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# An Augmented Reality Application in Healthcare: Coronary Artery Disease (CAD)

Rusnida Romli[1,2,*], Fatin Nur Hazwani Mohd Wazir[1], Nur Hafizah Ghazali[1,2], Nik Adilah Hanin Zahari[1,2], Safari Elis[3], Anizu Ariffin[3], Randi Rizal[4]

[1] Faculty of Electronic Engineering & Technology, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
[2] Centre of Excellence for Advanced Computing (AdvComp), Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
[3] KPJ Specialist Hospital, Bandar Baru Perda, 14000 Bukit Mertajam, Pulau Pinang, Malaysia
[4] Department of Informatics, Faculty of Engineering, Siliwangi University, Jawa Barat 46115, Indonesia

**ABSTRACT**

The use of Augmented Reality (AR) in Industry 4.0 is entirely in line with the principles of the fourth industrial revolution. This technology maximizes human perceptual experience and allows us to interact with information. Therefore, this research takes the opportunity to develop an AR application in healthcare that is related to Coronary Artery Disease (CAD). The purpose of using AR technology in disseminating CAD related information is that AR can attract the public attention as it is an interesting and sophisticated technology today. The scope of this research focuses on the human heart and aims to educate the public about CAD. Every stratum of society can use this application to get an overview of the human heart and they can also know the symptoms of having CAD. By using this AR technology, it can provide information in an engaging way and improve the user experience. The main objective is to study and develop marker-based AR apps in making an AR application in medical. The research was conducted using several proven existing applications that can help in building good applications. This research was designed and developed as a marker-based AR application using software like Vuforia to set the image marker, Microsoft Visual Studio to set the functionality of the application and Unity3D as the software that handles everything, supported by Android SDK software. Tests and evaluations have been performed and can provide information about CAD to the public. Overall, the AR-CAD application results are successfully generated to raise public awareness related of coronary artery disease.

***Keywords:***
Augmented reality; heart disease; healthcare; marker-based

## 1. Introduction

According to the World Health Organization (WHO), Ischaemic Heart Disease or also known as Coronary Artery Disease (CAD) is the leading caouse of death worldwide [1,17,18]. CAD is a common type of heart disease caused by atherosclerosis. Atherosclerosis is a disease characterized by plaques build up inside the arteries. Depending on the arteries affected, this can lead to stroke, myocardial

* *Corresponding author.*
*E-mail address: rusnida@unimap.edu.my*

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infarction (MI) or acute limb ischemia [10,11,15,16]. Some of the factors that can cause CAD can be controlled, such as cholesterol, diabetes and hypertension. However, some of the factors cannot be controlled, such as heredity, age, and gender . Therefore, it is important that the public is informed of the death of this World No. 1 [12]. There are several ways to disseminate information to the public. One of the ways is by using latest technology known as Augmented Reality (AR). AR technology will be used in this project as it can promote more effective understanding by providing information about heart disease.

Nowadays, AR has already become one of the biggest technological trends for all layers of society. In general, augmented reality is the combination of digital information with the user's environment in real-time. It connects the virtual and the real-world and also allows movements in three dimensions. AR is widely used in education, navigation, medical, entertainment, manufacturing, business and many more fields. In this project, augmented reality will focus more on healthcare, which can bring numerous benefits to humanity. By using the camera on smartphones, people can see the AR and enhance their AR experience. However, not all smartphones can display AR. For AR to appear on smartphones, the smartphone must support ARCore or ARKit. ARCore and ARKit are the platforms for developing augmented reality applications. ARCore is Google's offering while ARKit is brought by Apple. ARCore is for android users and ARKit is for iPhone users.

AR is revolutionizing health awareness campaigns by providing interactive and immersive experiences to educate and engage users. Through AR applications, individuals can interact with 3D models, animations, and simulations to understand complex medical concepts, visualize health risks, and learn about preventive measures. AR technology also enables healthcare professionals to enhance their skills through realistic training simulations, while wearables provide real-time health monitoring and feedback. Gamification techniques make learning enjoyable, and AR facilitates remote consultations, promoting access to healthcare services. Overall, AR is transforming how health information is communicated, empowering individuals to make informed decisions about their well-being and fostering healthier lifestyles. In this paper, a healthcare AR application of coronary artery disease was developed on an Android phone. This AR application provided a lot of information about CAD that can help the user to gain the knowledge and better understand this disease. Therefore, they can take the early precautions to have CAD.

