Development of mobile markerless augmented reality for cardiovascular system in anatomy and physiology courses in physiotherapy education

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***Abstract*—This paper focuses on the development of markerless Augmented Reality (AR) using ARCore platform, where interactive three-dimensional (3D) content was designed and developed based on the learning outcome syllabus to enhance the visualization and understanding of the anatomy and physiology for cardiovascular system topic. Currently, learning method is based on 2D images and slides, plastic models and cadavers have to deal with students' experience issues such as lack of interactive, uneasy feeling with dead body and cadavers storing and donation. Therefore, more advances using technology such as Augmented Reality (AR) in learning method are needed to overcome the current gap and enhance the students' learning. Thus, this study aims to develop markerless AR specifically focus on the cardiovascular system for undergraduate physiotherapy program at UniKL, RCMP. In this study, we describe a method used to create markerless AR content using 3D data from MRI images and 3D unity as an authoring tool. We present three processes, where the first design consideration based on author's previous works derived from systematic search strategy were outlined, the second 3D model was developed using a real object and subsequently converted to an AR asset that can be linked to a unique markerless using ARCore platform and the third AR content creation using 3D unity authoring tool. This application provides a better visualization for the anatomical parts to support for an innovative and flexible learning process. We have successfully analyzed the design consideration using a systematic search strategy and developed the markerless AR specifically for cardiovascular system in anatomy and physiology courses. This study has contributed to knowledge in design and development of AR used in physiotherapy education. Therefore, this will be a step forward to an exploration of design-based research for an AR benefit in experienced-learning approach application.**

Keywords—augmented reality, markerless AR, ARCore, physiotherapy education, anatomy and physiology, cardiovascular system

I. Introduction

Anatomy and physiology are one of the important courses, which are formally taught to the physiotherapy students. Generally, this subject help students to identify the specific structures of bones, muscles, tendon, ligament, joint and other soft tissues [1]. The main educational objective of this course is to provide knowledge on human anatomy structure and system, which is important to determine physiotherapeutic treatment and skills. In Universiti Kuala Lumpur, Royal College of Medical Perak's (RCMP) Diploma in Physiotherapy Program, anatomy and physiology learning activities involve with lecture-based teaching, using artificial bones and performing clinical tests on human cadavers. The traditional anatomy and physiology learning method which is based on 2D images and plastic model materials were taught by didactic lectures, while the use of cadavers is limited due to the issues such as storing, morality, public perception as well as reduction in cadaveric donation [2], [3]. Even though, the use of cadaver dissection allowed students to view the human anatomy structure, however students may experience the feeling of stress and anxiety because the patient is a dead one [3], meanwhile the physiology could not be observed on the dead organ. Therefore, more advances using technology such as Augmented Reality (AR) in learning method are needed to overcome this gap and enhance the students' learning.

The emerging technology such as AR which uses three dimension (3D) has given a better view for anatomical education. The use of AR with the optimization of ARCore as Software Development Kits (SDKs) allowed better experience for learning in merging the AR and real-world environment. Hence, with an improved understanding of the real-world environment, ARCore platform can make any horizontal or vertical surfaces in the real world to act as a plane to anchor the 3D objects with markerless AR. The AR has continued to improve learning experience by providing teaching aids which offer a close likeness to the human body which relates to its structures and functions [4]. The use of AR in education can improve teaching and learning in many ways. One of the most significant development is that, it enables students to obtain knowledge and better understanding of the human body within a virtual environment allowing users to manipulate action such as modify objects size in the virtual environment, which is the most important point for the student as this is impossible to accomplish in reality. Hence, through 3D interface technologies specifically AR, the digital content can be design and developed to simulate learning context, which might be difficult to realize and provide learners an experience-based learning environment [5].

Therefore, this study aims to develop markerless AR specifically focused on the cardiovascular system for undergraduate physiotherapy program at UniKL, RCMP. This

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paper presents three processes in the development of markerless AR, where the first design consideration based on author's previous works was derived from systematic search strategy, the second 3D model was developed using a real object and subsequently converted to an AR asset that can be linked to a unique markerless for ARCore platform and the third AR content creation using 3D unity tool. Hence, this study will contribute to the overall understanding from the design perspective in the AR development.

II. Markerless AR and ARCore Platform

In the year 2017, Google as one of the giant companies for mobile industry introduced an application programming interface to support AR creation for mobile devices, namely ARCore platforms, which allowed Android devices with new opportunities to develop immersive applications [6]. The ARCore features include environmental understanding, motion tracking and light estimation provide capabilities to integrate virtual content with the real world through the mobile's camera. This study employed the features of environmental understanding which enables mobile devices to sense its environment through size and location of surfaces such as ground, walls or coffee table to be detected for environmental understanding [7]. With this feature, users are allowed to place objects, annotations or information in a way which enables to integrate seamlessly with the real world by detecting feature points and planes, which appear in common horizontal or vertical surfaces such as walls or ground and turn these surfaces to mobile devices as planes. Thus, using this information virtual objects can be placed resting on the flat surfaces. Fig 1 shows the example of markerless AR with surface detection using ground floor.

