CREATING AN EFFECTIVE VIRTUAL MODEL FOR RADIO FREQUENCY ABLATION NEEDLE PLACEMENT

A PROJECT REPORT

Submitted by

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BONA FIDE CERTIFICATE

Certified that this project report titled Creating an effective virtual model for Radio Frequency Ablation Needle Placement is the bona fide work of M. Paavani (2018115065), A. Sakthi (2018115093), S. M. Vishnupriya (2018115133) who carried out project work under my supervision. Certified further that to the best of my knowledge and belief, the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or an award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

This project work implements a novel virtual reality (VR) based guidance method for kidney tumors radiofrequency ablation (RFA). Compared with the traditional computed tomography (CT)-guided method, our system provides a more natural and intuitive surgical mode for surgeons.

The current modalities for RFA are based on 2D images which lacks 3D structural and spatial information of the surrounding tissues. Besides, the “Heads up” display makes it difficult for surgeons to smoothly coordinate their hand operations with the vision. This further increases the operational difficulty and reduces the operation precision.

Virtual reality is a promising technology for surgical practice and guidance.RFA procedure needs the surgeon to master the psycho-motor skills to insert the needle into tumor cells without damaging the other internal organs. This system can help medical trainee and staff to practice the procedure until they master the procedure. Visual feedback for their actions (interaction with the model) and navigation to locate the target can be helpful for novice as well as experienced surgeons.

திட்டப்பணிச்சுருக்கம்

இந்த திட்டப் பணியானது சிறுநீரகக் கட்டிகளுக்கான கதிரியக்க அதிர்வெண் நீக்கம் (RFA)க்கான புதிய விர்ச்சுவல் ரியாலிட்டி (VR) அடிப்படையிலான வழிகாட்டல் முறையை செயல்படுத்துகிறது. ஒப்பிடுகையில் பாரம்பரிய கம்ப்யூட்டட் டோமோகிராபி (CT)-வழிகாட்டப்பட்ட முறை விட, எங்கள் அமைப்பு அறுவைசிகிச்சை நிபுணர்களுக்கு மிகவும் இயற்கையான மற்றும் உள்ளுணர்வு அறுவை சிகிச்சை முறை வழங்குகிறது.

RFAக்கான தற்போதைய வழிமுறைகள் 2D படங்களை அடிப்படையாகக் கொண்டவை. சுற்றியுள்ள திசுக்களின் 3D கட்டமைப்பு மற்றும் இடஞ்சார்ந்த தகவல்கள் இல்லாதவை. தவிர, தி "ஹெட்ஸ் அப்" டிஸ்பிளே, அறுவைசிகிச்சை நிபுணர்களுக்கு பார்வையுடன் கை செயல்பாடுகளை சீராக ஒருங்கிணைப்பதை கடினமாக்குகிறது. இது செயல்பாட்டின் சிக்கலை மேலும் அதிகரிக்கிறது மற்றும் செயல்பாட்டின் துல்லியத்தை குறைக்கிறது.

விர்ச்சுவல் ரியாலிட்டி என்பது அறுவை சிகிச்சைக்கான ஒரு நம்பிக்கைக்குரிய தொழில்நுட்பம் மற்றும் வழிகாட்டுதல் முறை. RFA முறையை மேற்கொள்ள அறுவை சிகிச்சை நிபுணர்கள் மனோதத்துவ செயல்திறன்களை வளர்த்துக்கொள்ள வேண்டும் மற்றும் மற்ற உள் உறுப்புகளை சேதப்படுத்தாமல் கட்டி உயிரணுக்களில் ஊசியைச் செருக வேண்டும்.

இந்த முறையில் மருத்துவ பயிற்சியாளர்கள் மற்றும் பணியாளர்கள் வரை எத்தனை முறை வேண்டுமானாலும் பயற்சி மேற்கொள்ளலாம் அவர்கள் அனுபவம் வாய்ந்த அறுவை சிகிச்சை நிபுணர்கள் ஆகும் வரை. அவர்களின் செயல்களுக்கான காட்சி பின்னூட்டம் (உடன் தொடர்பு மாதிரி) மற்றும் இலக்கைக் கண்டறிவதற்கான வழிசெலுத்தல் புதிதாக பயற்சி செய்பவர்களுக்கு உதவியாக இருக்கும்.

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LIST OF SYMBOLS AND ABBREVIATIONS

CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
HTC	High Tech Computer
MR	Mixed Reality
MRI	Magnetic Resonance Imaging
PBD	Position Based Dynamics
RFA	Radio Frequency Ablation
VC	Virtual Colonoscopy
VR	Virtual Reality

CHAPTER 1

INTRODUCTION

1.1 PURPOSE

The main purpose of our project proposal is to stimulate a virtual environment for the Radio Frequency Ablation medical procedure. The system proposes to assist the medical trainee through various textual information (visual feedback) as they practice and acts as a navigation platform to locate the tumor. The project concerns the kidney tumor where a virtual abdominal phantom will be created from patient's CT scan.The system can be used for pre-operative planning in order to prevent surgical errors.

1.1.1 Virtual Reality

Virtual reality is an artificial world made with software and presented to the user in a way that causes them to suspend disbelief and take it for granted that it is actually real. Virtual reality is typically experienced on a computer using sight and hearing, out of the five senses.

The most basic type of virtual reality is a 3-D image that can be interactively explored on a personal computer. Typically, this involves using the mouse or keyboard to move or zoom in and out of the image's content. More advanced initiatives include techniques like real rooms enhanced with wearable computers, wrap-around display displays, and haptics devices that enable you feel the display images.

1.1.2 Radio Frequency Ablation

A portion of the electrical conduction system of the heart, a tumour, or other dysfunctional tissue is ablated using heat produced by medium frequency alternating current (in the range of 350-500 kHz), which is known as radio frequency ablation (RFA), also known as fulguration, as depicted in Figure 1.1.

RFA is typically performed as an outpatient procedure, under conscious sedation or local anaesthesia. RFA can be used to treat malignancies in the lung, liver, kidney, bone, as well as less frequently in other body organs. A needle-like RFA probe is inserted inside the tumour once the diagnosis of tumour has been made. As a result of the probe's radiofrequency waves raising the temperature of the tumour tissue, the tumour is destroyed.

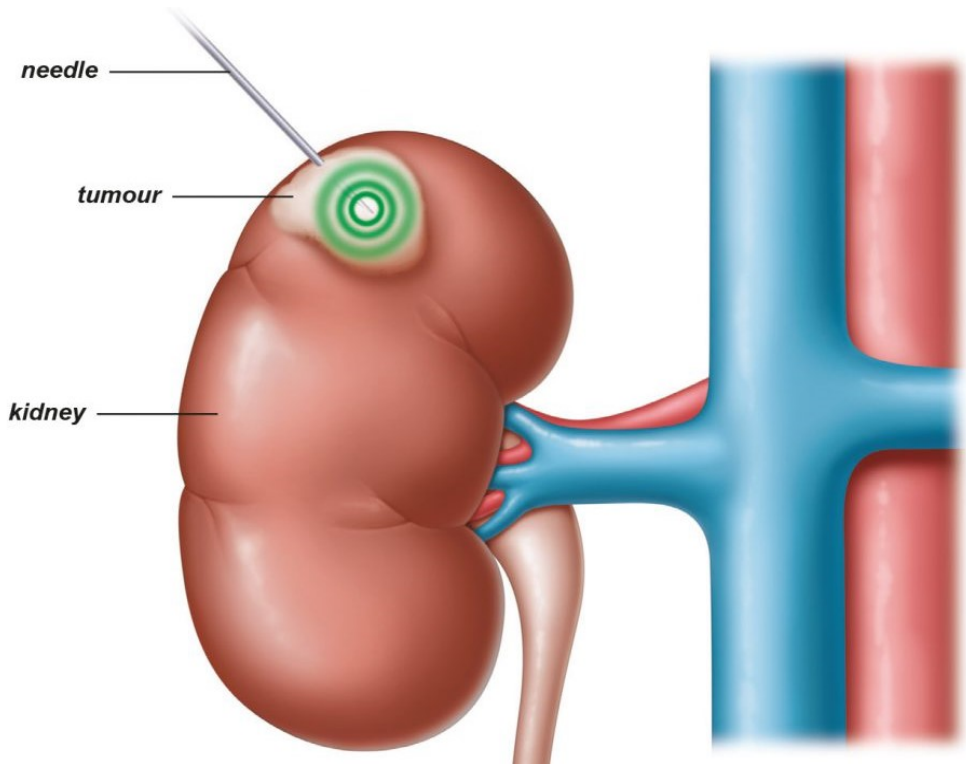

Figure 1.1: RFA Needle Placement for Kidney Tumor

1.1.3 HTC Vive

The HTC Vive uses ”room-scale” virtual reality, allowing users to move freely inside a play space as opposed to being confined to a fixed location. The positional tracking system used by the controllers and headset as depicted in Figure 1.2 is known as ”Lighthouse.” Several external base station units, also known as ”lighthouses,” are installed in the play area, and each of these contains an array of LED lights as well as two infrared lasers. The lasers are fixed to rotating spinners that use timed pulses to sweep the play area both vertically and horizontally. Photosensors built into the headset and controllers pick up LED lights from base stations and compare them to the timing of laser sweeps to establish their relative position in 3D space. The headphone must to a ”link box,” which has HDMI, USB 3.0, and power connectors, to be linked to a compatible PC.