## 2. Brief Review

AR can be defined as a technology that combines the real world and the virtual world that can be seen at the same time. By adding virtual computer-generated information to AR, a physical real-world environment that has been augmented in real-time direct or indirect can be viewed [2]. AR is interactive in real-time with a lot of virtual content. It is also registered in three dimensional that can make the virtual object appear in fixed space. Furthermore, AR involves with other technologies like a camera with sensors, depth tracking that calculates the distance between the device and the AR object and simultaneous localization mapping (SLAM). There are varieties of intelligent interaction including hardware device interactions, location interaction, tag-based or other information-based interactions in AR systems [3,14].

AR has six different types that can be dividing into two overarching categories [4]. The first category is triggered, and the second category is view-based. Triggers can be on a piece of paper or object markers, location-based, dynamic augmentations of objects and a complex augmentation. Complex augmentation is the combination of dynamic object recognition with GPS location. For the view-based category, it has indirect augmentation and non-specific augmentation. Table 1 shows the summary of all these types of AR that include the characteristics of each type.

**Table 1**
Summary of AR categories and types [9]

| Category | Type | Characteristics |
|---|---|---|
| Triggered | Marker-based: Paper | Paper marker activities stimuli |
| | Marker-based: Object | Most objects can be made into markers |
| | Location-based | Overlay of digital information on a map or live camera view, GPS may active stimuli |
| | Dynamic Augmentation | Meaningful, interactive augmentation with possible object recognition and motion tracking |
| | Complex Augmentation | Augment dynamic view and pull internet information based on location, markers or object recognition |
| View-based | Indirect Augmentation | Image of the real world augmented intelligently |
| | Non-specific Digital Augmentation | Augmented of any camera view regardless of location |

In today's digital era, AR becomes first popular with gaming and entertainment but now this technology was growing rapidly and already enters a lot of fields. Many applications were built year by year especially AR applications that can use using handheld devices. The existing projects that used AR technology had been researched [15]. Hereby Table 2 comes out with several reviews on AR systems related to healthcare especially about the human heart.

**Table 2**
Comparison between the existing systems

| Title | Advantages / Features | Disadvantages / Limitations | Tools / Software used |
|---|---|---|---|
| An Augmented Reality System for Image Guidance of Trans catheter Procedures for Structural Heart Disease [5] | - Embedded with voice recognition, hand gesture detection and combined with the 3D printed models | - Limited capability<br>- Expensive | Microsoft HoloLens, CT Scan, Materialise Mimics, Geomagic Wrap and Smart AR Glasses. |
| Cardiac: Augmented Reality [6] | - Heart rate calculating<br>- Combination between AR and IoT | - Limited information<br>- Only calculate the heart rate | Unity, Vuforia SDK, C#, Particle Photon, Arduino and laptop/smartphone. |
| Web based Augmented Reality for Human Body Anatomy Learning [7] | - Uses web application<br>- The users no need to install any application in their devices | - Not suitable for the users who does not have internet connection | Google Sketchup, 3Ds Max, ActionScript, C#, Kinect XBOX and laptop/smartphone. |
| Human Anatomy Learning Systems Using Augmented Reality on Mobile Application [8] | - Provided details explanations about the virtual object<br>- Enable users interact with it. | - Virtual object not animate | Floating Euphoria Framework, SQLite, Android Studio, AndAR, Unity, Vuforia and Android smartphones. |

## 2. Methodology

In this research, Unity Software will be the main software used to design augmented reality applications and an Android smartphone will be the main hardware to display the virtual augmented reality object. There are two known ways to create the augmented reality. The first way is using a marker, the second way is markerless-based. A marker-based technique is used in this project. Marker-based AR is a technique that allows the mobile device application to scan physical images,

render a 3D model and allow the user to interact with it through the device. This research uses a QR code as a marker and upload it to the Vuforia SDK to see the quality of the marker.

