

Upper Limb Anatomy Learning with VR

Janani S
Student, Information Science and Technology
College of Engineering Guindy, Anna University
Chennai, India
janani.aty@gmail.com

Yoheshwar S
Student, Information Science and Technology
College of Engineering Guindy, Anna University
Chennai, India
yoheshwar200079@gmail.com

Keerthana S
Student, Information Science and Technology
College of Engineering Guindy, Anna University
Chennai, India
keerthusundar100@gmail.com

Dr.K.Indra Gandhi
Assistant Professor(Sl.Gr), Information Science and Technology
College of Engineering Guindy, Anna University
Chennai, India
indra@auist.net

Abstract—Anatomy is the important subject for school level science students and medical students. Upper Limb anatomy is very complex. Memorising the details about all parts of upper limb is difficult and need much imagination. Virtual Reality (VR) is the best tool for the enhancement of learning process of upper limb anatomy. This helps students in the thorough understanding of the upper limb anatomical structure based on visualisation rather than memorising. Three Dimensional (3D) models of shoulder, forearm, arm and hand are created with its complete internal structure using Computed Tomography (CT) Digital Imaging and Communications in Medicine (DICOM). Refinement of 3D models is done further. Models created are rendered in virtual environment in unity. Anatomical labelling, audio description about the parts is also added. Finally well refined model is rendered in virtual environment using which students can learn the internal structures effectively. So our ultimate goal is to develop a VR application where students can learn upper limb anatomy through 3D models.

I. INTRODUCTION

A. Overview

Upper Limb anatomy is the most important topic for science stream students. Learning Upper Limb anatomy through textbook does not give students a clear picture about the internal structure and organisation of the parts. Learning upper limb anatomy helps students to know about parts of upper limb ranging from skin layer, muscles and bones but traditional learning is not effective to visualize the parts. VR could be the one possible solution which improves concentration, interest, enjoyment and knowledge of students about upper limb anatomy. The DICOM files from a CT scan of a patient upper limb converted into an STL file which can be used to encode the surface geometry of a 3D models of upper limb. DICOM files is a standard for printing, handling, storing and transmitting information in medical imaging. The intermediate 3D model is obtained from DICOM data using 3D slicer. Clear detailed 3D model

from that intermediate model is obtained using Meshmixer. 3D models of upper limb are rendered into the VR environment with detailed description of each parts and audio explanation for each model. C# script is used to create custom actions and interactions. Quiz modules were added to test their understanding. C# script is used to generate and evaluate quizzes. Finally well refined 3D model of upper limb is projected where students can learn its internal structure more clearly.

B. Problem Statement

Learning materials of upper limb anatomy is usually available in the form of textbooks with images. It is really hard for the students to understand concepts with those two-dimensional (2D) images on the textbooks [1]. There are few existing systems to learn upper limb anatomy through VR. Limitations observed in existing systems are 3D models are not effective, less flexibility for the students to interact with the models, VR hardware components are not affordable for the students to buy, learning and dissection of upper limb anatomy is not available together. So our ultimate goal is to develop a system where students can learn upper limb anatomy efficiently. Thus rectifying the issues in existing systems.

C. Observation and Motivation

The quality of teaching and learning process of upper limb anatomy is not efficient by traditional methods [2]. Because upper limb is capable of variety of functionalities like grasping, holding, manipulating, touching, feeling and many.

Problems that have arisen in teaching and learning methods of upper limb anatomy:

- 1) The teaching methodology and the goals of learning upper limb anatomy are discrepant. In many regions, teaching is based only on lectures.
- 2) Students find upper limb anatomy subjects to be abstract. Depth knowledge cannot be obtained only through textbook reading. Thus, the selection of

teaching and learning method plays an important role. These observations motivated us to do something related to upper limb anatomy learning with VR which could help students to learn the upper limb of human body with their detailed description.

D. Proposed Work

The first step of our process is creating a 3D models of upper limb from CT scan and further refinement of models need to done using other softwares. Final model is then rendered in VR environment. Detailed description of each parts is delivered to the student in both text and audio format. Next step is the evaluation phase where students can assess their understanding.

II. LITERATURE SURVEY

A. Survey on 3D Model Creation

Xuanhui Xu et al. reported on how CT scans can be converted into a 3D model using open source tools. This study focuses on canine anatomy which helps Veterinary students to learn in a more efficient way.