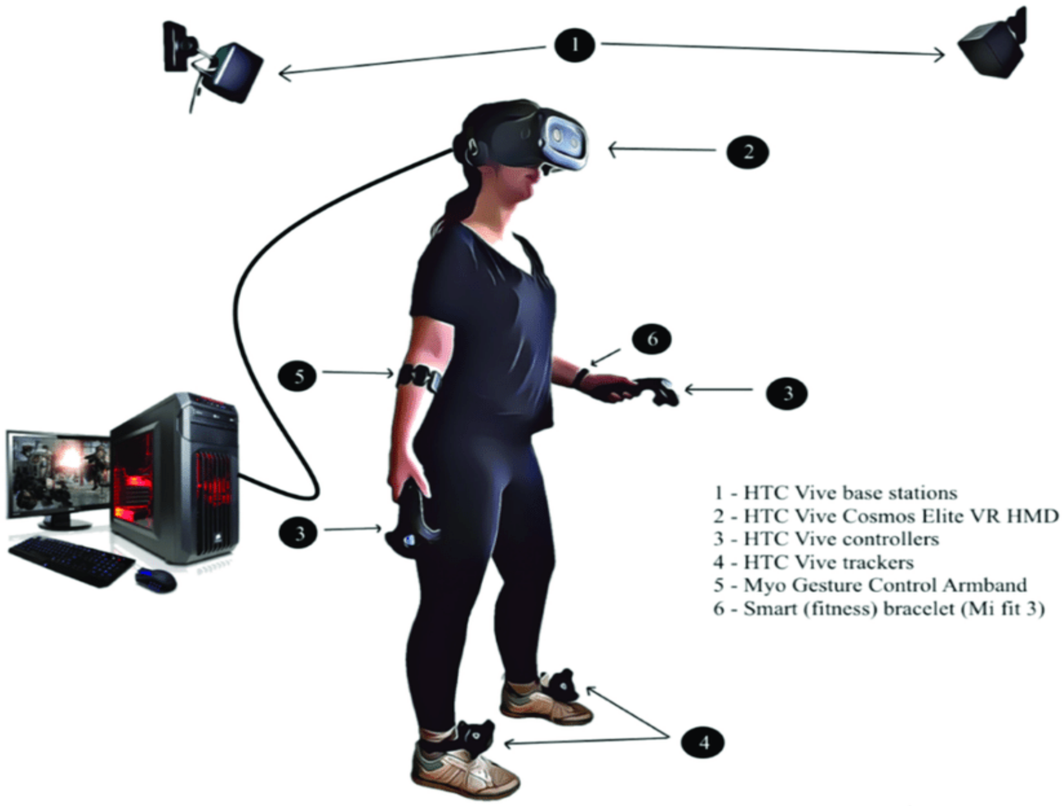

Figure 1.2: HTC Vive Hardware Components

1.1.4 Image Segmentation

The process of segmenting images, often referred to as contouring or annotating, involves removing portions of the image that typically correlate to anatomical structures, lesions, and other object space. It is a fairly common operation in medical image computing since it is necessary for 3D printing, quantification (measuring volume, surface, and form attributes), visualisation of certain structures, masking (restricting processing or analysis to a specific zone), and other processes.

1.1.5 Dicom Data

(Digital Imaging and Communications in Medicine) DICOM Library is a free online medical DICOM image or video file sharing service for scientific and educational purposes. DICOM incorporates standards for various imaging modalities such as radiography, ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), and radiation therapy.

1.1.6 SteamVR

The finest tool for experiencing VR content on any device is SteamVR. The Valve Index, HTC Vive, Oculus Rift, Windows Mixed Reality headsets, and other VR devices are supported by SteamVR. This tool's streamlined UI windows allow developers to easily customise audio, visual, and other input options. The project can easily be integrated with the HTC Vive using SteamVR thanks to Unity's inclusion of SteamVR plugins. Steam may be used to launch SteamVR, and it is simple to check the VR status. Any Unity project that has the SteamVR plugin imported can be connected to SteamVR after setting up the room scale and other common settings.

1.1.7 Line Renderer

Line Renderer is one of the components that are provided by Unity. The Line Renderer component takes an array of two or more points in 3D space, and draws a straight line between each one. It can be used to draw anything from a simple straight line to a complex spiral. The drawn line will be always continuous. The Line Renderer does not render lines that have a width in pixels. It renders polygons that have a width in world units. If multiple lines are need to be drawn, multiple gameObjects should be used each with it's own LineRenderer component. Our system uses this component to get a straight line from the outer skin to the tumor mass which is the path for RFA needle insertion.

1.1.8 Collision Detection

When a game object interacts with another object in Unity, there are many built-in functions and components to detect collision. The point of contact of collision can also be found. We make use of this functionality to calculate the depth of needle insertion from outer skin. When a collision between skin and needle is detected, we save the contact point. After that we calculate the distance of transformation of needle from the contact point to deform the anatomical structures. Also feed-backs are provided based on the target objects that are needle colliding with.

1.1.9 Deformation

The mesh models are deformed on the basis on needle insertion. The positions of the anatomical structures are changed (according to the mean displacement of organs provided by the various experiments conducted to find the accurate registration method) as the needle go deep into the body. The original values are correlated with the unity model values and are used. Instead of making mesh deformation, we used position based dynamics where the vertices of the models are changed directly to make rendering fast and efficient.

1.1.10 Position Based Dynamics

A quick, reliable, and controllable simulation method is position-based dynamics. It may model a variety of dynamic and interactive effects of objects such as rigid bodies, soft bodies, cloth, or fluids by directly manipulating the vertex positions of object meshes rather than forces or impulses. A position-based strategy's controllability is its key benefit. In force-based systems, overshooting issues with explicit integration techniques can be avoided. Additionally, by projecting points to legitimate locations, collision limitations and penetrations can be totally resolved.

1.2 PROPOSED SOLUTION

The proposed system starts with image segmentation of patient's CT scan. The CT image is segmented using semi-automatic segmentation software. The 3D model of the abdomen is generated from the segmented CT image using Volume Rendering technique. A virtual operation theatre scene is created on the Unity 3D Engine and the abdominal phantom is integrated into the scene as object. The whole scene is setup into the HTC Vive where the user can interact with the phantom model.

The system provides an introduction tutorial and gives a glimpse of various parts using Animation. The system tries to draw multiple straight line form various spots (in our case 13 spots) to the tumor mass. From these set of lines, the system checks for collision and distance of the path to select an efficient path. The system finds a straight line path (Line Renderer) from the outer skin to the tumor without colliding with any other objects to provide support for the user to navigate to tumor mass. The internal organs deform according to the needle insertion into the body. The system deforms the models by changing the vertices of the model (Position Based Dynamics). The system provides suggestions based on the path selected using constraints (distance and collision with other organs) and the user interaction with the models.

1.3 OBJECTIVES

The major objective of our project work is to provide the following features:

- Assistance for accurate needle insertion into virtual 3D kidney model. Visual feedback/notification pop-ups with respect to user interaction with the model. Any possible errors that can happen will be prevented. Thereby reducing the surgical complexity.
- Navigation via see-through display to locate the target mass.The major objective of this system is to act as navigation platform. In pre-operative planning, this can simplify the operation much.
- Reconstruct patient specific anatomy structure from CT scans. Instead of fixing up standard anatomy, reconstructing patient's specific anatomy structure helps in analyzing possible errors/damages that can happen in the actual surgery beforehand.
- When the needle gets inserted into the tissue, the tumor cells starts to move. This movement should be compensated so that the surgeons can proceed further accordingly. This calculation should be done fast

to accurately model the mechanical behavior of the kidney tissues with high efficiency.

- Providing basic knowledge about the VR environment and what the system is about using small introductory tutorial at the start of the system. Making sure the user understands the system and tools functionality.

- Check for possible paths from skin to tumor and select the most efficient and non-colliding path.

CHAPTER 2

RELATED WORKS

2.1 MIXED REALITY GUIDED RADIOFREQUENCY NEEDLE PLACEMENT: A PILOT STUDY

This study describes a mixed reality (MR) guidance technique for radio frequency ablation of liver cancers. In essence, our device is a holographic navigation platform that, during RFA, uses a Holo Lens to cast an MR overlay onto the patient. From the CT pictures of the abdominal phantom, we first recreate the anatomy structure specific to the patient. The virtual-real spatial information is then mapped using a customised accurate registration mechanism. Additionally, our guidance system incorporates a contact motion compensation computation through data-driven physically-based modelling in a holographic environment because tumour moving during biopsy significantly reduces the accuracy of RFA. In experiments, we compare MR-guided and CT-guided biopsy techniques using user research. User feedback suggests that our MR guidance system for the needle placement procedure has the potential to make the treatment simpler, less challenging, quicker, and more precise.

2.2 3D-MODELING OF STERNAL CHONDROSARCOMAS FROM ANGIO-CT-SCAN: CLINICAL APPLICATION AND SURGICAL PERSPECTIVES

Sternal malignant bone tumours are uncommon. For the purpose of defining acceptable margins during tumour excision, their surgical treatment is still primarily relied on exact information of preoperative imaging. To better comprehend connections between these tumours and surrounding organs, we offer a useful 3-dimensional (3D) modelling technique. Axial view images from CT scans were analysed by the free programme Horos after being made anonymous. The software created a digital mesh by first reconstructing a surface. Meshmixer software was used to treat this raw model and remove artefacts. These models were hosted on a safe, private platform and had their mesh surfaces reduced using Meshlab software. Three patients with sternal chondrosarcomas had six angio CT-Scans. A true 3-D anatomical board has been made possible by the segmentation of organs and arteries. Using the safe URLs supplied in this post, you can view each of these protected models on our server and alter them virtually in 360 degrees. Cheap cardboard virtual reality glasses allowed for 3D vision. The teaching of anatomy could benefit from the use of computer modelling, as could the patient's own comprehension of the illness. One possibility is the 3D printing of biocompatible materials in order to perform reconstructions that are specifically tailored.