The marker and 3D model are edited in Unity Software. Microsoft Visual Studio with C# programming language is also used to write the program and control the functionality of the application. Once the design is ready, install it on an Android phone and then the Heart Augmented Reality Application will be available. Figure 1 shows the general block diagram of the research.

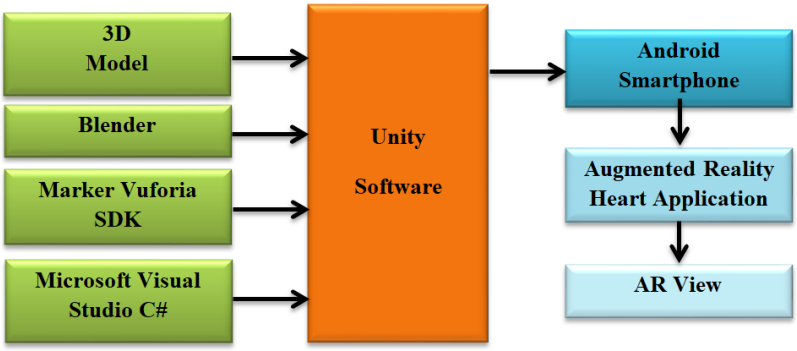


**Fig. 1.** The general block diagram of the research

The use case diagram shown in Figure 2 defines the functional requirements and interactions between the user and the AR CAD application. The use case diagram illustrates an overview of what users can do when using this app such as interact with the heart in 3D AR, perform self-assessments on having CAD, etc.

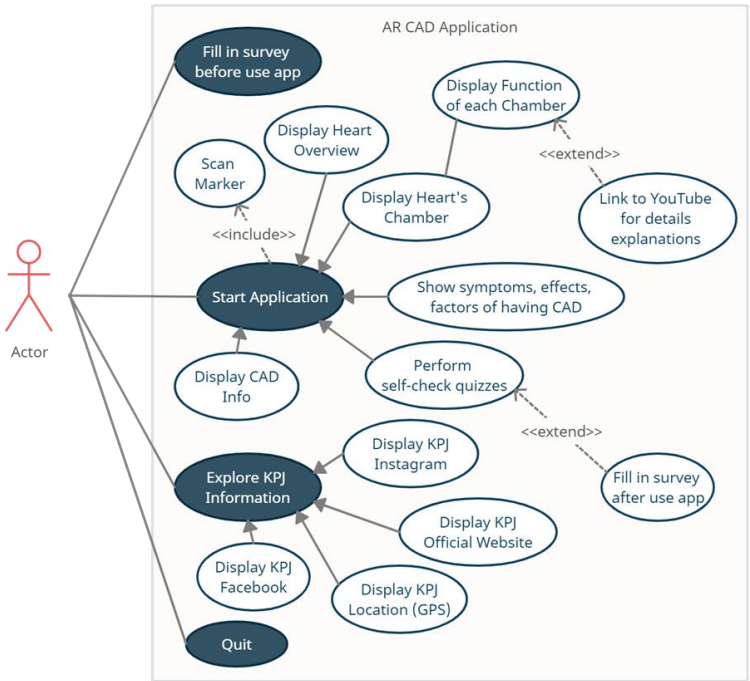


**Fig. 2.** The use case diagram of the research

Once the users open the application, they are presented with an interface that shows the app's main menu with various options such as starting the application, KPJ information and exiting. When users select the option to launch the app, the Vuforia's Camera will be automatically activated on the

smartphone. Once the camera is ready, the user must scan the provided target image to see the augmented reality. Target images represent images that the Vuforia engine can recognize and track. In this project, a QR code is created to be the target image. Therefore, the virtual object will pop out on that target image or also known as a marker. User can view the AR in terms of 3D virtual model, text, voice, etc. The AR has to do with the heart, such as the functionality of the chambers of the heart, the overview of the human heart, the awareness of CAD awareness, etc. Users also can choose from a variety of options in the application such as videos, self-assessment quizzes, etc. On the other hand, if the user wants to get information about KPJ, there will be a special interface for KPJ Penang information only. The information includes the location of the KPJ Penang, official website, etc. When users are done exploring the application, they leave it, but if they want to explore more, they return to the main menu options.