Jannat Falah et al. [4] has developed a VR and 3D visualisation system for anatomy teaching. The system rendered heart 3D model in interactive VR environment. Learning and assessment tools were provided in a more interactive way. The 3D heart model was developed using a polygon based modelling technique.

B. Survey on anatomy learning with VR

Sudanthe Wijewickrema et al. [5] introduced a VR tutor that provides training on clinically oriented surgical anatomy of the ear. This system used the VR temporal bone surgery simulator to provide a 3D model of a temporal bone generated using a microCT scan of a human cadaver ear and added haptic device which provides tactile feedback and is reflected in the virtual world as a drill.

J.J.Bourdin et al. is a study on teaching an anatomy to students with 3D models of few anatomical organs by using two different VR systems, a CAVE and a powerwall. Based on the study it is observed that students with a specific VR session where they can interact with 3D models of human body parts by using VR systems. VR allows the students to see the models directly visualized in 3D and interact with them as if they were real.

Patrick Saalfeld et al. presented a VR based prototype for learning hand anatomy. This prototype is designed to support embodied cognition. The embodied cognition is a learning process based on movements. Here the idea is by moving our own hand and fingers we can observe how virtual hand model mirrors our movement. Learning experience is here improved through Sense of Embodiment.

Yusuf Ozgur Cakmak et al. designed and implemented a virtual body ownership AR/VR tool for the human muscular

arm avatar. Human muscular arm avatar was developed using Unity and Leap motion camera. The hand/forearm muscles 3D-model was purchased from Turbosquid. A Leap Motion camera was used to detect the hand movements.

Ezequiel R.Zorzal et al. [9] proposed a collaborative Mixed Reality (MR) dissection table where one or many anatomists can explore large anatomical data sets and perform segmentation manually. MR provides better visualization of 3D models regarding the perception of distances and depth. Shi Chen et al. [10] study on the use of a 3D skull model. This study compares the results of the skull virtual learning resource (VLR) with the cadaver skull.

III. SYSTEM DESIGN

A. Model Creation

Inorder to create 3d models of parts of upper limb, the CT DICOM images of parts of upper limb have undergone 2 steps. They are image segmentation using 3d slicer , editing and sculpting using Meshmixer.

1) Image Segmentation

Image Segmentation is used to delineate regions in the image, mostly used for delineating the regions in CT scan to render 3D model of human anatomy. Image Segmentation is done using 3D Slicer. Here threshold method which is a region based image segmentation and semi-automatic is used for the image segmentation of parts of upper limb. Region based image segmentation segment different regions using the similarity of a certain feature attributes within the image area. When selecting the threshold, we need to judge based on experience and multiple tentative segmentation has to be done. Then further editing of segmentation from volumes can be done manually using scissors.

2) Editing and Sculpting

3D models of shoulder, arm, forearm, elbow, hand that are produced as a result of image segmentation needs to be refined further. For sculpting and editing 3D models, Autodesk Meshmixer can be used. All parts need to be joined to view full structure of upper limb. For this, the complex algorithm such as Boolean command Union can be used to combine two meshes into one. Based on our requirements we can use edit options like separate shells, plane cut, erase and fill, replace and fill. Volume and Surface brushes are the two types of sculpting tools available in Meshmixer. Based on our requirement suitable brush can be used to refine the 3D models of upper limb parts.

B. Learning Module

In this module, 3D models are projected in the virtual environment. For that purpose, Google VR, which is low cost and easy to set up, is used. Google VR includes GvrEditorEmulator which is responsible for emulation of head movement of the user in virtual environment. Here, 3D models of parts of upper limb especially hand is presented

with detailed explanation of their internal structures which include interactions with those models with the help of GvrReticlePointer. Here, each and every part of the upper limb is explained and the selected parts which are triggered by onClick() events are viewed separately and explained in detail by using 3D Resonance Audio. So students can gain knowledge about upper limb anatomy. This also includes quiz on 3D models which would help students to self evaluate themselves. In this module, the students can experience the VR and interact with them in an effective

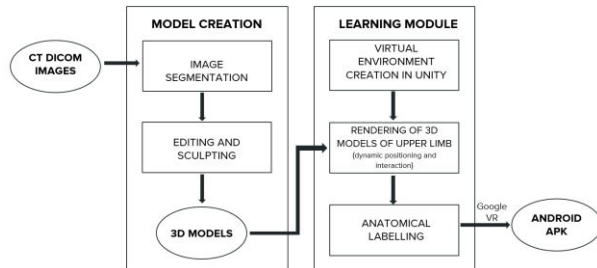


Fig. 1. Overall System Architecture

way and learn about upper limb anatomy in detail as well.