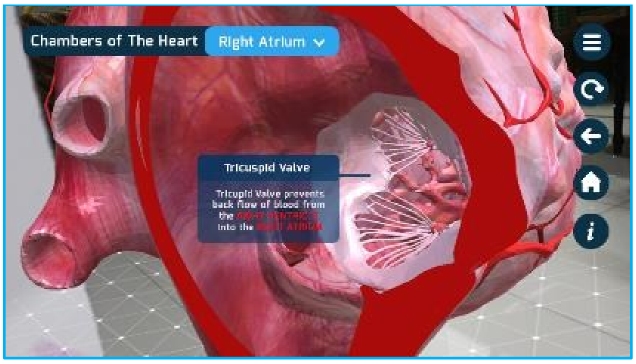

Fig 1. Surface detection using ground floor environment

Compared to marker-based AR which requires the device's camera to first recognize the distinctive picture or shape which later allows the information to appear or start immediately. This distinctive picture which can be recognized by the device, is defined as the marker. A marker can consist of one or more basic shapes using black and white or colors with contrast between them to allow proper recognition by a camera [8]. As a result, limitations on the marker-based that can be used need to remain basic or simple shape for error correction and better detection. Fig 2. Shows the example of marker-based pattern using a simple shape.

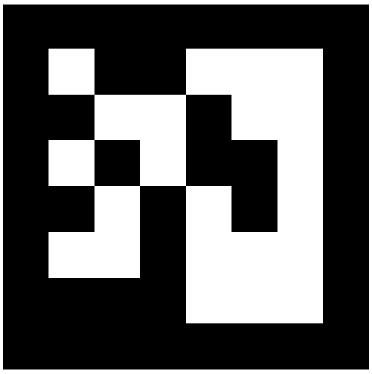

Fig 2. Simple shape of marker-based AR

III. Design Consideration for Markerless AR of Cardiovascular System

The development of AR application specifically for education field offers capabilities such as interactivity and learner control as an advantage to the learning process. Thus, it can be said that when a well-designed development is implemented properly, such materials have the potential to enhance learning [9]. Even though the development of AR application has many potentials, the construction of the AR content has become a major obstacle because of its complexity of the educational design in providing effective learning. Thus, crucial design plan are required to guarantee the final outcome is effective and efficient [10]. Therefore, through the systematic search strategy this study has performed a thorough literature search from 2016 until 2018 using the database namely Medline, Pubmed, SCOPUS and CINAHL The objective was to locate published articles which focused at the essential design consideration used in the AR development specifically for the anatomy and physiology course in the undergraduate physiotherapy program. Table 1 describe the component analysis used in the systematic search strategy [11], meanwhile Table 2 define all search terms use in the search strategy.

TABLE 1. Component analysis for the systematic search strategy

PIO	Search strategy
P (Participant)	To involve all studies that evaluating population or person, which receive, or using AR technology in physiology for physiotherapy education
I (Intervention)	Digital media program in physiotherapy education included hybrid or blended learning approach
O (Outcome)	Change found in attitudes, knowledge or skills after mix-media intervention. Behaviour of participants in terms of learning transfer to the workplace. Reaction of participants on views, perspective, satisfaction and experiences about mix-media application.

Table 2. Search terms use in search strategy

PIO search strategy	Search terms
Search databases (List of scholarly online indexing and abstracting databases):	MEDLINE, CIHAHL, PUBMED, SCIENCE DIRECT, ERIC, PSYCINFO
Participant (P)	Physiology, Physiotherapy students, physiotherapist
Intervention (I)	Augmented reality, mixed-media, virtual reality, new media design
Outcome (O)	Design characteristic, application design, application development

To gain varied insights into the design and development of AR cardiovascular system the data then were analyzed using cross-case synthesis approaches [12] which treats each individual written materials as a separate study. Thus, using the checklist criteria proposed by [13] are used as a basis for design consideration in this study. Table 3. explained the results retrieved from the literature search and used for the design consideration.