The option that the user can select via buttons in the application is like the information about the chambers of our heart. The human heart has four chambers namely the right atrium, right ventricle, left atrium and left ventricle. These all have their own buttons labeled with the 3D AR heart model. When the user clicks the button, a different scene is displayed. Suppose the user selects the right atrium button, then the text will explain the function of the right atrium and the video will appear explaining how the right atrium works. Apart from that, there are also buttons to see how the blood flow works in human heart. After knowing all of this, they will go to another stage, which is to learn about the CAD. They will see the video about CAD. Videos are preferred over text as videos can capture user's attention instead of reading the texts. After knowing what CAD is, the user is exposed to the factors and symptoms associated with it. This will give awareness to the users. There are self-assessment tests at the end of this application. There are several questions that the user must answer to verify if their heart is CAD free or not. If the users have the symptoms, they can take early precautions such as go to the nearest clinic or hospital to take further action because prevention is better than cure.

Evaluation of this application is an important thing. There are two parts of the evaluation that take place before and after the user uses the application. This step ensures that the developed application fully meets the software requirements and can achieve the project goal. To test the application, several formulas and calculations were programmed using code in Microsoft Visual Studio. For the user testing, this project used questionnaires as a method of evaluating the application. There are several criteria that need to be evaluated using the questionnaire, such as testing the functionality of the application, performance, reliability, usability and also testing user satisfaction.

## 3. Results and Discussion

The use of development software such as Unity 3D, Microsoft Visual Studio, Vuforia and Blender is very helpful in developing this AR application. Virtual AR objects are designed in Unity software and there are 3D objects that are modified using Blender such as heart models. The design of the application, like the main menu and user interface, is also designed in Unity Software. Materials from the Unity Asset Store were used to further refine the AR application. The design process is quite complicated and requires in-depth knowledge of AR and Unity. Microsoft Visual Studio, which uses the C# language, is very important for this application to work, since this code has the role of determining the history and operations performed on a software component. Script code is used to create virtual buttons, user interfaces, video controls, voice, animations and to control the movement of each virtual AR object within the scene.

### *3.1 Image Marker Registration*

This section describes how AR works using marker-based techniques, including how AR can be displayed when features found on the marker are triggered. If the AR marker is not present, users cannot see the virtual object even if they have the AR application installed on their smartphone. Therefore, the AR marker is a very important indicator to view virtual objects. The marker has a unique visualization that can be recognized by the Vuforia Engine to display the virtual on the user's device screen. The target image is of course checked against the Vuforia database. Vuforia Engine recognizes an image as long as the image is at least within the camera's scanner range. If the marker can be recognized, all designed virtual information can be displayed.

For this research, the QR code was chosen as a marker because the QR code has its uniqueness that the scanner can distinguish. Using a QR code will make the virtual information displayed on the user's device screen more stable. The QR code is uploaded to the Vuforia website and then registered as a marker, also known as a target image. Once the marker is uploaded, Vuforia will evaluate it and give it a star rating based on the quality of the marker. There are five levels of stars. If the marker gets 5 stars, it means that the marker is very good to use. If the marker gets 0 stars, then the quality of the marker is very poor and very unsuitable for use. This means that higher star levels can provide more accurate results and the detection or recognition process becomes easier. Figure 3 shows the marker used in this project, filled with yellow dots to indicate that Vuforia is detecting areas and then displaying virtual AR objects on the user's screen. Hence, if the user points the camera of their smartphone at this marker, all designed virtual information is displayed on this marker.

