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Marker-based Augmented Reality Application for Car Basic Maintenance

Goh Eg Su[1]*, Noor Hidayah Zakaria[2], Jasmin Farena Muhammad Kamarul[3] & Johanna Ahmad[4]
Faculty of Computing
Universiti Teknologi Malaysia
81310 UTM Johor Bahru, Johor, Malaysia
Email: eg.su@utm.my[1]*; noorhidayah.z@utm.my[2]; jasmin.farena@gmail.com[3]; johanna@utm.my[4]

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***Abstract*—In general, Augmented Reality (AR) is a technology that allows the virtual object to complement the real-world environment. The rapid growth of technology has enabled mostly anyone to use AR technology. Thus, applying AR technology in the learning experience should normalize as it is now easy to access and there is much positive feedback based on the past research regarding AR in education. Unlike watching tutorial videos, AR teaching applications would provide users with different learning experiences. Therefore, the aim of this research is to provide more immersive learning experiences to drivers to learn simple car maintenance. This application will illustrate 3D steps and procedures of simple car maintenance for drivers to learn in helping them to self-service their car. Consequently, there are 4 phases of this project that need to be carried out to achieve the objectives of this research. The first phase is to review the AR application concept and understand the car services techniques. The second phase is to design and develop the AR application that will provide simple car services techniques. The third phase is integrating the AR car services manual and finally evaluating the effectives of this application in providing the car basic maintenance tasks and knowledge to new drivers. The evaluation discovered that the drivers have more interaction during learning experience using the AR application.**

***Keywords*—Augmented Reality, Handheld device, Car maintenance**

I. INTRODUCTION

Technologies have a powerful impact on many aspects of our society such as economics, business, medical entertainment and most importantly education. These technologies have influenced our teaching and learning way. Improvement in education is not necessarily be affected by technological aspect, but there is an increase of interest on using new technologies for better learning experience. AR application is widely used in teaching methods for a more hands on procedure as can improve the educational quality.

AR is the purpose to complement the real-world environment with a virtual environment. Unlike virtual reality (VR), that create its own virtual environment, augmented reality adds to real-world. It is a trend in education field and among companies that are related in computing and business application. For example, Kangdon Lee [1] claims that AR has a potential to provide a strong contextual, influential experience and exploration of the information in the real world. In addition to that, the thriving growth of technologies nowadays make it possible for us to deliver AR experience through personal computer and mobile devices. The ease accessible of this technology plays parts in the growth of AR technology.

An augmented application has been developed by Freitas and Campos [2] to see how school student respond to learning experience that include AR application. The result of this studies shows that the AR application increase motivation of student and has a positive impact on the learning experience especially towards the less academically successful students.

Application of AR can be seen in higher education and in business settings including tourism, museums, gaming, and industry [3, 4]. Focusing on the field of industrial maintenance that widely us AR technology because it is practical in assisting their staff in their demanding technical work. According to Henderson and Feiner [5] studies which focus in the military sector, their military mechanical staff can perform their maintenance task in a safer and more convenient environment. A lot of car maker companies using AR in improving their maintenance services. Working with AR technology to assist with the maintenance work, fewer mistakes are done as it is easy to understand repair instruction, efficient training and fast learning [6].

However, most of the AR car maintenance are developed for a more challenging car services and is made specially for the typed car model. There are different categories of car services or car repairs. Major services are usually done by people who is trained in handling issue regarding car. While simple car services are general knowledge that should be learn by all drivers and can be done without expertise. A simple AR car maintenance to be used for new driver should be developed to teach and train these new drivers' basic knowledge about car maintenance. Learning these basic car services can avoid inconvenient breakdowns and costly repairs.

II. Literature Review

A. Augmented Reality (AR)

According to Azuma [7] AR is a variation of virtual environment, or as commonly called VR. While VR is to completely immerse the user into a virtual environment. AR complement the real world with a virtual element. In other words, the user could not see the real world around while immersing in a virtual reality. Milgram and Kishino [8] also add that AR can be thought of as the "middle ground" between VE and telepresence. As stated by Azuma [7] there are three (3) characteristics in AR system that are combines real and virtual, is interactive in real time and is registered in three dimensions.