IV. IMPLEMENTATION

A. Model Creation

Firstly CT DICOM images of bones and muscles of several parts of upper limb like shoulder, arm, forearm, elbow, wrist, hand are downloaded from embodi3d website [11]. Then these DICOM images are converted into 3D models by undergoing the following processes.

B. Image Segmentation

Image Segmentation is used to delineate regions in the image, mostly used for delineating the regions in CT scan to render 3D model of human anatomy. Image Segmentation is done using 3D Slicer. 3D Slicer is a free and open source software platform for image analysis and 3D visualization. Types of image segmentation are region based image segmentation and edge based image segmentation. Region based image segmentation segment different regions using the similarity of a certain feature attributes within the image area. One of its method is threshold segmentation, which is used for image segmentation of bone parts and muscles of upper limb.

C. Threshold Method

Threshold method for image segmentation is simple region-based segmentation. The common features of this method include gray scale and color features from the original DICOM images of bone and muscles of upper limb. Threshold method assumes that the DICOM images of bone and muscles of upper limb are composed of two parts, the background and the object. This threshold segmentation method is used to differentiate the gray level between the object and its background in those DICOM images. Basically DICOM images of bone and muscles of upper

limb are combination of two regions with different gray levels. So we have to select an appropriate threshold to determine if each pixel in the image should belong to the background area or the target area, in order to generate the corresponding binary image for the DICOM images of bone and muscle of upper limb.

$$g(x, y) = \begin{cases} E_A, & f(x, y) \in E, \\ E_B, & \text{others.} \end{cases}$$

Fig. 2. Basic principle of threshold segmentation

D. Converting DICOM to 3D Models using Threshold Segmentation

Firstly CT DICOM images of bones and muscles of upper limb are fed as input in 3D Slicer. In 3D Slicer, Segment Editor module has wide range of segmentation method from which threshold method is used. In this method, we have to specify the threshold range manually. When selecting the threshold, we need to judge based on experience and multiple tentative segmentation has to be done. Then further editing of segmentation from volumes can be done manually using scissors.

E. Editing and Sculpting

Intermediate bone and muscle models from the 3d Slicer is given as an input to the Meshmixer. Sculpting tool is used to create extremely detailed surfaces of 3D models. Editing has done to create different model from each separate shell. Combine options are used to combine different models. The Stability and thickness analysis has done to enhance these models. These bone and muscle models are combined to form the upper limb.

F. Google VR Setup in Unity

Firstly, Google VR Software Development Kit (SDK) for Unity is downloaded. Then after creating a new 3D project in Unity, and by selecting Assets > Import Package > Custom Package, the downloaded package is imported. Then in order to switch to Android platform, File > Build Settings is selected and the platform is switched to Android by selecting Android. After this, in Player Settings > Other Settings, Android 4.4 is selected as Minimum API level and under XR Settings, Virtual Reality Supported is checked and Cardboard is added. Then desired scene has to be created and the main camera must be a child of player in order to experience the virtual environment.

G. GvrEditorEmulator

Then GvrEditorEmulator game object is added into our scene. This GvrEditorEmulator game object contains GvrEditorEmulator script component which is responsible for emulation of head movement. When this game object is enabled in our scene in play mode, it allows us to control head movement by moving the mouse while holding the ALT or CTRL keys.

H. GvrReticlePointer

GvrReticlePointer provides a gaze-based reticle pointer. It must be a child of the main camera, so that the pointer and reticle follow the player's gaze. It is responsible for interacting with game objects. While interacting with game objects, this pointer expands.

I. Projection and Labelling of 3D Models

Then the 3D models of muscles and bones of upper limb are projected into scene that is created, by adjusting the position, rotation and scale such that it is visible to the player. Firstly, 3D model of the complete upper limb is projected and parts are labelled by using planes. Then the selected parts are triggered by onClick() events and they are viewed separately for which parts are labelled.

J. Directional Light

Directional lights are used to add convincing shading to the game objects without specifying where the light is coming from. Directional lights are distant light sources that exist infinitely far away. A light object can be placed anywhere in the scene. In our scene, directional lights are placed in such a way that bone and muscle models are seen with proper lighting.