**Fig. 3.** Project's marker

### *3.2 Virtual Object Design*

In this section, the construction of virtual objects will be described in detail using Unity 3D. After registering a marker in Vuforia, the next step is to create virtual information such as words, models, images or videos that will be displayed on the marker when recognized by the device's camera. A lot of virtual object design has been created. For example, Figure 4 shows a virtual object that is a 3D heart designed in Unity scenes by placing it on the marker so that user can see the same. The Vuforia database package must first be downloaded and then imported into Unity to use it. Not only the Vuforia database must be imported, but all assets like photos, 3D models and more have to be imported into Unity.

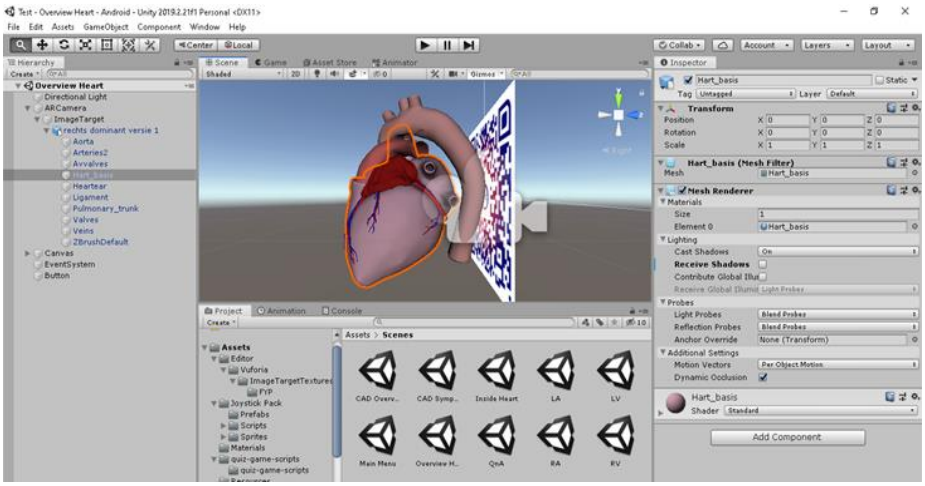

**Fig. 4.** Design for the overview of 3D heart model

Figure 5 shows a 3D model depicting a visualization of the appearance in a heart that was edited using Blender software and then imported into Unity. Subsequently, the model was designed by labeling specific parts using 3D text and 3D shapes in Unity. The 3D text in the figure has a function like a button that can be pressed. When the user presses the word, it will go to the next scenes. Subsequent scenes will come out depending on what the user has pressed. This project uses formats that can be supported by Unity such as fbx, obj, png and several other formats. There are also assets imported from the Unity Store such as Joystick packs and user interfaces

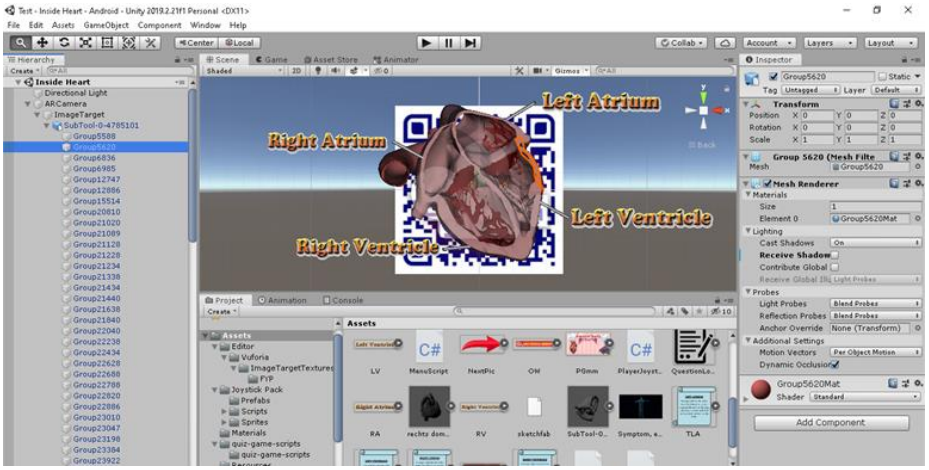


**Fig. 5.** Design for the overview of 3D inside heart model

### *3.3 User Interface of Application*

Aside from creating virtual objects, the intelligence for these applications detects whether markers can be detected or not have been designed. If the marker cannot be detected, the application will display “Scan Marker”. To create this design, it requires the C# script to program it in Microsoft Visual Studio. There is also a virtual video design that explains CAD, symptoms and effects of suffering from it. In addition, users can also gain experience answering quizzes virtually. The design for the AR quizzes questions shown in Figure 6. To control the video and quizzes, C# scripts were also used.