TABLE 3. Design consideration for AR cardiovascular system derived from systematic search strategy

Checklist criteria [13]	Definition
1. Interface design	Information presentation: • Effective learning through the presentation of 3D organ which provides actual object position in human body together with explanation [14]. • Provide information about organ system and its function [15]. • Use realistic images and smooth object transition between one object to another within a 3D view angle [16]. • Provide 3D digital model to represent the real human anatomy [17].
2. System Input and Feedback	Selection & Control of the System: • ~~Use accurate trackable image for object interaction and~~ enable user to choose from menu selection [14]. • Allow user to modify virtual structure position to offer different perspective of the subject matter [17], [18] • Non-linear navigation to offer free navigation within the application [16].
3. Text Overlay	Standard ergonomic requirements : • Provide labels with relevant information to assist greater understanding and retains memory [16]. • Provide description panel which contains more information about the subject [16].
4. Audio Content and Speech Recognition	Content relevance & system control: • Use of instructive audio as complement to support 3D digital model [18].

Results retrieved from this systematic strategy were then used as design input in the development of markerless AR specifically focused on the cardiovascular system. Each of the design consideration found in this activity has been designed properly for the effective design output in the markerless AR application.

IV. Materials and Methodology

This study presents a systematic design approach to AR content creation which comprises two processes: creation of 3D models from MRI object using 3Ds max application, conversion of the 3D model into AR asset using 3D unity and create the interactive interface with design consideration from the literature search. The proposed methodology is shown in Fig 3.

A. *Three Dimensional (3D) Creation*

The following figure illustrates the method used for the AR content in this study. Adapted from [19] work, firstly, a real object of heart anatomy will be scanned using MRI for reconstructing 3D modeling. To create a realistic human heart anatomy, texturing process were done. Next animation is created for the 3D model. The Autodesk 3ds Max software is used for 3D modelling development, creating the texturing, and animation process. The cleanup of 3D model then was imported into Unity software using fbx format. Two types of adjustment will be done on the 3D model and layout. The programming language of C# scripting is used for navigation and user interactivity, while debugging process is performed to identify issues and problem in the Unity development.

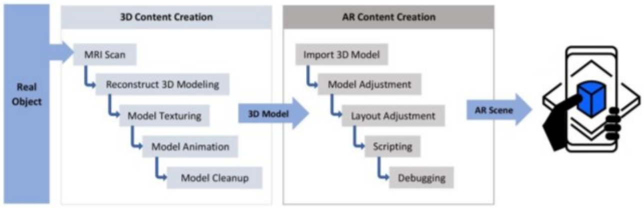

Fig 3. AR creation method adapted from [19]

Fig 4. describes the AR process which starts with identifying real object of the cardiovascular organ, which then is scanned to retrieve the MRI image. Based on the MRI 3D modelling was constructed, later texturing is applied to create a realistic model of cardiovascular for the AR application.

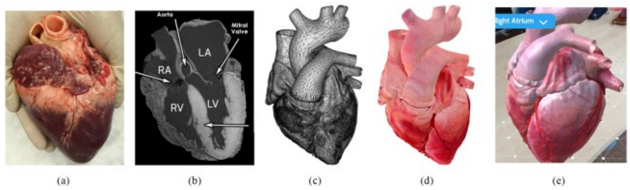

Fig 4. AR creation process (a) real object, (b) MRI image, (c) 3D model, (d) texturing, (e) augmented reality.

The final and clean up model in fbx extension then were imported into Unity and become an asset for the AR content development. The development use Unity as an authoring tool software to create the interactive content and integrate ARCore package which uses the features of environmental understanding to enable the AR experience. Although many AR tools development such as ARToolkit, Vuforia, Wikitude and Maxst are available, we selected Unity software because of the flexibility and high performance end-to-end development platform which allowed to create rich interactive AR experiences [20]. The following section describes the AR prototype for the cardiovascular system with explanation of each design consideration found from the systematic search strategy through the previous works.

V. The AR Prototype

The AR prototype of cardiovascular system have been designed carefully with the design consideration proposed through the systematic search strategy and subsequently employed a proper method for the 3D and AR content creation. Based on the [13] works, proposed four criteria checklists as design guideline specific for cardiovascular system in AR development namely interface design, system input and feedback, text overlay and audio content and speech recognition. The first design consideration on interface design as shown in Fig 5. shows the interface design used to present the information for the cardiovascular system: (a), (d) The representation of 3D organ was developed based on the MRI images which provide actual object position in human body and resembles as close as to represent real human anatomy [14], [17], meanwhile (b) The explanation using annotation provide information about organ system and its function [15],

(c) The interface allowed smooth transition between one part to another within a 3D view angle for better visualization of the inner and outer part of the cardiovascular system.

