*., 2013)

RESULTS AND DISCUSSION

A PlayStation 3 console stereoscopic-based mobile augmented reality disassembly system has developed based on the system architecture that proposed in this study. Unity Software has been used to develop stereoscopic mobile augmented reality assembly system. Unity used as a game engine and can be used for building augmented reality environment.

The hardware components for the developed system include a mobile device (Samsung Note5) which is plugged into a head-mounted display (Samsung Gear VR) and both of these devices will serve the developed system by providing the stereoscopic view perspective (Fig. 2).

Then an image had selected as a target component for the developed system to superimpose both virtual PlayStation 3 console and virtual buttons on the real world. The user can start the augmented reality application with activation of the mobile device's camera and look at the target image which placed beside the physical PlayStation 3 console to see the virtual PlayStation 3.

Disassembly process animation: There are seven virtual buttons in the developed system and each one of them represents a disassembly process, the user can interact with any one of them. Below is the description for the function of each button:

- First cover disassembly: an animation will start by removing the black rubber on the console side then unfastening the screw that placed behind the black rubber then slide down the first cover towards the hard drive
- Second cover disassembly: an animation of a screw driver that will show how to unfastening seven screws then lift the second cover up

Fig. 2: Samsung mobile device plugged into Samsung Gear VR

- CD room disassembly: an animation that illustrates how to remove the CD room by first unplugged the power cable then lifts it up
- Hard drive disassembly: an animation will start by opening the hard drive door then removing the screw that secure the hard drive, after that the user must grab the hard drive pull tab and pull it toward the console face and then pull it out
- Bluetooth and wireless card disassembly: an animation of a screwdriver will show how to unfastening two screws then left the card up
- Power supply: an animation will show how to unplug the power supply cable and how to unfasten the five screws that secure the power supply then shows how to lift it up
- Reset button (R): when the user interacts with this button all 3D models will reset all the animation and to go back to initial state

In the AR environment, the gaze interaction method has used to interact with the virtual buttons. User can control the virtual reticle using the head movement which will trigger the disassembly process animation by hover the virtual reticle on top of the virtual button. Seven virtual buttons will surround the PlayStation 3 3D model. Each button from 1-6 represent one step of the disassemble process and the seventh button (R) responsible of resetting the whole disassemble process from the beginning. For example, if the users want to trigger the first disassemble step they have to move the reticle over virtual button number one; if the users want to trigger the second disassemble step as shown in Fig. 3, they have to move the reticle over virtual button number

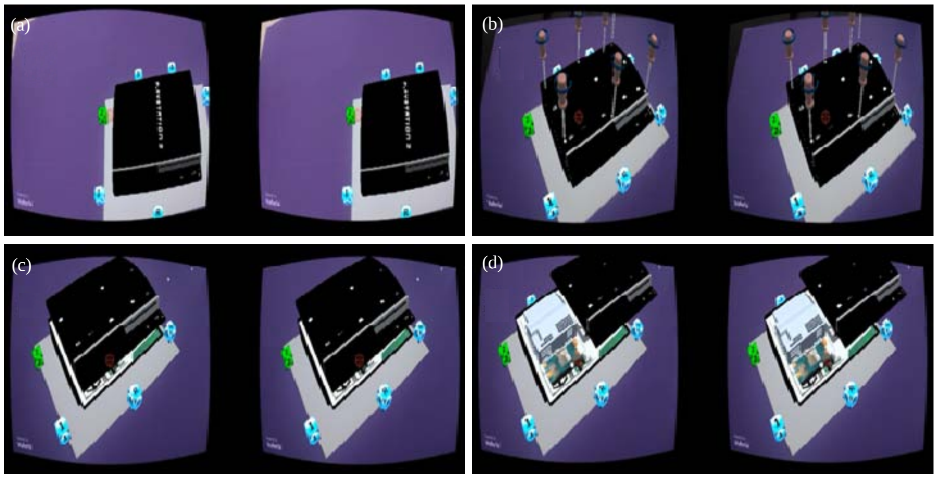

Fig. 3: Illustration of the disassembly steps of the second cover: a) User selects the virtual button to start the animation; b) Animation of removing the screws and c-d) Animation of removing the second cover from the console

two and so on. If the users want to reset everything from the beginning they have to move the reticle over virtual button (R). Animation for each step will keep repeating itself until the user activates another process by looking at another button.

CONCLUSION

This study proposed stereoscopic mobile augmented reality assembly system architecture. This system architecture includes hardware components, target components and AR environment.

The hardware components consist of mobile device that have computational power to handle AR technology and HMD that provide the users with stereoscopic perspective, the target component contain different type of tracking in AR which are image, object and environment type use to superimpose the virtual objects over the real world and AR environment include 3D models, interaction method and assembly animation. At the end of this study, stereoscopic mobile augmented reality assembly system for PlayStation 3 was successfully developed based on the proposed system architecture.

RECOMMENDATIONS

In the future research, vocal instructions also seem as a good feature for the assembly system to guide the user through the assembly process. An evaluation to the vocal instruction enabled system is needed and will be conducted.

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