K. Interaction with Game Objects using Box Collider

Box Colliders are rectangular cuboids, which are used as collision primitive. This Box Collider component is added to each and every 3D model game objects. Box Collider should be kept in such a way that player should be able to interact with the game objects using the reticle pointer. When reticle pointer collider with box collider, it expands and we can interact with those game objects.

L. Including Event Trigger Component

Event Trigger component is used to specify functions that are to be called for each Event System event. Here we can assign multiple functions to a single event and whenever the Event Trigger receives that event, those functions will be called. In order to display the desired 3D models of bones or muscles, and to display the parts of bones, OnClick() events are assigned to Event Trigger component.

M. Traversing the 3D Models

In order for the player to get clear view of the 3D model, a play button is inserted. And by clicking that, player will be rotated automatically around the desired bones of upper limb. To achieve this, multiple game objects are placed around the particular model and during run time, the player position will be changed to each game object placed around the models, so that the player can get clear view of 3D models in all possible directions.

N. Inserting Audio using 3D Resonance Audio

The Resonance Audio SDK is first downloaded and imported into our project in Unity. Then in order to configure our project to use Resonance Audio, Edit > Project Settings > Audio is selected to open the Audio Manager settings. In that, Resonance Audio is selected as the Spatializer Plugin and Ambisonic Decoder Plugin.

Resonance Audio SDK includes various components for rendering spatial 3D audio.

O. Resonance Audio Source

Resonance Audio Source component is used to enhance the unity Audio Source by including additional parameters like rendering quality, directivity patterns and occlusion. This component requires a Unity Audio Source in the same object. In Audio Source, the desired mp3 files are inserted, and Spacial Blend is changed from 2D to 3D. Then check Spacialize and Spacialize Post Eff for 3D audio.

P. Resonance Audio Listener

[6] discussed about an eye blinking sensor. Nowadays heart attack patients are increasing day by day."Though it is tough to save the heart attack patients, we can increase the statistics of saving the life of patients & the life of others whom they are responsible for.

Q. Quiz Section

Quizzes were created to test their understanding. Text quiz and drag and drop quiz were created.

R. Text Quiz

Twenty questions were created from audio content of upper limb parts. Question and two options get displayed. Canvas is created in unity where panel and two buttons are placed. Question gets displayed in panel and two options are displayed in buttons. With the help of GVR reticle pointer options can be selected. For every correct and wrong answer different audio clip gets played. Finally score gets displayed.

S. Drag and Drop Quiz

Here bone of upper limb is projected in center. Six cubes which mark the parts of upper limb is created and left empty. Six cubes are given in left side where names of six parts are displayed in random order. Player need to pick the cube from left side and place it in the empty cubes which mark the parts of upper limb. Once done player can submit and view their score. This works completely based on transform values of cubes that has been created.

V. RESULTS

A. Model Creation

The DICOM file consists of multiple images which is of high resolution. We downloaded CTs of the shoulder, arm, forearm, and hand from embodi3D website. The downloaded file is NRRD file type which we have converted into DICOM file. One sample file of palm CT is given in Fig. 3.

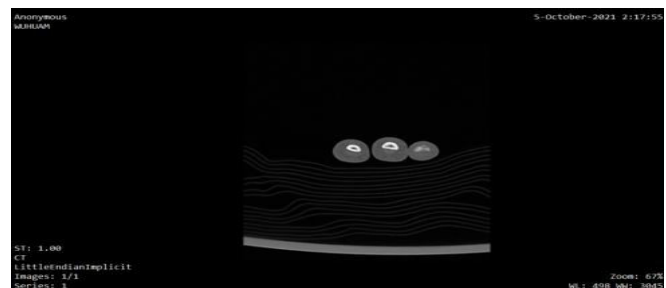


Fig. 3. CT DICOM image

3D slicer is an application used to visualize and analyse medical image computing data sets. DICOM file is loaded first. Then image segmentation should be performed to generate 3D model. We have used threshold method for image segmentation. Threshold range should be set such that required region is selected and 3D model is generated. Scissors were used to refine the model. Palm 3D model generated in 3D slicer can be viewed in Fig. 4.