Although AR has only been around for a little over a decade, it has seen tremendous development and improvement in recent years [9]. With the transformation and miniaturization of physical devices and displays, the concept of mobile AR evolved towards the notion of "mobile device", also known as AR on a mobile device [9]. Since AR technology is being easily access, it is widely used in many fields such medical, manufacturing, retail, military and in education.

1) AR Tracking

A crucial challenge for developing an AR application is to get an accurate tracking and registration between the virtual object and the real-world objects. In other words, accurate tracking of the viewing pose in relation to the actual environment and the objects being annotated is required to achieve proper alignment between virtual and physical objects [10].

Zhou *et al*. [11] divided the augmented reality tracking approaches in sensor-based, vision-based, and hybrid tracking techniques. Sensor-based tracking approaches are based on sensors that are put in an environment. While vision-based tracking systems employed picture information to track the location and orientation of a camera [12].

Vision-based tracking is the most active area of research in AR [11]. According to Bajura and Ulrich [13], computer vision methods are used to calculate the camera pose relative to the real-world objects. Early vision-based tracking utilized fiducial markers in prepared AR settings [14]. Currently, vision-based tracking research is based on marker less approach [15-17].

Marker-based tracking technique involves marker detection, identification of marker and calculation of the location and orientation [18]. This technique used a visual marker or fiducials and is placed inside the scene of the AR application. To track the position of the computer-generated object in the real-world, some specific extract features on the marker are determined. In 2004, ARToolKit [19] is introduced as an open-sourced tracking library to create an AR application.

Contrary to marker-based tracking, marker-less tracking does not use a visual marker to place the virtual object in the real-world. According to Ziegler [20], Marker-less tracking only uses what the sensors can observe in the environment to calculate the position and orientation of the camera. Techniques for natural feature tracking for AR require information about the item in three dimensions. This model is capable of being encoded in a variety of methods, such as computer-aided design (CAD), three-dimensional point clouds, and plane segments, depending on the requirements of the approach. [21]. For an outdoor environment, global positioning system (GPS) is widely used.

2) Handheld Display

Instead of using optical see-through Head-mounted Display (HMD) or video see-through HMD, AR system can also be built using monitor based. The cameras for this approach may be static or mobile. Similarly, to the video see-through HMD example, the video of the real world and the graphic pictures generated by a scene generator are mixed and presented on a monitor in front of the user [7]. It is known to be the least difficult AR setup, as the display is more conventional desktop monitor or a handheld. Thus, this setup eliminates HMD issues.

According to Wagner [22] Handheld Augmented Reality (HAR) is an AR system designed and embedded on a handheld device which can be hold by the user's hand. Two of the most important benefits of HAR are its portability and its widespread use of camera phones [23-25]. Constantly holding a handheld device in front of one's face and the distortion of wide-angle mobile phone cameras when contrasted to the real world are some of the drawbacks of using this technology [26].

In many industrial situations, using a display to give instructions is already a technical answer. This technology is known as a computer-assisted instruction system (CAI) and is thought to be a more flexible alternative to operating manuals. The CAI method is expanded in this paper by including a camera, which is helpful for feeding the AR algorithm as well as providing a background for the AR scene. Moreover, this kind of approach is also robust because it is constituted by current stable technologies and is relatively inexpensive to deploy, install and maintain in industry [27].

3) Handheld Interaction

HAR has different technique of interaction compared to computer-based AR interaction. HAR interaction is known as magic lens because user see the physical environment through the camera lens. Currently, there are two interaction technique approach for HAR, which are embodied interaction and tangible interaction.

Embodied interaction is a touch screen interaction and device movement. As explained by Michael Rohs [28] Penalty Kick is an AR gem developed using registered 3D marker printed on the back of a cereal box (see Figure 1). The aim of this game is to strike a goal by rotating and tilting the phone while a virtual goalkeeper tries to parry the ball. Henrysson *et al*. [29] developed the first collaborative handheld AR application. This AR tennis application use two user play tennis using mobile device (see Figure 2). Users need to press a key button to serve the virtual ball and moving their mobile device forward to hit the ball back. Mobile device will play sound and vibrates if virtual ball is hit. With recent mobile devices, handheld AR interaction using key button, keypad, and styles such as stylus is being replace with touch screen.