Method for citing journals can be seen in References [1], [2].

2.3 STUDY ON DEFORMATION TECHNOLOGY OF VIRTUAL SURGERY SIMULATOR BASED ON LIVER PUNCTURE

Virtual surgical simulators, which makes use soft tissue deformation technology as one of their core approaches, are now the most efficient way to train doctors because to advancements in robotics and virtual reality technology. In virtual surgery, the interaction between visual and force perception is made possible by the combination of the deformation modelling technique and force feedback device. Although the standard approach to mass spring modelling is straightforward, the accuracy is subpar. The position-based dynamic modelling approach is highly effective but inaccurate. In this study, a method for modelling soft tissue deformation that takes into account the non-linear visco - elastic characteristics of hepatic soft tissue is proposed. It combines the mass spring method with position-based dynamics.

2.4 COLLABORATIVE VR FOR LIVER SURGERY PLANNING USING WEARABLE DATA GLOVES: AN INTERACTIVE DEMONSTRATION

Preoperative planning is an essential step in determining the viability of a liver resection and helps surgeons identify the damaged veins and resection volume. To facilitate the planning using desktop-based 3D and 2D representations, traditional surgical planning programmes are frequently employed. In contrast to virtual reality, desktop-based systems have less interactions and representations (VR). It is necessary to find a method that will help surgeons working together. Here, we demonstrate a collaborative VR prototype that combines wearable data gloves and VR controllers to facilitate liver surgery planning with simple interactions. Both 2D and 3D representations of the patient data are available for user exploration. Then, lines are drawn on the 3D model representation to specify a virtual resection. To ensure safety margins away from the tumours, the virtual resection is further improved. Additionally, to assist the surgeons throughout the modification, real-time risk maps are presented. The outcomes of the virtual resection are then represented as resection volumes with their corresponding amounts and colours. A comprehensive clinical investigation will be conducted in the future to compare the suitability of these input devices.

2.5 BENEFITS OF 3D IMMERSION FOR VIRTUAL COLONOSCOPY

Human colon cancer can be found via Virtual Colonoscopy (VC), a non-invasive clinical method. Since the conventional optical colonoscopy is more painful and less successful at detecting cancer, VC aims to augment and increase the compliance rates for individuals who have been diagnosed. We go over the advantages of a 3D immersive user interface for VC in this paper. We go over different design options for such a design, utilising the impacts of different arrangements of virtual reality (VR) system components.

2.6 3D RECONSTRUCTION OF ORGAN FROM CT IMAGES AND VISUALIZATION IN A VIRTUAL REALITY ENVIRONMENT

Virtual reality (VR) displays artefacts or computer-generated scenes that closely resemble real-world scenarios. Processing and 3D reconstruction of medical pictures is a crucial stage in VR that has made substantial advancements in the field of medicine. In order to give the professional a different tool for the interpretation of medical images, we suggest a methodology for processing medical images that segments organs, reconstructs structures in 3D, and represents structures in a virtual reality environment. In order to create a virtual environment in Blender, we offer a DICOM image processing approach based on the area differentiation and 3D reconstruction using the ”isosurface” and ”alpha-shape” methods. Numerous research demonstrate how VR can be used in healthcare settings and as an educational aid. To acquire more precise definition and detailed structures for use in routine procedures, improved 3D segmentation is required.

2.7 VIRTUAL SURGERY SYSTEM FOR ABDOMINAL ORGANS BASED ON VR HELMET

Nowadays, doctors analyse CT scans of the human belly, which never allow for a natural, three-dimensional viewing. According to statistics, human error accounts for 80 percent of clinical mistakes. Therefore, surgical training is crucial to the development of young surgeons' experience. This study develops a surgical system for abdominal organs based on VR helmet in order to efficiently examine the body structure of the human body and enhance the technical skill of doctors. The system can transform the reconstruction of the human abdominal body into a three-dimensional model using 3D Labeling method and time-varying phase difference algorithm. From there, a VR helmet may perform a real-time visualisation of the human organs in various states. In order to cut the abdominal organs, our system offers a virtual tool set (scalpel, surgical clamp) that may be used in conjunction with a collision detection and cutting algorithm. According to experimental findings, our system is capable of creating a three-dimensional model of the abdominal organs, and virtual surgery tools could enable medical professionals to fully replicate an operation while also utilising force-feedback technology.

2.8 APPLYING MULTI-USER VIRTUAL REALITY TO COLLABORATIVE MEDICAL TRAINING

This paper provides paramedics a novelty training tool with multi-user virtual reality (VR) and improves learning techniques. Two interactive trainees have two-user full-scale YR environment with head-mounted displays and one trainer participant have additional desktop as their hardware setup. The software shows a paramedic emergency simulation, a representative scenario that happen rare within the term of vocational training. Multi-user VR providing hands-on experience and paving a way for current and future development in research areas like user navigation, interaction, level of visual abstraction and level of task abstraction. VR provides realistic ground for vocational training scenario. The setup uses HTC VIVE to track user heads, hands and other body parts. VR - enabled Windows - PC runs Unity game engine and TriCAT Spaces.No standards are established for interactive features like navigation, manipulation etc. The discussion based on the current state of this system and continuous evolvement of technology are also proposed. The EPICSAVE prototype whose demonstration makes users to join in remote virtual environment for paramedic training. This prototype experience helps stakeholder and researchers to discuss future work towards developing VR training standards.

2.9 ANALYSING USABILITY AND PRESENCE OF A VIRTUAL REALITY OPERATING ROOM SIMULATOR DURING LAPAROSCOPIC SURGERY TRAINING

Immersive Virtual Reality (VR) laparoscopy simulation is emerging to enhance the attractiveness and realism of surgical procedural training. Virtual Operating Room (VOR) which has user evaluation and immersive environment during laparoscopic procedural training. A 360 degree computer generated operating room is displayed by VR headset around a VR laparoscopic simulator during laparoscopy procedures. Complete cholecystectomy task in the VOR is performed by 37 surgeons and surgical trainees. Semi-structured interview which is followed by set of Questionnaires (i.e., Localized Postural Discomfort scale, Questionnaire for Intuitive Use, NASA - Task Load Index, and Presence Questionnaire) were used to collect the data. The participants could intuitively adapt to the VOR and were satisfied when performing their tasks (M=3.90, IQR=0.70). The participants, particularly surgical trainees, were highly engaged to accomplish the task. Despite the higher mental workload on four subscales (p ¡; 0.05), the surgical trainees had a lower effort of learning (4 vs 3.33, p ¡; 0.05) compared to surgeons. The participants experienced very slight discomfort in seven body segments (0.59-1.16). As VOR provides immersive training during laparoscopy simulation, it gains a potential to become a useful tool based on the usability and presence noted in the study. Future developments of user interfaces, VOR environment, team interaction and personalization should result in improvements of the system.

2.10 3D MEDICAL IMAGE SEGMENTATION IN VIRTUAL REALITY

The achievements of accurate and intuitive 3D image segmentation are endless. For our specific research, we aim to give doctors around the world, regardless of their computer knowledge, a VR 3D image segmentation tool which allows medical professionals to better visualize their patients' data sets, thus attaining the best understanding of their respective conditions. We have implemented an intuitive virtual reality interface that can accurately display MRI and CT scans and quickly and precisely segment 3D images, offering two different segmentation algorithms. Simply put, our application must be able to fit into even the most busy and practiced physicians workdays while providing them with a new tool, the likes of which they have never seen before.

2.11 PERFORMANCE AND QOE ASSESSMENT OF HTC VIVE AND OCULUS RIFT FOR PICK-AND-PLACE TASKS IN VR

This paper presents a assessment methodology and results for two VR systems : HTC vive and Oculus Rift. The parameters used for comparison are frame rate, ambiance light, sensor obstruction and also a pick and place task which involves grab and positioning objects.The objective and subjective parameter measured are spatial precision, time to complete the task, quality of experience, intuitivness, ease of use. Frame rate for HTC Vive is between 99 and 101 fps and between 93 and 96 for Oculus rift.For LOS obstruction, HTC Vive gives good performance because sensors in vive tracks both controllers and HMD while in Oculus each sensor tracks only HMD or only controllers.For time to complete the task, more time needed for Oculus rift than HTC Vive. By CCR evaluation, HTC Vive performed better especially mostly on overall QOE.

2.12 DEVELOPMENT OF A SIMULATOR WITH HTC VIVE USING GAMIFICATION TO IMPROVE THE LEARNING EXPERIENCE IN MEDICAL STUDENTS

This paper aims to increase the experience of learning of medical students who specialize in surgeries using gamification techniques and HTC

Vive device to simulate a VR scenario since students will improve the learning process by results and feedback.When it comes to VR Technologies, for HMD HTC Vive was chosen mainly because of the area that a player can put to interact with VR and also due to better sensors and for game engines, Unity3D was used because it is multiplatform and has a better learning curve than Unreal.The game starts inside the operating room, but before you can start the surgery, the system asks for a record with a name that you write on a virtual keyboard.In this you can write with the HTC Vive commands and in doing so it is saved in the database for data management. Then, the system will ask you if you want to start the simulation of surgery with a tutorial if you do not feel safe or if it's your first time in this video game.If the tutorial is chosen, the system will give you help with messages with a description of the steps to follow with the surgery;In addition, you will have a shading of the tools to know which one to use at that moment.Finally, the tutorial will have error messages if the user is committing some process badly.