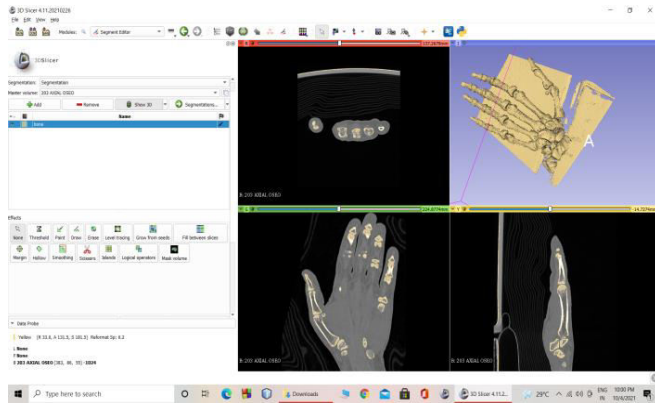


Fig. 4. Intermediate 3D model from 3D slicer

Autodesk's Meshmixer is a 3D software for 3D printing and it is used to elaborate some new designs. The intermediate models obtained from the 3D slicer is given as STL file input to meshmixer. Sculpting is used to customize our model. Results can be viewed in Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9 and Fig. 10.

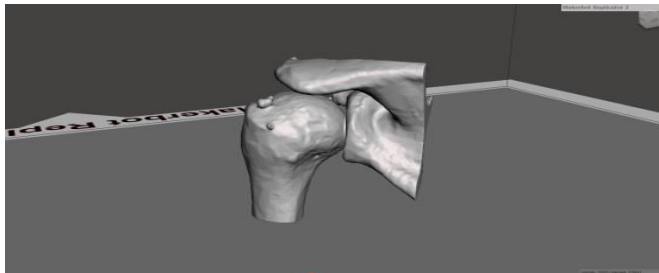


Fig. 5. 3D model of Shoulder joint



Fig. 6. 3D model of Elbow joint

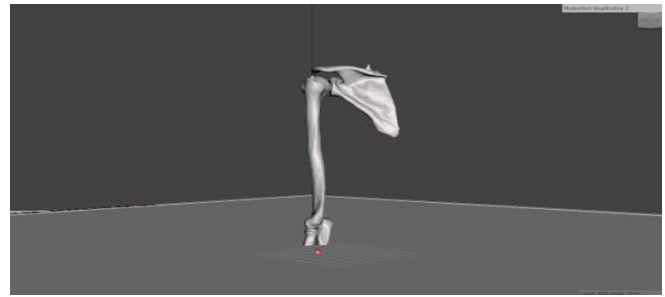


Fig. 7. 3D model of Shoulder with arm

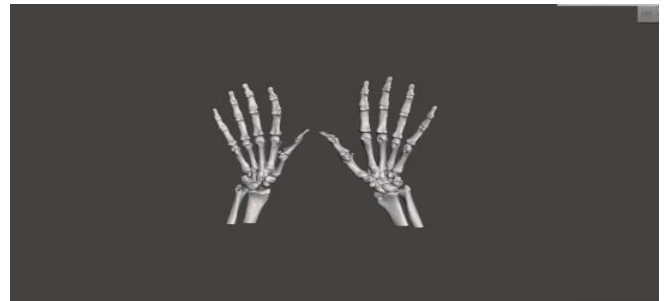


Fig. 8. 3D model of wrist and palm

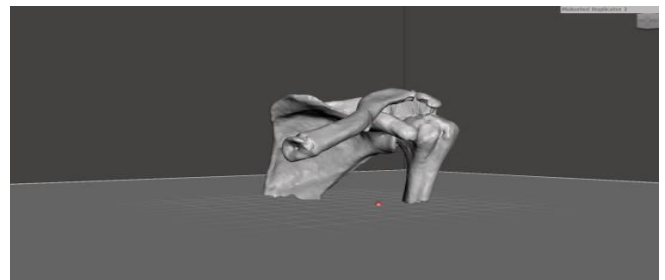


Fig. 9. 3D model of Shoulder joint



Fig. 10. 3D model of hand

Meshmixer have lot of 3D tools such as 3D sculpting tools, stamp, analysis, remeshing or mesh smoothing features. [3] discussed about Nanorobots Control Activation For Stenosed Coronary Occlusion, this paper presents the study of nanorobots control activation for stenosed coronary occlusion, with the practical use of chemical and thermal

gradients for biomedical problems. The 3D model is exported in object file format which can be viewed in Fig. 11 and Fig. 12. [7] discussed about a disclosure which is made regarding a driving alert system which is designed in the form of a neck cushion which has the capability to sense the posture of the drivers neck position so as to identify whether the driver is alert and if he is dozing of.