Fig. 1. Penalty Kick AR

Fig. 2. AR Tennis

4) *Knowledge on Car Maintenance*

Car maintenance is one of the most important aspects of road safety since it can prevent accidents caused by defect in a vehicle's roadworthiness. According to Rohr *et al*. [30], the availability and use of car safety systems by motorists has a significant impact on the death toll reduction. Poor car maintenance not only pose danger to drivers and the passengers of the car but also put other road users.

According Jawi *et al*. [31], there are three main area that contributes to issue of car maintenance.

a) cost – car users' economic factors.
b) supply – availability of inappropriate automotive parts resources; and
c) knowledge – car users' knowledge and awareness.

Lack of knowledge regarding car automotive or basic vehicle operation and specific needs of car are the lead of poor maintenance attitude. Hence, drivers maybe incapable to perform self-assessment on their cars, falling victim to irresponsible mechanics at workshop, unable to make the right decision for maintenance work and failure to appreciate a professional maintenance work [31].

III. RESEARCH METHODOLOGY

As shown in Figure 3, a waterfall approach is applied for this research and a flow chart is created to illustrate the research flow from one phase to another phase.

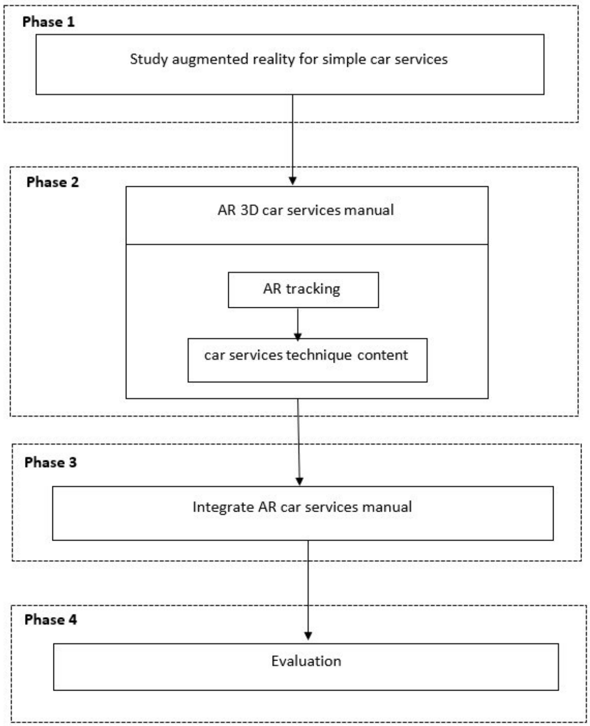

Fig. 3. Research Methodology

A. *Phase 1: Study AR application for car services*

The first phase of this research is to study augmented reality and car services to get to know and understand both part in details. The information of characteristics of AR and the process of AR is being focused during the study. The AR technology is being studied to identify the most suitable approach to be applied in this research regarding the tracking technique and the interaction technique. Besides, identifying related information on car services is also crucial.

B. *Phase 2: Development AR car services manual application*

Based on the information gathered in previous phase, this phase focused on the designing and developing the AR application for simple car services. The process of development in this phase is to achieve the stage where the application can display the car services technique in AR for user observation. Information that are gathered after the AR study are to be applied while developing this application. Moreover, finding the suitable hardware and software that suits the type of AR tracking and display and interaction is crucial. The graphic user interface (GUI) to provide accurate information for the user is also being focused on this phase.

a) Multi Marker Implementation

Vuforia Engine provide a software development kit (SDK) to build an augmented reality application for mobile devices. First step is to register an account on Vuforia Developer to have access to all Vuforia Engine. On the Vuforia engine developer portal, in developer tab, there are two manager that are license manager and target manager.

License manager that has active status provide a license key that need to copy and pass inside the augmented reality application. While target manager is used to create and manage database for targets or marker. For this research two database is created to provide a multi marker augmented reality application. Target that is added into the database can be an image, cuboid, cylinder or a 3-dimensional (3D) object. A pair of identical image target is added into the databases that has been created and ready to be download and import into the research.

b) Multi Marker Detection

After the Vuforia Engine package has been import into the application, functions provided by Vuforia Engine can be accessed. AR Camera asset is dragged into the hierarchy of scene in unity to enable the marker detection. On the AR Camera object, a basic license key is entered to unlock all the features and services to build an AR application. Then, an Image Target asset is added into the scene to be use as a marker.

