World Academy of Science, Engineering and Technology
International Journal of Medical and Health Sciences
Vol:16, No:9, 2022

MR-Implantology: Exploring the Use for Mixed Reality in Dentistry Education

Areej R. Banjar, Abraham G. Campbell

Abstract—The use of Mixed Reality (MR) in teaching and training is growing popular and can improve students' ability to perform technical procedures. This paper outlines the creation of an interactive educational MR 3D application that aims to improve the quality of instruction for dentistry students. This application is called "MR-Implantology" and aims to teach and train dentistry students on single dental implant placement. MR-Implantology uses cone-beam computed tomography (CBCT) images as the source for 3D dental models that dentistry students will be able to freely manipulate within a 3D MR world to aid their learning process.

Keywords—Cone-Beam Computed Tomography, dentistry education, implantology, Mixed Reality, MR.

I. Introduction

MR provides the user an unobstructed view of their real surroundings and a HMD overlays digital imagery with elements of interactivity between the two [3]. This ability to integrate both real and virtual objects can prove to have tangible benefits in the creation of interactive 3D educational applications [5]. Developments in digital dental solutions have been readily adopted in both the clinical dental field and dental education. This trend will continuously challenge both conventional dental clinical practice and learning strategies in dental education [2]. Educational applications can improve dental students' ability to perform a technical procedure such as dental implant placement [6] in VR but this work has not been examined in AR.

In this paper, we present an interactive MR educational tool for learning and practice for single dental implant placement using cone-beam computed tomography (CBCT) images. This work differs from prior explorations by using an MR device and examining how CBCT images could be used as the source to generate the 3D model. CBCT systems are used by dental professionals to capture data using a cone-shaped X-ray beam, these data are then used to reconstruct a three-dimensional (3D) image which can be used to examine dental, oral and maxillofacial regions.

The objective in the creation of MR-Implantology is to aid dentistry students in completing the follow learning objectives:

- Interact with 3D model of real patient's CBCT scanning.
- Define and analyze patient's CBCT case
- Define and characterise human teeth and name each one.
- Study dental implant tools and their function.
- Identify the differences between natural teeth and dental implants.
- Recognise and characterise dental implant components and their functions.
- Demonstrate an understanding of the dental implant operation procedure.

A. R. Banjar is with the the School of Computer Science, University College Dublin, Belfield, Dublin 4, Ireland (phone: 353833668816; e-mail: areej.banjar@ucdconnect.ie).

A. G. Campbell is with the School of Computer Science, University College Dublin, Belfield, Dublin 4, Ireland (e-mail: abey.campbell@ucd.ie).

II. Methodology

A. System Overview

This system uses Unity as the game engine for application development. We also use Vuforia as the software development kit SDK, with C# as a programming language for developing the key feature of the application. The application aims to be run in MR head mounted displays (HMDs) such as Microsoft HoloLens 2. Fig. 1 illustrates a system overview.

This tool allows dentistry students to visualise the 3D geometry of the digital 3D models to introduce fundamental implantology knowledge. Alternatively, the system may use markers created by a Vuforia engine to import CBCT images from the patient's files in a database and to determine the location or position of the 3D object. The resulting MR engine allows students to explore and investigate dental implant structures as components, and tools, and to understand the mechanics of an implant operation. Furthermore, the students can integrate the 3D implant components and adjust the position of the dental implant replacement into CBCT model. The position of the marker is observed using sensors or eye cameras in the HMDs. Data are sent to the MR engine, which is a data transmitter. The data can then be viewed through a software or processor.

In this system, digital content can be signalled through gazing and hand gesturing. To implement the instructions, students gaze at the targeted components and then perform any of the HoloLens' core hand gestures. The developed application allows students to view the structures of 3D models of human teeth and dental tools. The digital model can be transformed, as well as scaled, translated, and rotated, to enable students to explore its structure. Furthermore, when a component of the digital model is selected, a text description of the component is displayed. Students not only experience digital content but are also supplied with text descriptions for enhanced learning.