2.13 A GLANCE INTO VIRTUAL REALITY DEVELOPMENT USING UNITY

This paper represents which is the best game engine for virtual reality development and its benefits over others. The main programming language that Unity uses is C sharp, a language that is easy to learn, versatile, object oriented and complex.When it comes to Unreal Engine or CryEngine, the programming language that is used for developing on these platforms is C++ which is more sophisticated and harder to learn being especially used by professional developers who want a certain level of flexibility. Alongside having a friendly user interface that is easy to use and explore, Unity also provides its users with high quality tutorials as well as a structured documentation which can be found easily on their website. In addition, for a beginner, finding assets for their projects can represent a difficult task, but this game engine has an integrated

Asset Store in which the community can share assets that they create.Another advantage of using Unity over an-other game engine is that it has the ability to compile the games for a large variety of plat-form such as: Oculus Rift, HTC Vive, Gear VR, Daydream, etc.

Proceedings should be cited as given in the References [3], [4],[5],[6], [7], [8], [9], [10], [11], [12] and [13]

2.14 DEVELOPMENT OF A PATIENT SPECIFIC SURGICAL SIMULATOR BASED ON VIRTUAL REALITY

A surgical simulator can provide doctors with a new way to realize surgical planning and surgical training. In this study, they developed a surgical simulator based on virtual reality technology and haptic device, which can be used to simulate drilling, cutting and catheterization in a virtual environment. The virtual spring model and collision detection algorithm are used to simulate the feedback force while the subdivision mesh algorithm, the voxel remove algorithm and trajectory method are used in order to simulate the deformation of models in the surgical simulator. All the models are reconstructed from CT data of the patients, which allow the surgical simulator to be patient-specific.

2.15 EFFICIENT SURGICAL CUTTING WITH POSITION-BASED DYNAMICS

For more than 20 years, simulations of cuts on deformable bodies have been a focus of research. However, complex surgical scenarios cannot be scaled up using earlier efforts based on mass spring meshes and finite element methods. This paper proposes a novel approach for mesh-free cutting simulation based on position-based dynamics (PBD). The suggested solutions comprise a technique for force feedback rendering while cutting, a heat diffusion model that simulates electrocautery effectively, and a revolutionary adaptive skinning method based on oriented particles.

Articles should be cited as given in the Reference [1], [2], [14], [15] Reports and thesis should be referred as given in the Reference [16].

2.16 OBSERVATIONS AND MOTIVATIONS

Pre-operative planning by generating the patient specific anatomical structures is the main motive of this project. By using segmentation software, volumetric 3D models from CT scan is generated much faster. Flying Edge Algorithm, used for image segmentation is highly efficient, reliable and high - performance scalable isocotouring algorithm. By analysing papers on image segmentation and available software for image segmentation, 3D slicer is used for this project which implements Flying Edge Algorithm.

The related works that has been done before on this domain (i.e. Virtual surgical simulators) used pre-defined models. By introducing CT image specific models, medical trainees can work with different types of models. Also, this helps in pre-operative planning efficiently.

Instead of just introducing interaction with the 3D organs, feedbacks for user's action and guidance for needle placements make the system much more easier to use.

The movements of tissues and tumour cells with respect to the needle insertion should be calculated quickly and accurately. These movements should be compensated correctly on the 3D models.

CHAPTER 3

SYSTEM DESIGN

3.1 ARCHITECTURE DIAGRAM

An architectural diagram as shown in Figure 3.1 provides an overall view of the software and its evolution roadmap.

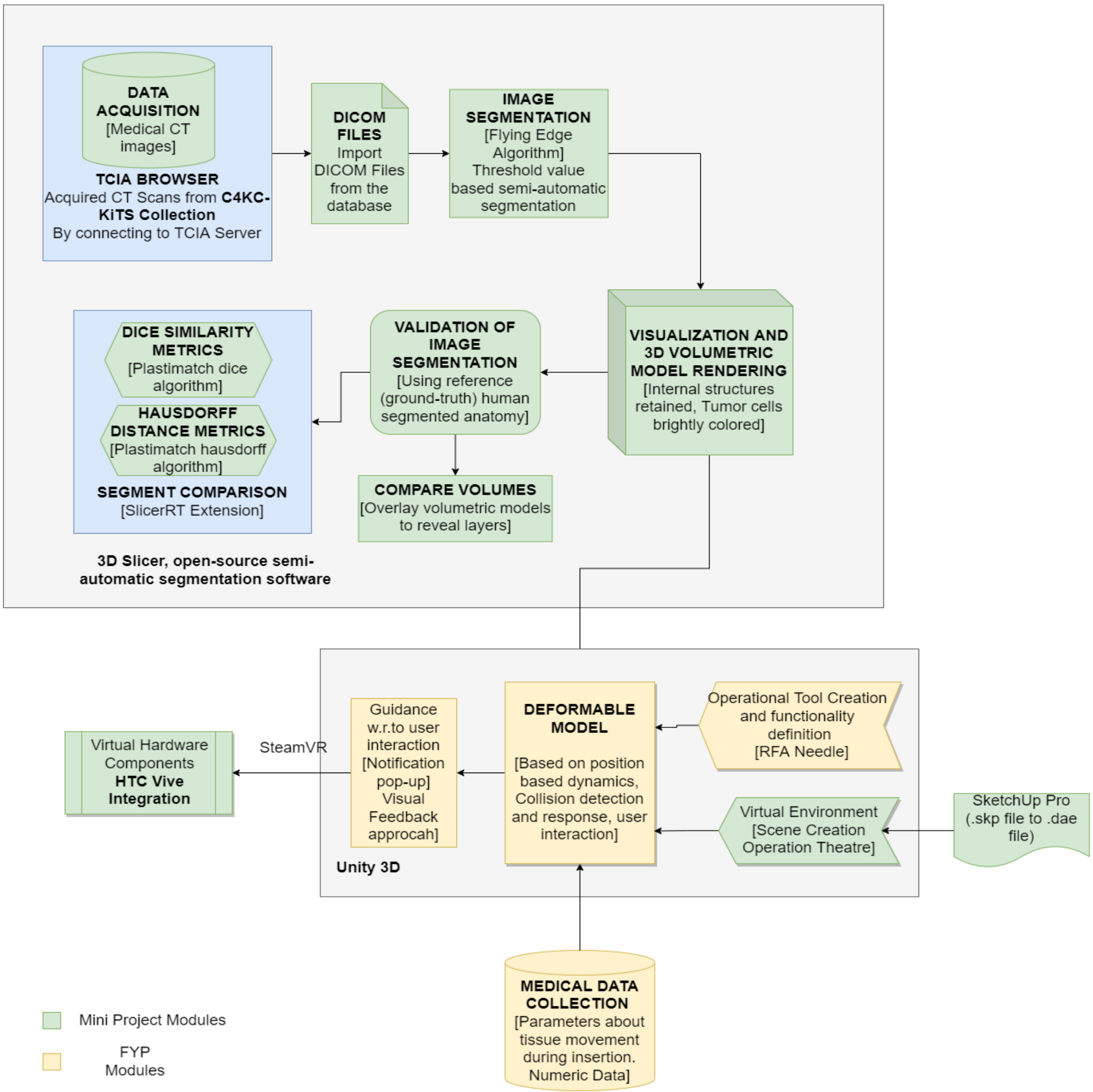

Figure 3.1: Overview of creating an virtual model for RFA placement

The input for our system is DICOM data from medical CT image which is acquired from Kits collection of TCIA browser which is an extension of 3D slicer.Then image segmentation happens, in which mask model is created and then thresholding (Threshold values are determined for each structure) and removal of noise for the mask model takes place which results in the final 3D model of an organ.

Validation is done by comparing ground truth (3D model generated from segmented image obtained from online sources) and model that we created for the same image from 3D slicer using metrics like dice similarity metrics, hausdroff distance metrics along with comparison of volumes. A virtual operation theatre scene is created on the Unity 3D Engine and the abdominal phantom is integrated into the scene as object. The whole scene is setup into the HTC Vive where the user can interact with the phantom model.

3.1.1 Phase 2 Architecture Diagram

The phase 2 architecture diagram for the further software development is shown in Figure 3.2. FYP modules highlighted in the previous architecture diagram are explained here to provide more visibility on those concepts.

In the second phase development, we started with the creation of an animation introduction tutorial to briefly explain about the VR environment and the body parts. The visual representation of the body parts name along with audio on the background is setted up to explain the flow of anime. It also explains about the functionalities of the system and what the system is about. Then we made the VR environment interactable and added functionalities for locomotion and objects interaction. The path finding module's main objective is to find a straight line from outer skin to tumor mass center without touching any other object. For this, Unity's Line Renderer component and collision detection is used. From various spots, the system checks for a straight line possibility without collision. After a path has been selected and drawn, feedbacks are provided if the user does not follow this path or collide with any other object. Then, when the needle is inserted according to it's distance from the point of it's contact on the outer skin, the internal organs deform. The deformation is based on position based dynamics where the vertices of the models are directly changed instead of force feedback which provides fast and efficient rendering. The entire system is mounted on HTC Vive Headset using Steam to experience VR and all the functionalities generated.