The fiducial markers are arranged in the environment of the research to display the virtual object at its position. Inside the Image Target Behavior inspector, type of image target is set to database and the name of the database and image target to be use in the scene is chose. The database that has been download from the Vuforia Portal and imported into the application to be listed out in the database section for Image Target Behavior.

c) Interaction in AR

In this section, interactions that are created in this research is discussed. The first interaction is clicking virtual object via touching screen using ray casting. Next, interaction to drag virtual object to the right position.

i) Clicking Object using Ray Casting

A virtual label indicating the services for car component is display and user need to click on the label to start the car services procedure. This touch screen interaction is made possible using ray-casting in AR. Firstly UnityEngine.Events is added to script to detect events on the object. On mouse click or touch screen is detected as the input. Then, Ray is defined to start the ray casting and RaycastHit to detect the ray hit on the object.

A collider is added to the game object to be use as an indicator when the ray hit the game object collider. When ray hit the collider is detected, it will go to the next scene which is the choosing suitable tools for the service. Figure 4 shows the car maintenance services displayed when marker is scanned.

Fig. 4. Jump Start a Dead Battery Service

ii) Dragging Object using Lean Touch

Lean touch is an asset provided in unity for unity to enable dragging, scaling and rotate of virtual object. This asset can be downloaded for asset store for free and imported into the application. After importing package, numbers of script are provided to enable such manipulation. Just drag related script to the game object to enable the function inside the script. Script provided in this package that is use in this research is the lean drag translate to drag the right tools for the service to the car component.

Then Lean Touch object is added into the scene hierarchy so that dragging function provided in this package. Right click on scene hierarchy part in unity and choose Lean, then click touch. Next, the parameter for Lean Touch object such as Tap Threshold and Swipe Threshold is manipulated to suit the application requirements. Lastly click add simulator to enable the simulator. Then, on the game object that wants to be drag, add script Lean Drag Translate to enable the object to be drag.

Now the chosen tool that needs to be dragged has successfully been made, a range of its position needs to be set to give hint to users when dragging it around. The goal for this scene is to drag the tool toward related car components. First, the position of the tool is retrieved and if the position satisfies the if condition, it will alert the user with new direction. Every tool that is related to the dragging interaction has their own specific range. The reason for this is different tools have different sizes and positions. Thus, the range for each tool is different and needs to be unique.

As seen in Figure 5, if user drag the engine oil towards the left side, it will instruct user to move to the right. On the other hand, jump start a dead battery service's tool, the direction only includes drag to the right and drag downward. In Figure 6, when the x-axis parameter is more than 0, it asked the user to drag the jumper cable downward.

Fig. 5. Dragging Engine Oil Scene

Fig. 6. Dragging Jumper Cable Scene

To detect whether the tool has reached the car component position, Box Collider component is added to both objects.

Thus, when both colliders hit each other, it indicates that user has successfully dragged the tool towards the car component. Moreover, Is Trigger option under the Box Collider is ticked to enable collider trigger.

C. Phase 3: Integrate the AR car services manual on application

The third phase focuses on integrating the AR application with car services manual. After the tracking and registration is successful, the next progress is to focus on integrating the AR content on application to ensure that the application is displaying quality and accurate car service techniques for user beneficial. This AR application allows users to choose which type of car service technique they want to learn by pressing the technique. For instance, the car service techniques will hover on the parts of the car allowing the user to choose. After choosing the steps of procedure to service that specific car component.

Detailed step by step procedure is delivered to made sure that user can enjoy their learning experienced using this augmented reality application. To achieve an accurate car services technique, research is performed to collect information such as important and suitable tools and precautions regarding the services procedure that is important for user learning outcome.

As seen in Figure 7, explanations in writing and voice will be provided for user learning experiences. On top of that animation with related 3D virtual object is included to make sure that user will understand the procedure of the car services better. The right tools and animations are planned to make sure that there is no confusion in learning related car services.

Fig. 7. Jump Start a Dead Battery Steps

D. Phase 4: Evaluation

The final phase of this research focused on evaluating the AR car services application. User testing is mandatory to get feedback, suggestions, and comments from the user regarding the performance of the application. 10 targeted users from different genders and ages will be decided to ensure a quality response. All the targeted users should be a new driver or someone who is just about to take driver license to know whether the simple car services in this application can help teach new drivers about some basic car services. A questionnaire is provided for the participants to record the feedback on the application for future improvements and implementation on the applications.