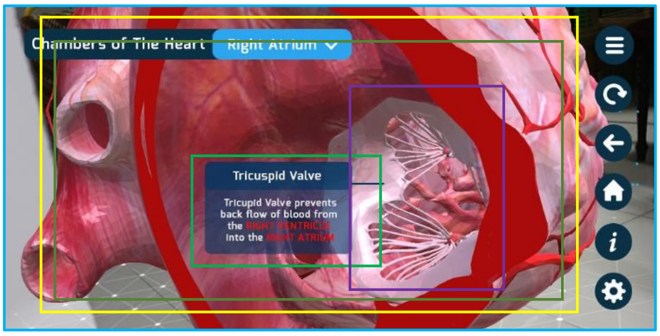

Fig 5. Interface design for information presentation

Secondly, the design consideration for system input and feedback which focuses on selection and control of the system is shown in Fig 6., informed that (a) enable user to choose from menu selection [14], (b) Allow user to modify virtual structure position to offer different perspective of the subject matter [17] and (c) Use non-linear navigation to offer free navigation within the application [16].

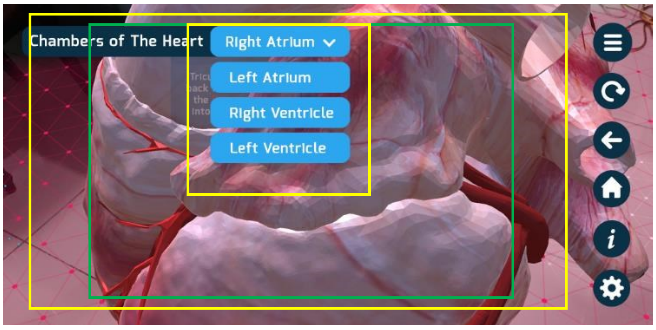

Fig 6. System input and feedback for selection and control of the system

Thirdly, for text overlay used standard ergonomic requirements which (a) provide labels with relevant information to assist greater understanding and retains memory and (b) provide description panel which consist of more information about the subject [16].

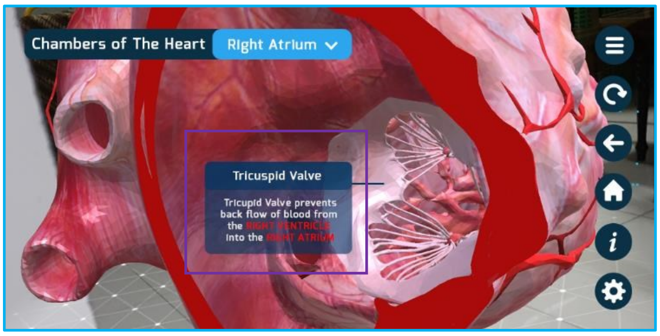

Fig 7. (a) Text overlay using ergonomic requirements

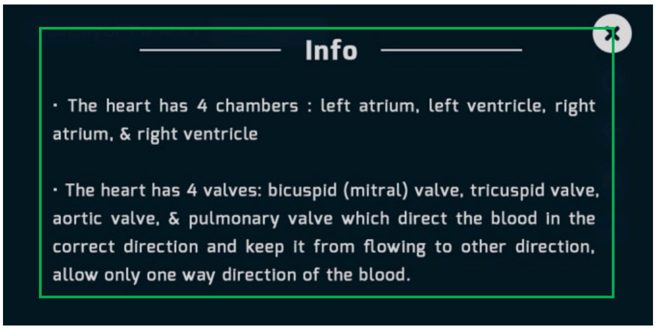

Fig 8. (b) Text overlay using ergonomic requirements

Fourthly, for audio content and speech recognition use with content relevance and system control which employed (a) instructive audio as complement to support 3D digital model [18].

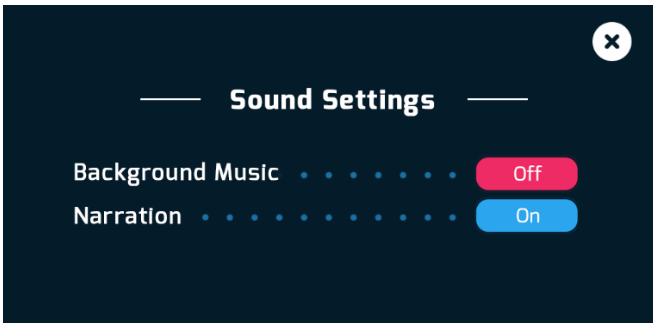

Fig 9. Audio content & speech recognition with content relevance & system control

VI. Conclusions and Future Work

The research aims to design markerless AR using ARCore platform from the view of instructional designer; hence the study has defined a proper research-based design practice set-up for the development process which specifically focus on anatomy structure learning by immersing students in augmented reality environment. We have successfully analyzed the design consideration using a systematic search strategy and developed the markerless AR using ARCore platform specifically for cardiovascular system in anatomy and physiology courses. This study has contributed knowledge in design and development of AR used in physiotherapy education. Therefore, this will be a step forward to an exploration of the AR benefit in experience-based learning approach application.

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