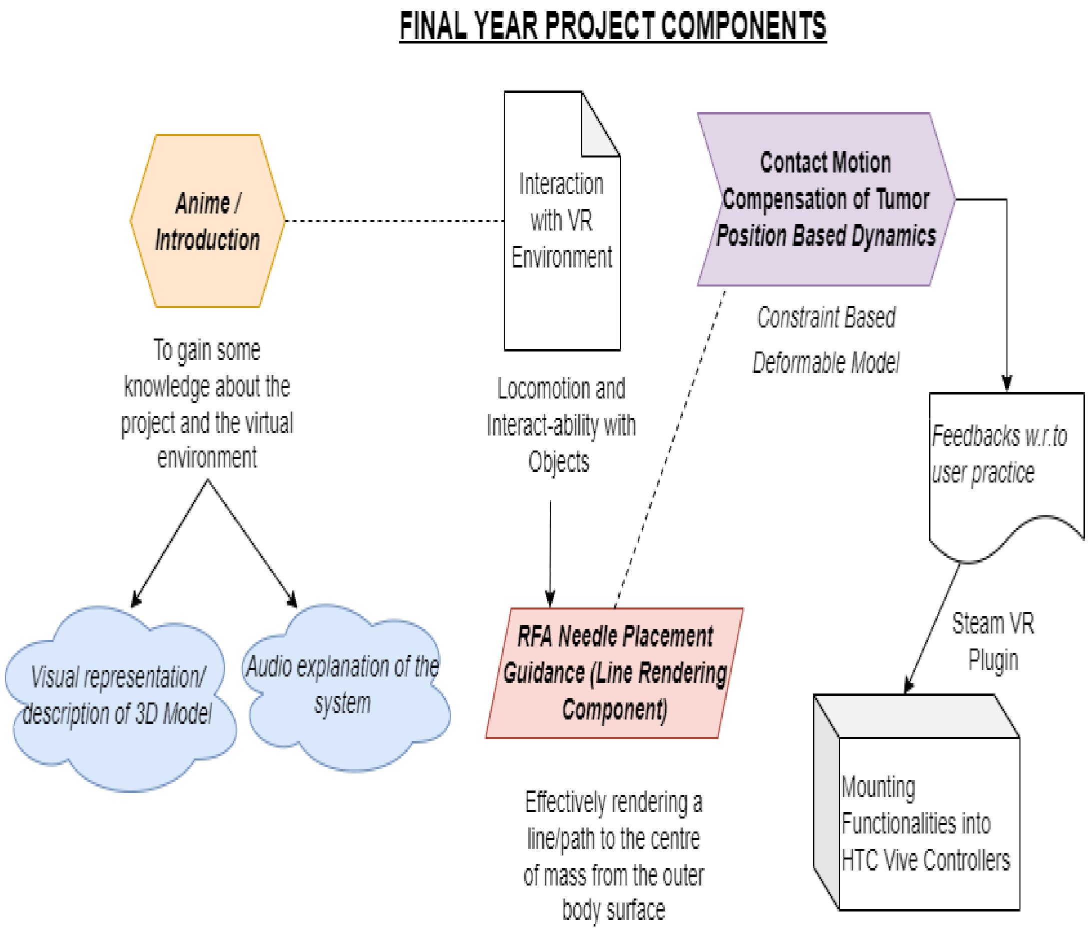

Figure 3.2: Phase two Architecture Diagram

3.2 CT IMAGE SEGMENTATION

An image segmentation has following steps as shown in Figure 3.3

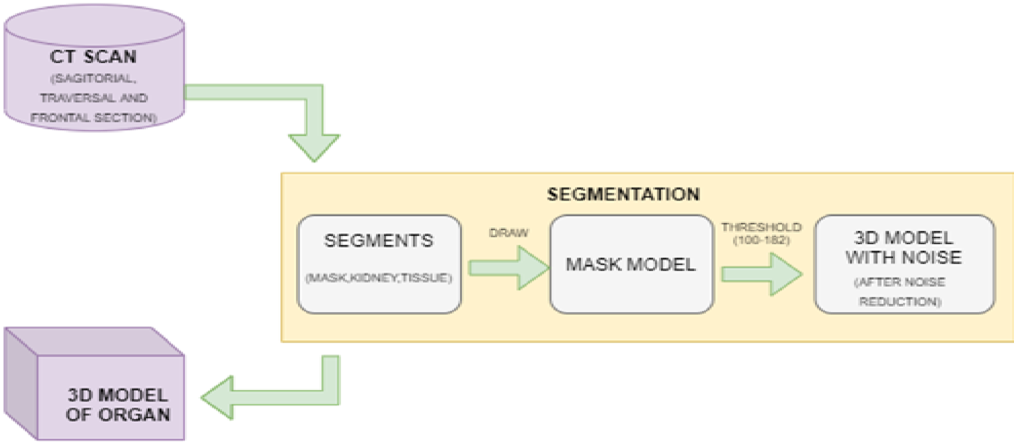

Figure 3.3: Image Segmentation Flow Diagram

- Selection of mask segment.
- In mask section effect, using paint, mask organ in frontal, sagittal, traversal section in all slides of the CT scan.
- View 3D model for mask.
- Thresholding for mask model(for kidney mask model 100-182)
- 3D model with noise
- Removal of noise using erase.
- Final 3D model of organ.

Segmentation Algorithm

An picture is divided into sets of pixels or regions via segmentation techniques. To better grasp what the image depicts, partitioning is done. The sets of pixels may indicate image elements that are important for a particular application.

Cube Cut

A common manipulation of 3D images is to cut the data so that it removes that which you are not concerned with. To make this as easy to use as possible, when called, this method will start with an interior cube which cuts the data. All that falls inside will be displayed whereas the data outside will not. Sometimes the segments are inaccurate.

Region Grow

With points of origin (seed points) and a threshold specified, this algorithm looks at neighboring voxels and their difference in color value, and if they are within the tolerance, adds them to the segment. On low-contrast medical images, the results of this algorithm are slow and inaccurate. Sensitive to noise and very slow.

Max-Flow Min-Cut

A minimum graph cut is computed between the source and the sink to segment the image at the frontier with the weakest edge, or sharpest change in color intensity. Because this method of segmentation uses the relative difference between voxel intensities instead of relying on absolute magnitudes it is able to process data with poor contrast and gradual edges. But it cuts off very small isolated parts.

Flying Edge

Flying Edge Algorithm is a high - performance iso contouring algorithm for structured data that is designed to be inherently scalable. Over several passes, processing is carried out entirely independently along the edges. The parallel bottleneck caused by coincident point merging is also removed by this unique technique, which also uses computational trimming based on geometric reasoning. Since the technique enables heterogeneous parallel computation, which combines data parallel and shared memory approaches, it works well in serial or parallel execution. Additionally, it can process data that is too big to fit entirely in GPU memory, doesn't incur extra costs from preprocessing and search structures, and is the fastest non-preprocessed isocontouring method on shared memory, multi-core systems that we are aware of.

Because of the comparable performance and open source software availability we segmented the CT scans in 3D Slicer which implements Flying Edge Algorithm. Because of it's parallel computation the segmentation is done fast and reliable. The volumes were rendered quickly so it was convenient to make changes and proceed further easily.

3.3 UNITY 3D SCENE SETUP

Unity 3d scene setup has following steps as shown in Figure 3.4

- Downloading skp file.
- Converting skp file to dae file using Sketchup Pro 2021.
- Dragging dae file to unity 3D.
- Adjusting the position of dae file and setting the parameters(x,y,z).

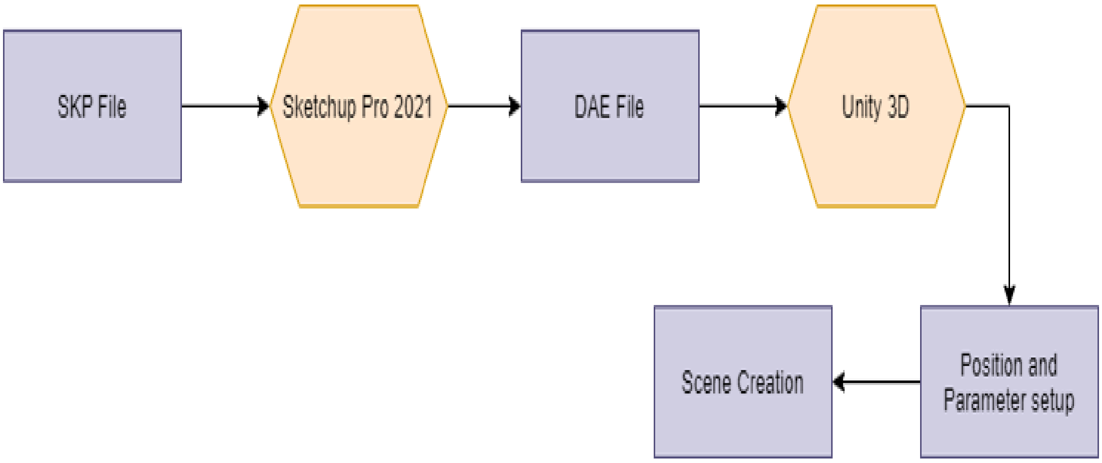

Figure 3.4: Unity Setup Flow Diagram

- Setting up the directional light and hence the scene is ready in unity 3D.