IV. EXPERIMENT

This evaluation is design in order to understand the effectiveness of AR Application for Car Services as a new learning method. Thus, a set of usability testing and user acceptance testing is used to evaluate the effectiveness of the application.

A. AR Car Services Application Setup

1) Experiment Setup

This application was built to provide an AR application for car services to new drivers who wants to learn new skill about simple car services. Not to deny there are many car mechanics and services applications provided in the application store, but there are not many applications that use AR technology. The system is set up under the car hood where all the car components related to the services provided are at. The marker is placed close to the car component to display virtual car component and its services. Figure 8 below shows where the markers are placed under the car hood.

Fig. 8. System Setup

2) Procedure

User needs to stand in front of the car hood, while holding the handheld device using two hands and tilt the device toward the marker to improve AR. The handheld device should be about one front between the markers to get a better outcome. After user has finished with the experiment, a post-questionnaire will be given to be filled out.

B. Respondents

The testing is done on 10 respondents, four of whom are female and 6 of whom are male. These respondents consist of three people age below 17 years old, six people at the aged of 18 to 24 years old and one person that is 25 years old and above took part in the evaluation phase shown. These users are compelled to answer the pre-experiment questionnaire before testing the application to gather the basic information about the users. For preliminary testing, the number of participants is enough for this purpose [32, 33].

C. Post-Quistionnaire

Instead of asking a straightforward question, the post-testing questionnaire gives a statement and asks user to rate the statement from disagree to agree. Lastly, asked the user to leave any comment on the AR application.

The responses of the post-testing questionnaire are presented in a bar chart and a table that displays list of comments from respondents. The first statement gave to respondent is whether they think this application is easy to use and most of the respondents agree with the statement. Showed in the bar chart at Figure 9, 70% of the respondent rate highly agree that the application is easy to use. The remaining 30% also agree with the application easiness.

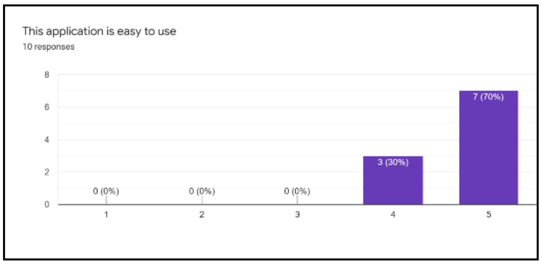

Fig. 9. The result on application easiness

Next statement is target to identify if user has encountered any problem during using this AR car basic maintenance application. Bar chart in Figure 10 shows that 40% percent of the user highly disagree with the statement. While another 40% percent of the user just disagree with statement, assuming that they may have countered a small problem. However, another 20% of the user highly agree that they encounter problem while using the AR application. Both users encounter problem during detecting the marker to display the car maintenance provided. These users have little experience using AR application thus causing the marker detection problem.

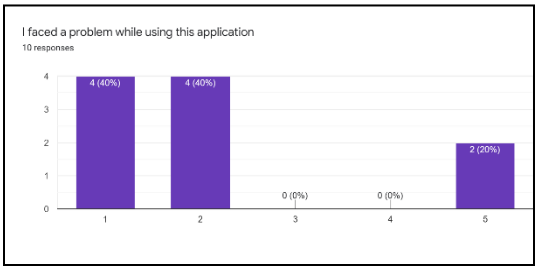

Fig. 10. The result on problem faced

As shown in Figure 11 shows that majority of the respondents which is 80% of the respondents highly agree that the GUI of this AR application is easy to use. However, another remaining of 20% also agree that the GUI of the application help user interact with application easily.

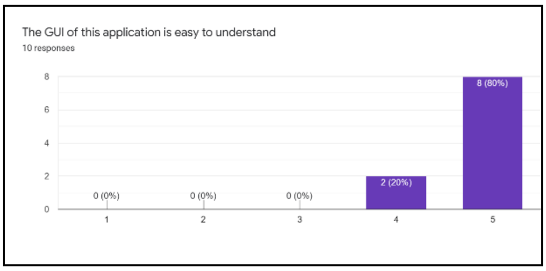

Fig. 11. The result application GUI

Figure 12 shows the scale agreeance on the level of easiness to understand the steps of the car services. The majority respondents which are 60% of the respondent rate highly agree on the steps of car services provided in this application is easy to understand. Another 40% of the respondents agree with the statement.