Fig. 11. Final output from Meshmixer



Fig. 12. Final output from Meshmixer

B. Learning Module

1) Video Lesson

Video lesson on upper limb bone is created as part of this module. 3D model of right upper limb is projected. By clicking each parts, 3D model of selected part gets displayed. [8] discussed about a disclosure which is made regarding a wallet safety where a locking system is designed along with an automatic credit –debit card eject system. The wallet is provided with a screen display to select the card and to provide finger print authentication to access the wallet and to select the card which needs to be ejected out of the wallet for usage. The wallet is connected to a mobile device which can remotely monitoring its usage and location in case

wallet is lost. Custom colors were added to give bone and muscle a realistic view. Muscle can be viewed in Fig. 15.

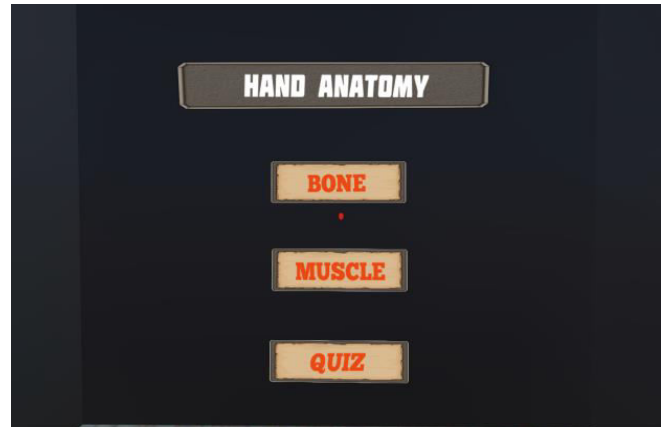


Fig. 13. Video lesson on upper limb bone



Fig. 14. Video lesson on upper limb bone

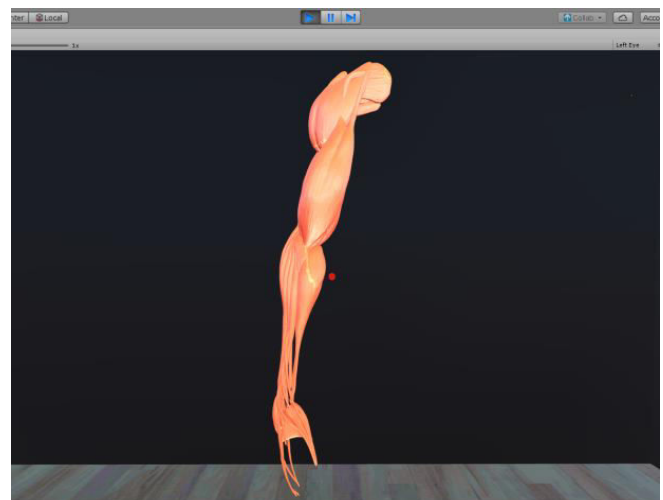


Fig. 15. Muscle of upper limb

2) Quiz Section

Text quiz and drag and drop quiz is created as part of this module. Click event is enabled using GVR reticle pointer. C# script is used to generate questions and evaluate the answers. Finally score gets displayed. This can be viewed in Fig. 16 and Fig. 17.