3.4 HTC VIVE HARDWARE INTEGRATION

HTC Vive hardware integration has following steps as shown in the Figure 3.5

- Downloading steam application.
- From steam, steamVR application is installed which is used to detect VR headset plugin
- Setup for the hardware components is made where the steps are shown in the fig.
- Room setup is made.
- SteamVR plugin is imported in unity 3D.
- Camera setup is made for head, left and right controller.
- By playing the scene virtual reality environment will be created

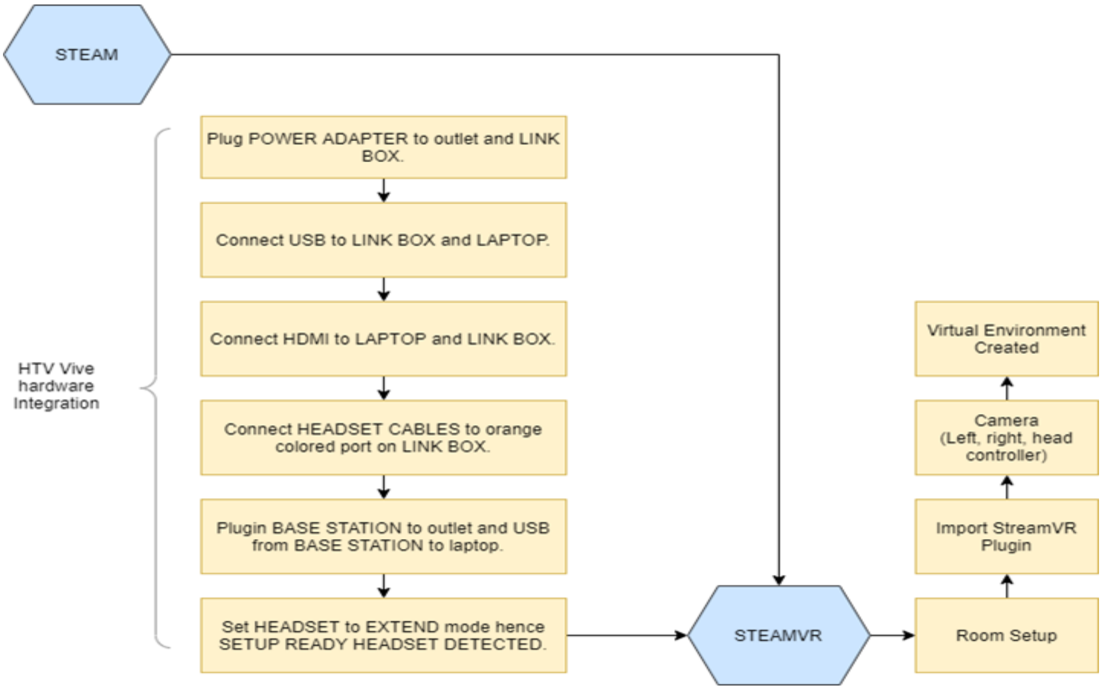

Figure 3.5: HTC Vive Hardware Integration Flow Diagram

3.5 NAVIGATION TO MASS USING LINE RENDERER

The Line Renderer component provided by Unity takes an array of two or more points (Vector3 data structure) in 3D space, and draws or computes a straight line between them.

To create a Line Renderer:

- In the Unity menu bar, go to GameObject, then Effects, then Line.
- Select the newly created Line Renderer GameObject.
- By directly specifying array values in the Inspector window or by utilising the Create Points Scene Editing Mode, you can add points to the Line Renderer's Positions array.
- To change the line's colour, width, and other display options, use the Inspector window.

Here in our project we kept 13 spots which are uniformly distributed to identify the shortest path to mass. Using Line Renderer , all 13 paths have been drawn to mass. We have selected the path which is non-collidable with other objects. Among the all non-collidable to mass, shortest path will be choosen. So likewise, we can also have more spots where we can find more non-collidable paths but all the spots should be uniformly distributed.

3.6 ANIMATION TUTORIAL

For each organs in the body, individual gameobject is created. Inside this gameobject, name board which is used to identify these is made. This name board consist of arrow, plane and floating text. The plane with reduced scale is used as an arrow, and plane on which floating text is placed to name each organ. Using animation feature, at given peroid of time, at a given frame only one name board has to be displayed. For this animator feature has to be added in each name board. Audio explaining our process will be played in the background when the scene is played which is done by importing ResonanceAudioSource package and adding audiosource to any of the obeject in the screen.

3.7 INTERACTION AND LOCOMOTION

The steps to integrate locomotion and interaction in VR environment is included in Figure 3.6

Download and configure SteamVR: To import the SteamVR plugin, click Download. A CameraRig and SteamVR will be included in the steamVR prefab. Drag CameraRig and SteamVR to the Hierarchy after choosing both of them. The two Controller children of CameraRig have the controllers assigned to them.

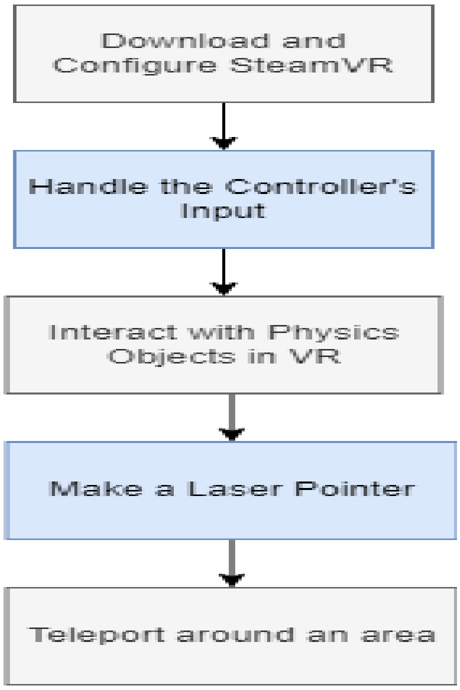

Figure 3.6: Interaction and Locomation

Handle the controller's input: Each controller has following inputs: Application menu, Touchpad, System menu, Grip, Hair trigger

- Defining action: Using the action system, you can consider user actions rather than which buttons or triggers should be queried for input. SteamVR determines which inputs to employ for a specific action. All action sets and actions are contained in the SteamVR input window. The buttons here function as tabs to transition between the action sets. The standard set of actions, including input and output. Here, the actions can be added, modified, or removed. The save and generate button creates a large number of helper classes for quick access to the actions as well as saves all action sets and individual actions to JSON.

- Binding action: After defining actions, default hardware bindings can be created.

Interact with physics objects in VR: Select both controllers in the Hierarchy and add a Rigidbody and BoxCollider component to them. The collider goes right over the top part of the controller, which is the part you use to pick up objects.

Make a laser pointer: A laser pointer is handy in a VR world for all sorts of reasons. It is used to navigate, pop virtual balloons, aim guns better and frustrate digital kittens.Lasers shouldn't cast shadows, and they're always the same color, the desired effect can be created by using an unlit material.

Teleport around an area: Teleportation is a more practical means of transport in VR world. A quick position change is easier for the player to adjust to than one that happens gradually. More than unexpectedly finding yourself in a new location, subtle alterations in a VR environment can throw off your sense of balance and velocity. You'll utilise a marker or reticle that is included in Prefabs to illustrate exactly where you'll finish up. The reticle is a straightforward, round, lighted disc. You must add the LaserPointer script in order to use the reticle.

3.8 COLLISION DETECTION

In our project, we have attached a sphere to the needle. So whenever sphere touches the body collision will be detected. So we added a script in which if a object(sphere) touches body(another object), collision should be detected is written. Then add rigid body to both objects because it gives sort of mass and gives it a structure. Now rigid bodies are affected by gravity but if we don't want to move we can use the freeze positions constraints and make it non-movable. Also a Interpolate function is enabled so that one object can be moved inside the other object. So once a collision is detected , we can find the distance, contact points and furthermore.

3.9 DEPTH OF NEEDLE INSERTION CALCULATION

The depth of the needle endpoint inserted into the skin is crucial for deformation. Therefore, it is calculated and checked for any change continuously. On the basis of these distance values, the organs transform.

- Using Collision Detection, the point of contact of needle on the outer skin model is stored.
- On collision with skin model, the distance from the contact point to the needle transform point is calculated
- Last updated distance is set to distance
- For every 5 frames (update function) the distance is calculated and checked for any further movement
- If changed, the last updated distance is set to current distance
- Else, no change

The distance is calculated using Vector3.Distance() function between Vector3 Contact point and Vector3 sphere (At the endpoint of the needle, a sphere is attached to get the vertices of the needle endpoint).

3.10 ANATOMICAL STRUCTURES DEFORMATION

The deformation of internal organs is done with respect to the needle depth into the body. The mean displacement of organs on surgery is collected from various sources (from experiments done to find accurate registration method for finding organ displacement on surgeries). The deformation of internal organs is done by changing the vertex positions of the organs directly(PBD). The entire deformation is done in 3 phases. The suggested path distance is divided into three ranges. When the needle enters the first range, 1/3 of the displacement is done. When the needle enters the second stage, 2/3 of the displacement is done. Finally, when needle enters third range of distance, the complete displacement is done.

3.11 FEEDBACK

Feedback for user interaction with body model is provided on the basis on collision detection. If user doesn't follow the suggested path or collide with other organs, then feedback is provided.Based on the path constraints, a static line renderer is set. If the user follows a path (collides) other than this line renderer, suggestions are given. User should start from the selected spot to get a straight way to tumor without colliding with other organs.

CHAPTER 4

IMPLEMENTATION

4.1 SEGMENTATION

CT images are segmented in the 3D slicer software by selecting threshold values for different anatomy structures and by masking their volumes. It is semi-automatic segmentation software and renders volume comparatively fast. The segmented image of kidney is shown in the Figure 4.2 and segmented image of liver and spinal cord are shown in Figure 4.3 .Respective models of skin, muscles and internal organs are shown in Figure 4.4, Figure 4.5 and Figure 4.6. In 3D slicer, Segmentation is done using flying edge algorithm.