B. Materials

Apparatus: Our setup was built on a laptop computer (Lenovo IdeaPad L340 Gaming, Intel Core i7-9750H CPU @ 2.60 GHz, 9th Gen, x64-based processor, 8 GB RAM,

World Academy of Science, Engineering and Technology
International Journal of Medical and Health Sciences
Vol:16, No:9, 2022

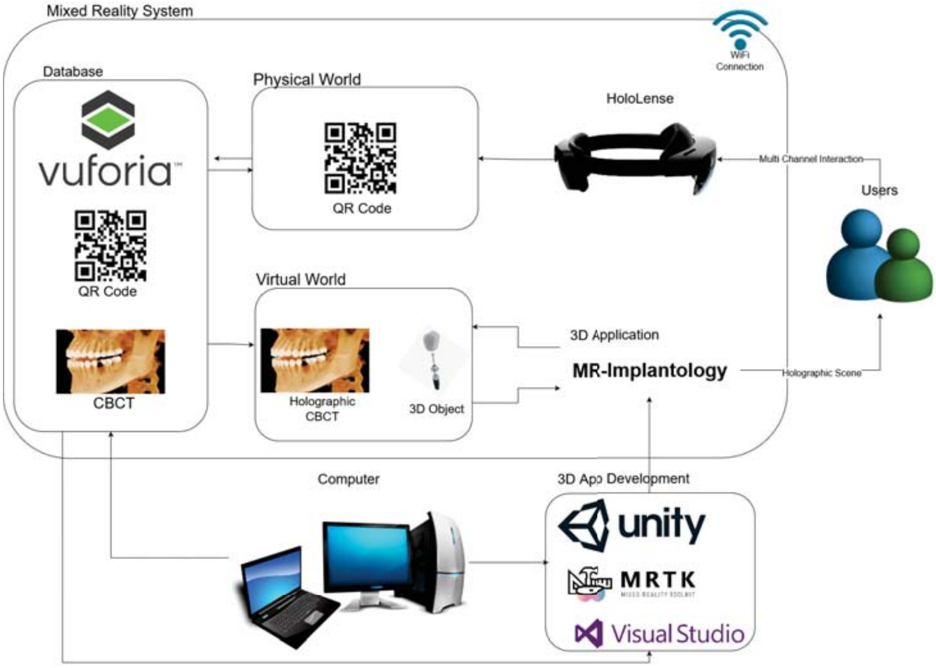

Fig. 1 System Overview

NVIDIA GeForce GTX1650) running Windows 11, and the application aims to be run on an MR HMD like the Microsoft HoloLens 2.

Unity 3D: Unity is a cross-platform game engine that can be used to create real-time 3D projects. It is chosen as the development environment because of “rapid development and deployment capabilities” according to Kounlaxay [4]. For this application, we use Unity version 2020.3.25f1, which supports Universal Windows Platform Build Support and Windows Build Support (IL2CPP). The computer language used in the program is C#.

MRTK: We use the Mixed Reality Tool Kit (MRTK), an open-source development kit for mixed reality applications, originally designed to develop software for the Microsoft HoloLens devices. It provides a cross-platform input system, foundational components, and common building blocks for spatial interactions. MRTK version 2 intends to speed application development for the Microsoft HoloLens, Windows Mixed Reality immersive (VR) headsets, and OpenVR platform [1].

Vuforia: Vuforia Engine [1] is used to build Augmented Reality Android, iOS, and UWP applications for mobile devices and AR glasses. Apps can be built with Unity, Android Studio, Xcode, and Visual Studio. The Vuforia Engine can be imported into the Unity project and it is used to create markers for AR applications. Once a target marker is detected by Hololens, it displays the information stored in Vuforia database.

3D Slicer: 3D Slicer[2] is an open-source software platform for medical image informatics, image processing, and 3D visualization. It can generate 3D models of DICOM files that can segment the DICOM data automatically and create individual models with different tissues and layers. The software imports DICOM data from dental CBCT scanning and exports the 3D model as a STereo Lithography (.stl) file to be processed (cleanup, simplify, re-mesh, and smooth) by another tool.