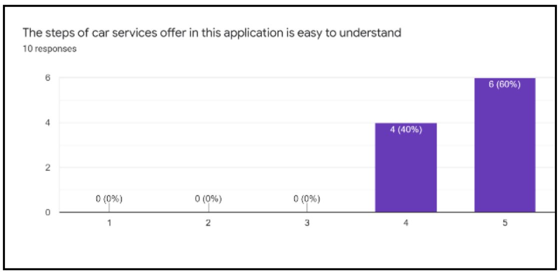

Fig. 12. The result on car services procedure

To identify whether this AR car service application help user gain knowledge regarding car services, questionnaire include a statement whether the application help user improve their car services skills. Based on Figure 13, half of the respondents highly agree that this application help them improve their car basic service skills. While another also agree with the statement.

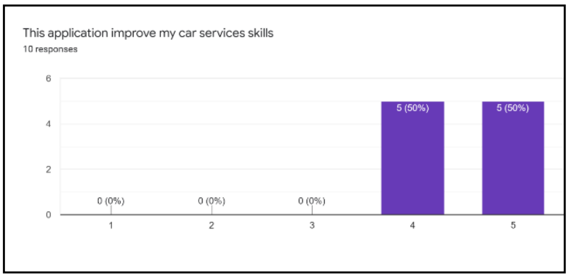

Fig. 13. The result on car services skill improvement

D. User Acceptance Testing

This section is about user acceptance testing by using black box testing. The participants were not informed about the testing that was done in the back room. When the participant used the application, the black box did what it was supposed to do by watching what the participant did. A comparison is made between the expected result and the actual result that was accomplished by the participant. Referring to table 1, there are nine actions that are anticipated by the participants. There are nine actions that are anticipated to be carried out by the participants. A check mark (/) will be assigned to actions that are successfully carried out, and a cross (X) is assigned to actions that the respondent is unable to carry out.

TABLE 1. Black-Box Testing Results

Action	Action From Respondent									
	1	2	3	4	5	6	7	8	9	10
Scan marker	/	/	/	/	/	/	/	/	/	/
AR button	/	/	/	/	/	/	/	/	/	/
Tools button	/	/	/	/	/	/	/	/	/	/
Drag tool	/	/	/	/	/	/	/	/	/	/
View drags direction	/	/	/	x	/	/	/	/	/	/
Read service step	/	/	/	/	/	/	/	/	/	/
Click Next button	/	/	/	/	/	/	/	/	/	/
Click previous button	/	x	/	x	/	/	x	x	/	x
Watched animation	/	/	/	/	/	/	/	/	/	/
Completed service	/	/	/	/	/	/	/	/	/	/

Every respondent had utilized the AR application for car services with great success. Everyone who used the application can navigate the application in the right way by touching on the appropriate buttons. Every single respondent was able to obtain the desired outcome with the AR application, scanning the marker, viewing the instructions, and following the instructions, respectively. One of the respondents did not read the direction information when dragging the tool to the related car component. While half of the participants did not click the previous button when viewing the car service procedure. The previous button is intended to bring user back to the pervious step of the car service.

V. Conclusion

In conclusion, this application successfully meets all of the three objectives of this research. The application also well integrated and able to help the new driver learn simple car services to self-service thier vehicle.

The limitation of this research is There are only two car services provided in this application that are adding engine oil and jump start a dead battery. Next limitation is the range of dragging position in this application is limited. Users need to stand at or near a specific spot so that the range of distance between the dragging tool and the car component are accurate. Based on the limitation of the research, suggestions to improve the research in the future are recommended. The first suggestion is to add more general car services to the application to add diversity and to help new driver self-service their own vehicle. The concept of the car services would be the same as the existence services in the application. Although depth research regarding the car services needs to be done to avoid any misleading information.

Next, my suggestion is to find the solution to provide a wider range of positions so that users can explore more on the AR application. For now, the dragging tool only covers a small area of the car. In the future, it would be better if the user could drag the tool to varying positions. Moreover, a new interaction idea could be added to create a more interesting learning process using AR technology.

Most importantly, improvement to the marker needs to be made to offer better marker detection for the user. The level of discomfort could be lowered if the marker is easily detected and does not take much time and energy. A more unique marker can be created to improve marker detection. A lot more interaction can be made if the marker could detect better.

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