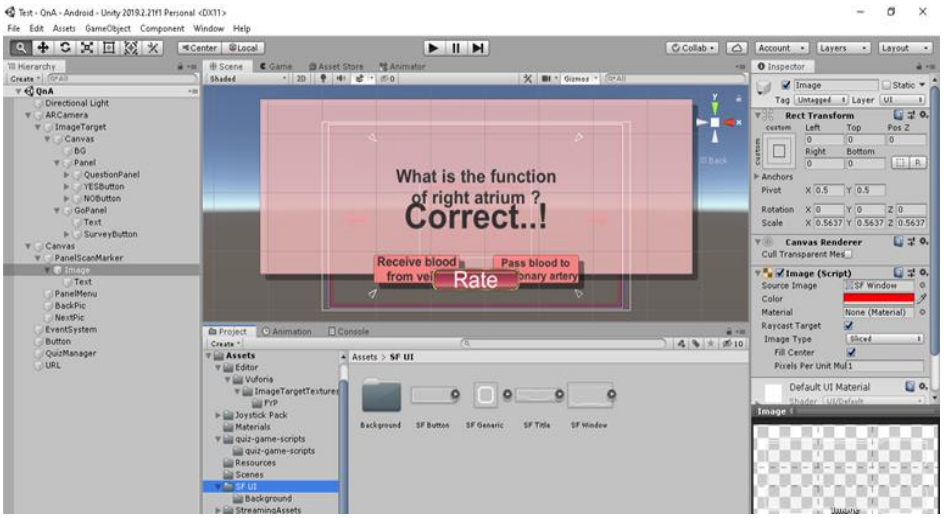


**Fig. 6.** Design for the AR quizzes questions

As soon as the user presses the icon of this application to open it, the main menu display will come out as shown in Figure 7. There are 3 buttons displayed, namely Start Application, KPJ Info and Quit buttons. The code scripts created and program it to make each button work properly. When the user presses a button, it will switch to another scene.


**Fig. 7.** Design for the Main Menu interface

Main Menu is the first interface that will be displayed as soon as the user opens this application. There are 3 options, Start Application, KPJ Info and Quit. At the right side, there are survey questions that users can answer before using this application. If the user clicked the icon of the survey question, the app will be linked to the google form. The user can answer all of these questions first before exploring more about this app. The function of this survey question is to check whether the public knows about AR and CAD or not. If the user selects the KPJ Info button, the KPJ scenes will appear. There are several social media of KPJ Penang. If the user clicked any of the buttons, it will go to the particular selected websites. Figure 8 shows the overview of the human heart. At the bottom right, there is a control joystick that the user can interact with the heart and play around by moving or rotating the heart to see how the human heart looks like.