Flying Edge Algorithm

The image segmentation is done using Flying Edge Algorithm.The algorithm performs following operations:

- Traverse the grid row-by-row to compute grid x-edge cases; count the number of x intersections; and set the row computation trim limits.
- Traverse each grid cell row, between adjusted trim limits, and count the number of y- and z-edge intersections on the ai jk , as well as the number of output generated.
- Sum the number of x-, y-, and z-points created across the ai j k of each row, and the number of output.
- Traverse each grid cell row, between adjusted trim limits, and using the ai jk generate points and produce output.

The cell axes aijk coordinate system. The algorithm processes the aij k in parallel along x-edges Ejk to count intersections and the number of output. The

$$E_{jk} = \bigcup_{i=0}^{n-1} e_{ijk} \quad \text{and} \quad R_{jk} = \bigcup_{i=0}^{n-1} v_{ijk}.$$

input for segmentation is the frontal, transversal and sagittal view of the ct scan image which is shown in Figure 4.1

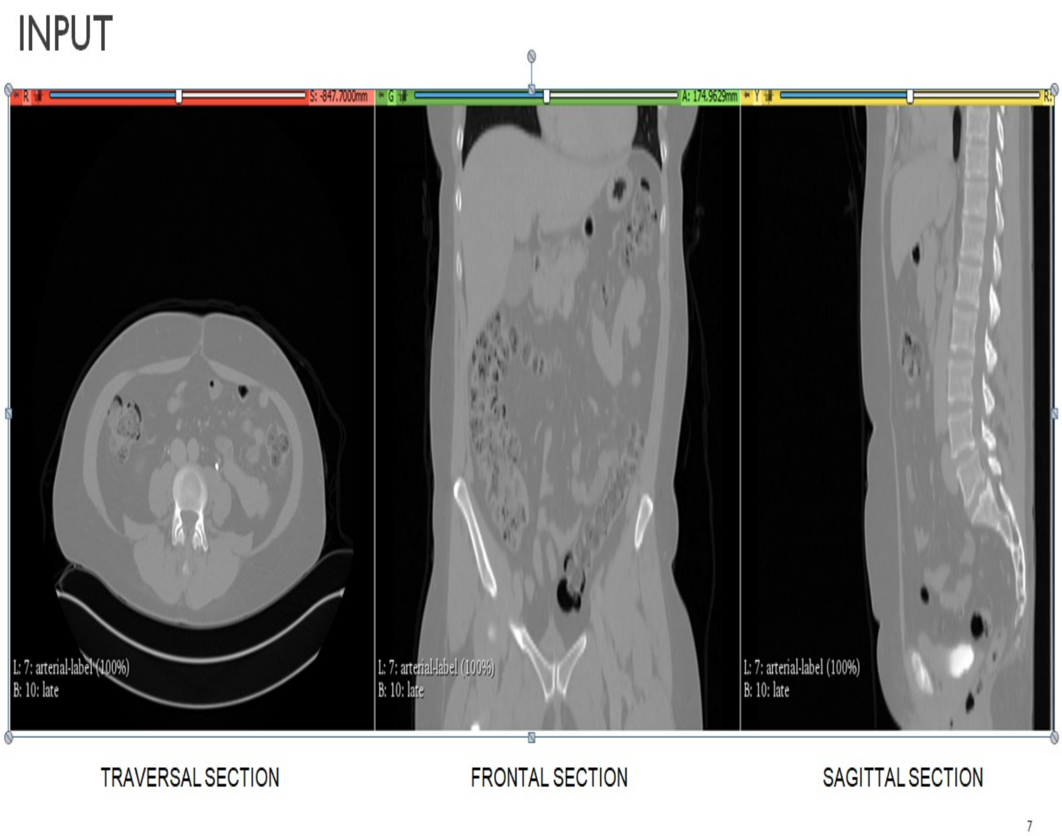

Figure 4.1: Three sections of CT scan

The process of segmentation from the ct scan image involves selection of mask segment using paint in all section of ct scan which produces mask model of that specific organ. After applying threshold to the mask model, it gives model with noises. Removal of noise produce final 3d model. Such process is explained for kidney in Figure 4.2 and for liver and spinal cord in Figure 4.3.

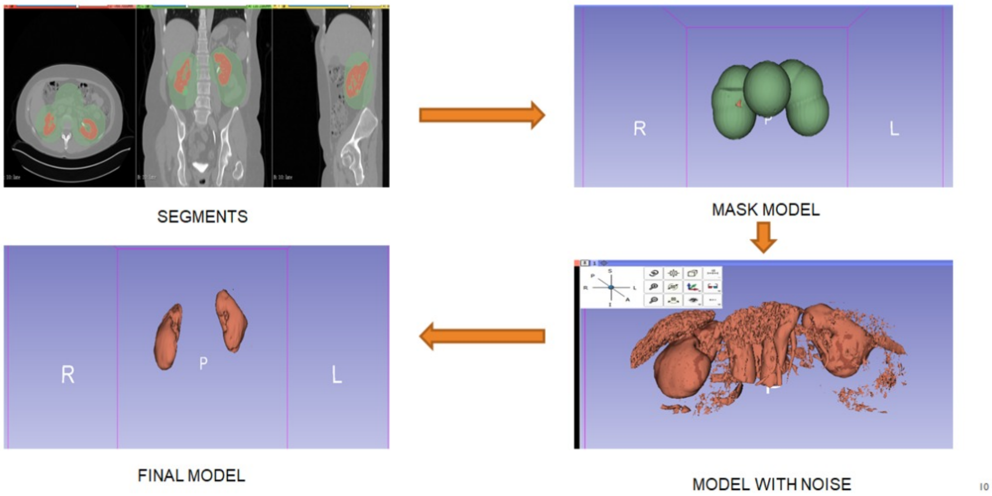

Figure 4.2: Kideny Segmentation Process

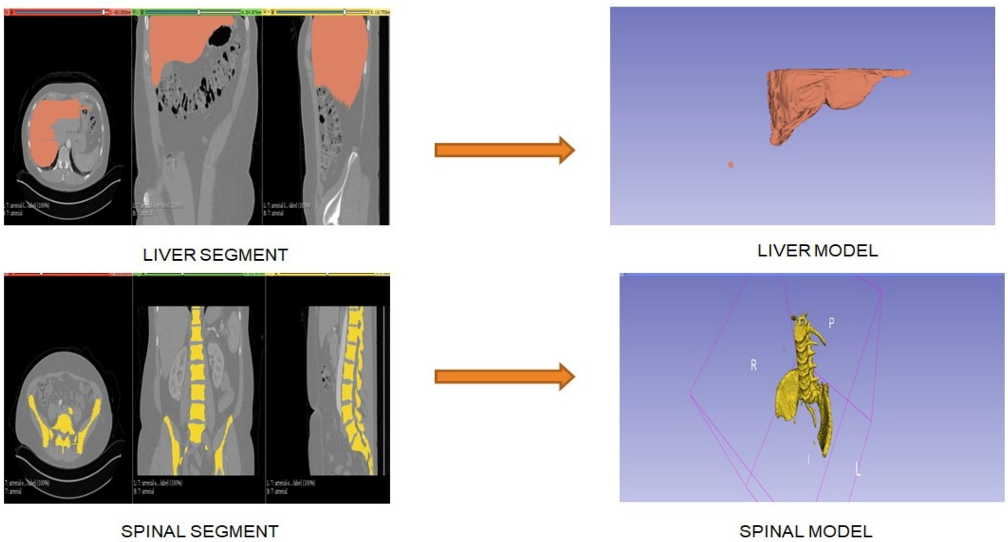

Figure 4.3: Liver and Spine Segmentation Process

3D models of outer body base and bone-muscle framework are taken from online sources. The files are converted into .OBJ files in MeshMixer to standardize the format for integrating it into Unity. Figure 4.4 and Figure 4.5 shows the body base model and bone-muscle structure respectively after they are integrated into the Unity.