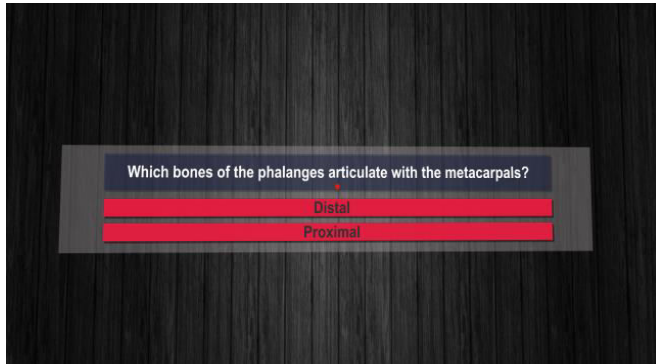


Fig. 16. Text quiz

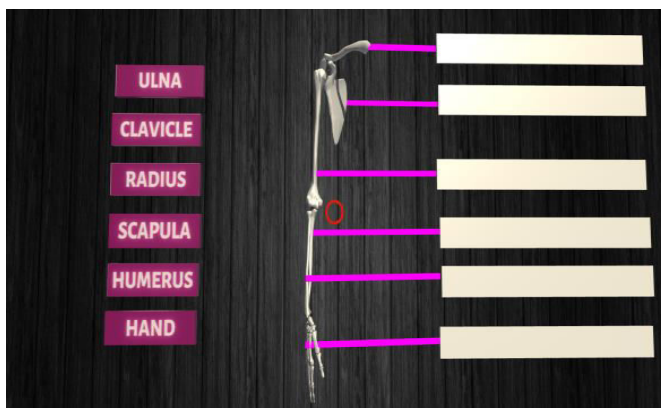


Fig. 17. Drag and drop quiz

VI. CONCLUSION AND FUTURE WORK

This paper helps students in the thorough understanding of the upper limb anatomical structure since upper limb anatomy is the important subject for science stream students and it is complex to learn. This paper not only allows students to learn but also to self evaluate themselves by using the quiz modules. And students can experience the virtual environment as well. By this paper we can conclude that VR is the best tool for the enhancement of learning process of upper limb anatomy.

The future work includes extending and enhancing the learning module for muscles of upper limb by which students can learn each and every muscle in upper limb. The future work also includes locating dislocations in every joint of upper limb and dissecting and reconstructing 3D models of upper limb anatomy.

REFERENCES

- [1] M. Fairen, J. Moyes, and E. Insa, "VR4Health: Personalized teaching and learning anatomy using VR," *Journal of Medical Systems*, 2020.
- [2] "How VR & AR Are Changing Human Anatomy Programs," Accessed on: Sept 15, 2021. [Online]. Available: <https://zspace.com/blog/how-vr-ar-are-changing-anatomy-class>
- [3] Christo Ananth, R.K. Shunmuga Priya, T.Rashmi Anns, S.Kadhirunnisa, "NANOROBOTS CONTROL ACTIVATION FOR STENOSED CORONARY OCCLUSION", *International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)*, Volume 2, Special Issue 13, March 2016, pp: 60-76.
- [4] Jannat Falah, Soheeb Khan, Tasneem Alfalah, Salsabeel F M Alfalah, Warren Chan, and David K Harrison, "Virtual reality medical training system for anatomy education," *Science and Information Conference*, August 27-29, 2014.
- [5] Sudanthi Wijewickrema, Bridget Copson, Xingjun Ma, Robert Briggs, James Bailey, Gregor Kennedy, and Stephen O'Leary, "Development and validation of a virtual reality tutor to teach clinically oriented surgical anatomy of the ear," *IEEE 31st International Symposium on Computer-Based Medical Systems*, 2018.
- [6] Christo Ananth, S.Shafiq Shalaysha, M.Vaishnavi, J.Sasi Rabiathul Sabena, A.P.L.Sangeetha, M.Santhi, "Realtime Monitoring Of Cardiac Patients At Distance Using Tarang Communication", *International Journal of Innovative Research in Engineering & Science (IJIRES)*, Volume 9, Issue 3, September 2014, pp-15-20.
- [7] Christo Ananth, Dr. S. Selvakani, Dr. R. Latha, Dr. S. Pushpa, Dr. R. Kesavan, "Neck Cushion Based Alert System", Application number: 320692-001, Cbr number: 15490, Journal No.: 40/2019, Journal Date: 04/10/2019, Indian Patents, Design & Trademark Office, 4th October 2019.
- [8] Christo Ananth, S. Allwin Devaraj, B. V. Santosh Krishna, M. Usha, K. Nagarajan, Narendran. S., "Biometric Wallet", Application number: 321292-001, Cbr number: 16845, Journal No.: 41/2019, Journal Date: 11/10/2019, Indian Patents, Design & Trademark Office, 11th October 2019.
- [9] Ezequiel Roberto Zorzal, Mauricio Sousa, Rafael Kuffner dos Anjos, and Daniel Mendes, "Anatomy studio: a tool for virtual dissection through augmented 3d reconstruction," *Technical Report in Computers & Graphics*, October 2019.
- [10] Shi Chen, Jiawei Zhu, Cheng Cheng, Zhouxian Pan, Lingshan Liu, Jianhua Du, Xinhua Shen, and Zhen Shen, "Can virtual reality improve traditional anatomy education programmes? a mixed-methods study on the use of a 3d skull model," *BMC Medical Education*, 2020.
- [11] "embodi3D," Accessed on: Sept 21, 2021. [Online]. Available: <https://www.embodi3d.com/>