Blender: Blender[3] is an open-source software for 3D model creation and modification. It supports the entirety of the 3D pipeline—modeling, rigging, animation, simulation, rendering, compositing and motion tracking, in addition to video editing and game creation. The noise of the raw 3D model is cleaned manually using Blender. Then the decimation modifier is used to reduce the vertices for faster exporting into retopology, software segments the 3D models into corresponding parts to be imported into the game engine. *Instant Meshes:* Instant Meshes is an open-source auto-retopology software. It replaces the complex 3D model with a low-poly model to save the computation capacity of the target device while maintaining the details of the model.

3D Models: We imported 3D models as new assets into the Unity engine, including human teeth, implantology components and tools, and 3D images of CBCT scans. The 3D models of adult teeth, dental implant components, and an implant surgical tool were imported from the Unity Assets Store[4] and Cgtrader[5]. The dental CBCT datasets of patients are provided by 3D dental view website [6] that generate medical report for the CBCT imaging as well as have CBCT systems.

[1]https://developer.vuforia.com
[2]https://www.slicer.org/

[3]https://www.blender.org/
[4]https://assetstore.unity.com/
[5]https://www.cgtrader.com/
[6]https://www.3ddentalview.com/home1

C. Application Development

This application demonstrates the procedure of dental implantology for a single implant. Students will watch a short video about single tooth implant procedures. Then, they will perform an implant operation task on a CBCT lower jaw model. Digital content can be signaled through gazing and hand gesturing. To implement the instructions, students gaze at the targeted components and then perform any of the HoloLens'core hand gestures. Furthermore, the students can integrate the 3D implant components and adjust the position of the dental implant replacement in the single implant exercise, which allows students to explore and investigate dental implant structures as components and tools and to understand the mechanics of an implant operation. Then, it allows students to practice the correct order of the procedure on the real CBCT image on the HoloLens using the provided dentist tools and dental implant components: the fixture, the abutment, and the dental prosthetic. Table I documents the dental implantology content and assessment in the MR application.

TABLE I
DENTAL IMPLANTOLOGY SECTION

Learning strategies	Organizing, problem solving and experimental.	
	Tool	Type
Content	Embedding video of single dental implantology operation	Learning resources: video Learning support: Hints using tap to place.
Assessment	Arrangement of the correct order of dental implant operation steps.	Formative assessment: The correct step order awards points, and incorrect step order deducts points.

1) Convert CBCT to 3D Model: To create the 3D models, the CBCT images from a real patient's dental CBCT scan where converted to the .fbx format. They have been visualized using 3D slicer software in DICOM format [7]. During this process the DICOM format is converted into the .stl format, using the Thresholding tool to classify a voxel (an element of volume in a 3D object) that depends only on its intensity for 3D model segmentation to obtain a 3D representation of the hard tissue. After segmentation, the label map is used to make a 3D volumetric model. The model can then be saved and exported as a 3D triangular or polygonal mesh in .stl file format. The next step is model simplification to simplify the matrix of polygonal meshes, which is important for reducing the size of the models' megabytes. Models directly generated by CBCT acquisition from the 3D slicer are noisy and have many redundant details that need to be cleaned. Those redundant parts are removed with Blender. We then use the decimation modifier to reduce the vertices and export the model into Instant Meshes for retopology. Then, the 3D model has been re-imported into Blender and segmented into corresponding parts. After that, the 3D model will be exported into Film BoX (.fbx) file formats to be imported into Unity.

2) Create Marker on Vuforia: The target marker was created on the website Vuforia and downloaded.

3) Import and Setup the 3D Model and Marker into the Unity: In this phase, The MR-Imaplantolgy application project was developed in the Unity using resources created such as 3D models, Marker and downloaded video. The following are the development workflow in the Unity project:

- Set up Unity project
- Configure Unity for Windows Mixed Reality
- Import resources using mixed reality feature tool
- Configure the project for MRTK
- Add video to the scene
- Create a new script for play and pause the video.
- Import and setup the 3D model and marker into Unity.
- Add hand interaction scripts into the 3D model.
- Import implant structures asset into the unity
- Add component into the implant structure to place them in the 3D model
- Create a new scripts for place implant structure in correct order.
- Create Canvas for UI menus to select tools to interact with the 3D model.