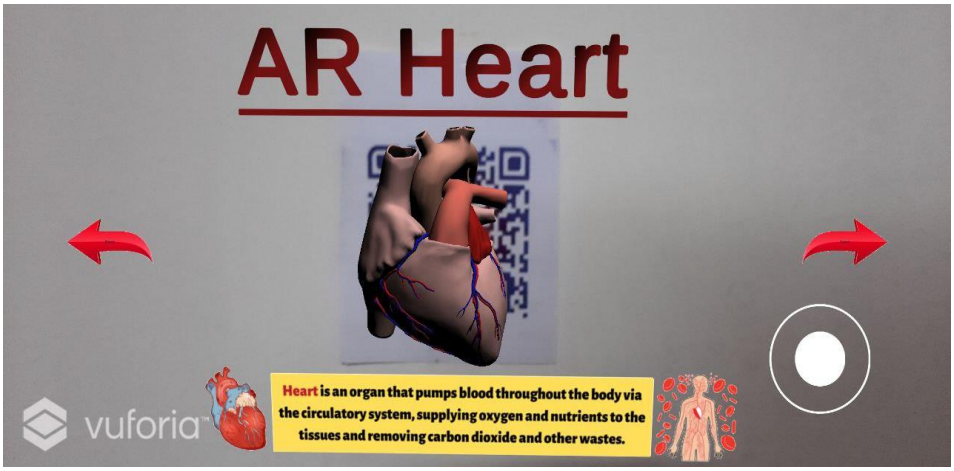


**Fig. 8.** The AR overview of the human heart

Other than that, there are scenes shows how the inside heart looks like and labelling the chambers. There are 4 chambers inside the heart. Each chamber has its functionality. Therefore, the user can click on the name of each chamber to see the functions. Let say the user clicked on the Right Atrium name, the scene will display about the right atrium that describe the function of the chamber's part. If they want to know more about the chamber's part, they can click on the button provided. If they clicked the button, they will be direct to YouTube because the button is embedded with the YouTube for the specific Uniform Resource Locator (URL) link.

Next, there are scenes that have an AR video that explains CAD by the cardiologist. By watching the video, the user will know what is CAD and can find out how dangerous it is. There is also a visualization of what happens if a person has a CAD attack. Scene in Figure 9 also has an AR video that explains the symptoms and effects of having CAD. By watching this video, the user will know about it and hopefully, they will take precautionary steps to avoid this disease happened to themselves. Factors of having CAD are shown in AR view.


**Fig. 9.** The AR video of symptoms and effects of having CAD

After viewing all the videos and AR virtual objects, users can answer self-check questions about whether they have CAD symptoms or not. Several questions will be asked and they need to answer these questions by clicked yes or no. After answering all the questions, the results will come out. Users will get results whether low risk or high risk. If they are at high risk, they will be aware and can make further examinations at a nearby hospital. Lastly, the user also can rate this app. If the user

clicked the Rate button, the app will be linked to the google form. The user can answer all these questions after they finish exploring this app. The function of this survey question is to get feedback and outputs from users after they use this app. This is also to compare the impact or effects before and after the use of this application.

Once the application is developed, testing on the effectiveness of the AR CAD application to the public should be conducted. Application testing was conducted on the public around the residential area. Tests are performed to analyse the position of virtual information and the dissemination of knowledge related to CAD to the user. There are three phases that users must go through, the first phase is to answer the question before using the application, the second is to explore the application and the last is to answer the question after using the application. There are 15 respondents that involved in this survey. Table 3 shows the percentage (%) of the overall results from the conducted survey.

**Table 3**
Overall AR CAD Application results

| Features from user testing | 3 (% Neutral) | 4 (% Agree) | 5 (% Strongly Agree) |
|---|---|---|---|
| Level of knowledge delivery | - | 26.67% | 73.33% |
| Level of application convenience | - | 13.33% | 86.67% |
| Level of position and understanding on virtual information display | - | 20% | 80% |
| Level of user's AR experience | 6.67% | 13.33% | 80% |
| Level of App rating | - | 46.67% | 53.33% |

## 4. Conclusions and Future Works

In general, this research can help to spread AR technology to the public. This application project is user-friendly and easy to use by every layer of society. The application that had been developed is easy to understand and straight to the point. Since it is used marker-based technique, it is easy for the public to use it especially to the senior citizens. They just require scanning the marker. By using Vuforia to register image markers, Unity 3D to create AR information, Blender to edit 3D objects and Microsoft Visual Studio to enable various functions in the application, then this AR CAD application can be created and developed successfully.

AR is a technology that is developing and evolving nowadays. AR can provide useful and interesting information not only in the field of healthcare but also in other fields such as manufacturing, business, advertising, education and many more. AR can attract the interest of many people. It can visualize objects that cannot be seen by the human eye because it is in virtual form. Therefore, the final project testing was successfully done without any waste, adverse effects, or dangers. The achievement of the results is very encouraging if seen from the survey results that had been tested by some users.

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