4) Build the Project and Setup the Application on HoloLense: Before we run the application, we must build the platform using Universal Windows Platforms and then set up the application on the HoloLens. Fig. 2 shows system state chart diagram illustrating the working steps of the system development scenario.

III. CONCLUSION AND FUTURE RESEARCH

MR has huge potential for education in the future, especially as this paper has shown in the field of odontology education and training. "MR-Implantology", an MR educational tool that facilitates learning and practice for 3D dental implant placement was introduced and an outline of its methodology was given. Future research includes evaluation of the current system with students and the creation of an experience lab using artificial intelligence (AI). Furthermore, future studies should investigate the implementation of MR that is geared towards group collaboration rather than just for individual learners.

ACKNOWLEDGMENT

We acknowledge the 3D dental view for providing the CBCT scan. The first author has scholarship from Umm Alqura University. This work has been granted by the Ministry of Education in Saudi Arabia.

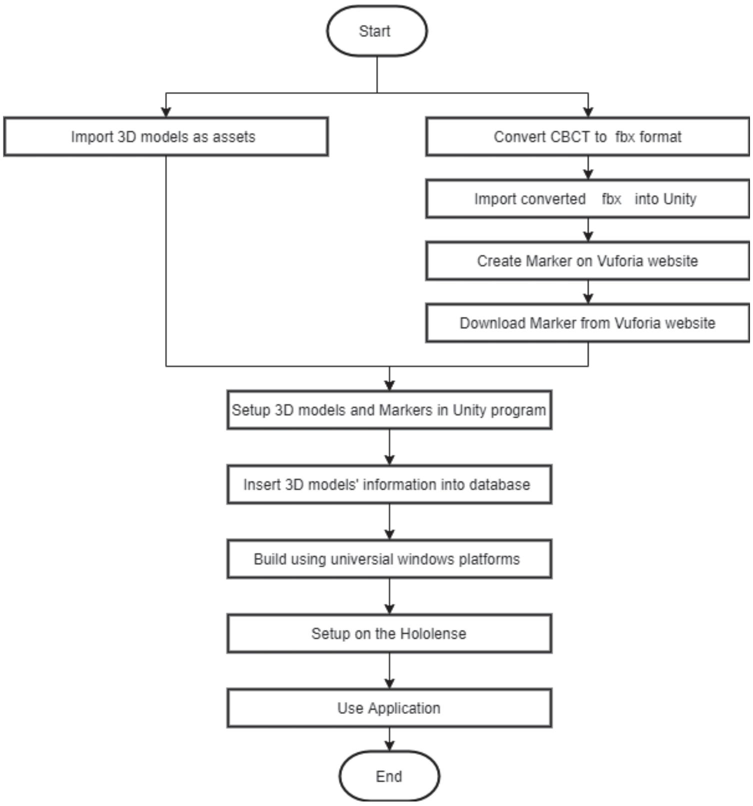

Fig. 2 System state chart diagram

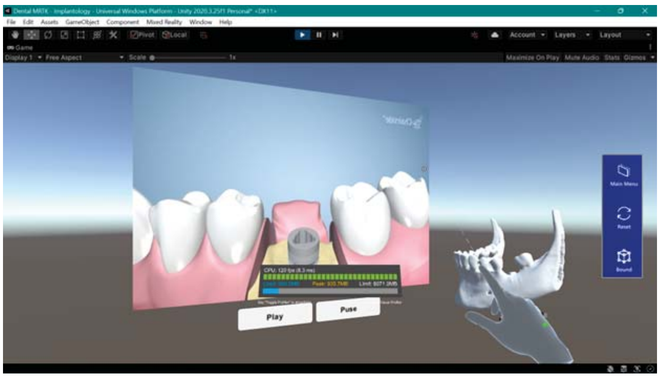

Fig. 3 Representation of CBCT in implantology module

References

[1] Docs.microsoft.com. Introducing mrtk for unity - mixed reality, 2021.

[2] T.-K. Huang, C.-H. Yang, Y.-H. Hsieh, J.-C. Wang, and C.-C. Hung. Augmented reality (ar) and virtual reality (vr) applied in dentistry. The Kaohsiung journal of medical sciences, 34(4):243–248, 2018.

[3] J. Knox, I. Chen, J. N. Huang, R. Martinez, M. Udovich, H. Zhao, and M. Knox. Integration of mixed reality into an engineering laborato experience for online students. In 2019 IEEE Frontiers in Education Conference (FIE), pp. 1–5. IEEE, 2019.

[4] K. Kounlaxay and S. K. Kim. Design of learning media in mixed reality for lao education. CMC-COMPUTERS MATERIALS CONTINUA, 64(1):161–180, 2020.

[5] E. Kucera, O. Haffner, and R. Leskovsk ‘y. Interactive and virtual/mixreality applications for mechatronics education developed in unity en- gine. In 2018 Cybernetics Informatics (KI), pp. 1–5. IEEE, 2018.

[6] E. R. Zorzal, S. F. Paulo, P. Rodrigues, J. J. Mendes, and D. S. Lopes. An immersive educational tool for dental implant placement: A study on user acceptance. International Journal of Medical Informatics, 146:104342, 2021

[7] X. Xu, E. Mangina, D. Kilroy, A. Kumar and A. G. Campbell, ”Delaying when all dogs to go to heaven: virtual reality canine anatomy education pilot study,” in 2018 IEEE Games, Entertainment, Media Conference (GEM), pp. 1-9, 2018.

Mrs. Areej R. Banjar is a lecturer for Al-Jumum University College in the Computer Science department at Umm Al-Qura University, Makkah, Saudi Arabia. She received the B. S. in Physics Science from Taibah University, Al-Madinah, Saudi Arabia in 2007; the Graduate Diploma in Information Systems and Technology in 2011; and the M. S. degree in Information Communication and Technology in 2012 from the University of Wollongong, Wollongong, Australia. She is currently pursuing a Ph. D. degree in Computer Science at University College Dublin, Dublin, Ireland with awards from the Ministry of Education in Saudi Arabia. Her research interests include human–computer interaction, Extended Reality XR (Virtual Reality VR, Augmented Reality AR, and Mixed Reality MR), Holograph, and Visualization to explore the effectiveness of these technologies in education, and to create XR applications to support traditional teaching in education.

Dr. Abraham G. Campbell is an Assistant Professor for University College Dublin(UCD) Ireland, who is currently teaching as part of Beijing-Dublin International College, a joint initiative between UCD and BJUT. Abraham coordinates UCD's VR lab which examines the use of Augmented Reality and Virtual Reality to explore telepresence applications to allow true distance learning. He is a funded investigator for the CONSUS SFI center and was a collaborator on the EU-funded AHA – AdHd Augmented project. Along with this research, he is exploring its potential commercialization as Chief Technical officer with MeetingRoom, an online VR collaborative meeting software company. These projects contribute to Abraham's future vision of teaching through telepresence, where one day a Virtual Abraham can teach his classes in Beijing.

This research expands on his previous research in using Multi-Agent systems to create Mixed Reality Applications that were conducted as part of his Ph.D. In pursuing research into the combinations of Augmented Reality, Multi-Agent systems, Ubiquitous Computing, and Immersive Virtual Reality, Abraham has published over 50 peer-reviewed papers. Abraham has also been involved in the founding of CAMARA, a charity that teaches IT skills to disadvantaged school children in Africa. As well as charity work, he is also known as a Tech advocate for the use of Virtual Reality and Augmented Reality technologies to change the world, in this role he has appeared on TV, Radio, and newspapers discussing the effect of these futurist technologies.