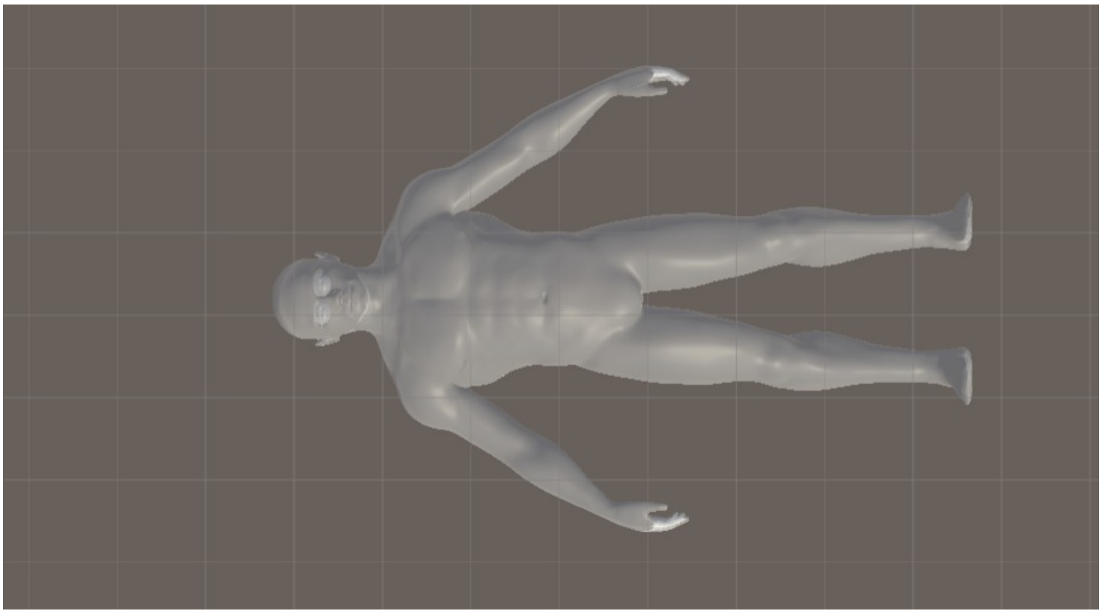

Figure 4.4: Outer skin

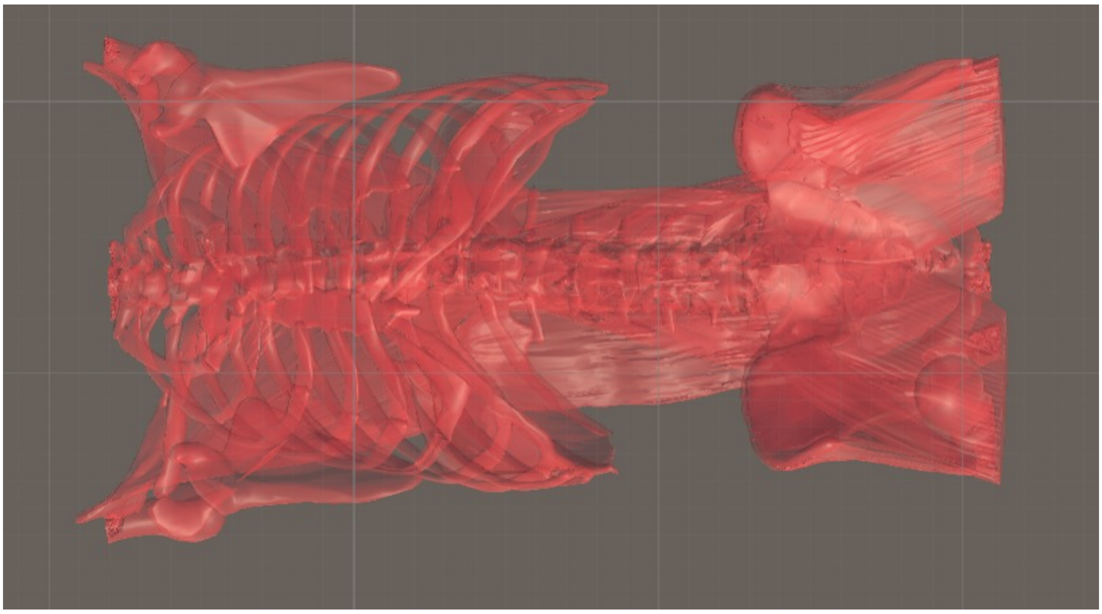

Figure 4.5: Muscle

The internal structures models developed from CT scan are integrated into Unity and are aligned properly as shown in Figure 4.6

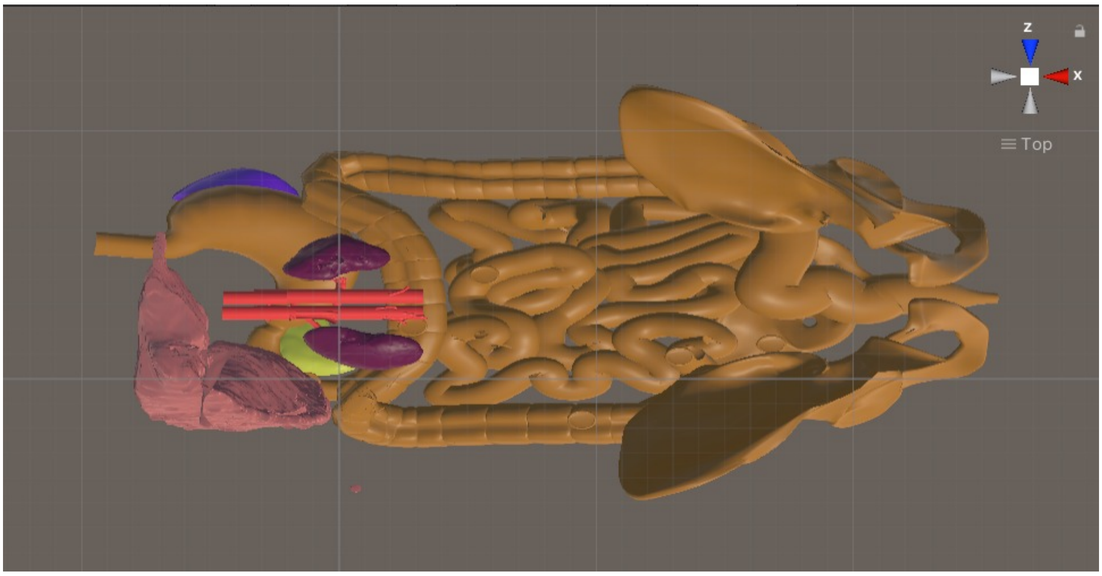

Figure 4.6: Organs

4.2 OPACITY REDUCTION AND SCENE INTEGRATION

Unity 3D Engine is used to develop an operation theatre scene. The 3D anatomy structures developed in the 3D slicer platform are imported to MeshMixer where we smoothened the model and merged some structures. Then the models are imported into Unity as OBJ files. In Unity, the models are restructured and aligned with the scene.Opacity of the models are also controlled in unity engine to acquire more visibility of tumour cells.Reduced opacity for skin, muscle and inner organs are shown in Figure 4.7, Figure 4.8 and Figure 4.9. The front and side view of the body with skin, muscles and inner organs are shown in Figure 4.10 and Figure 4.11. The tumor ,coloured in green ,which is in kidney is seen via see-through view of the body which is shown in Figure 4.12.

HTC Vive Integration is done on using SteamVR plugin which is available on Unity. HTC Vive Headset is connected with the project and the scene along with structures can be seen in the Virtual Environment.

This 3D model is acquired from online source and is converted into standard file format (.OBJ file) and integrated it into Unity Engine. Then, the opacity of the model is reduced to the least value used in the entire material files. A specific material file is created and designated for this object.Body base of the human is shown in Figure 4.7.

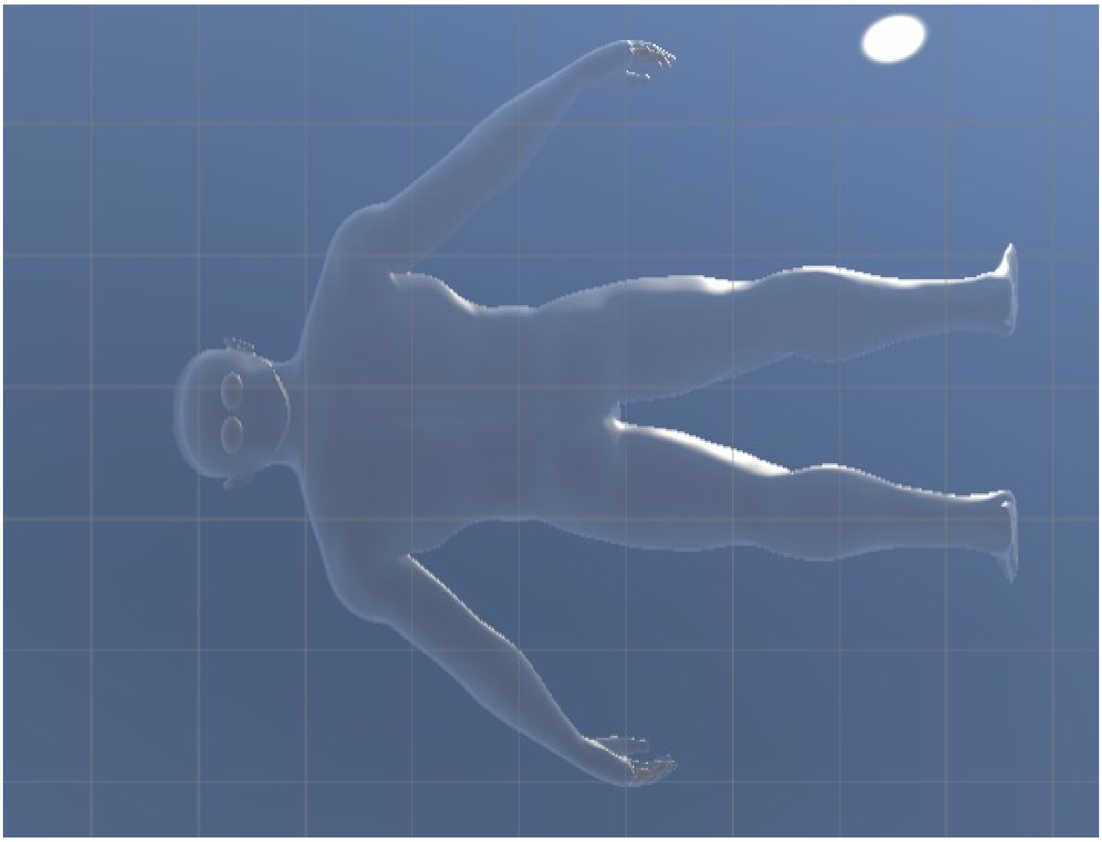

Figure 4.7: Outer skin with reduced opacity

Figure 4.8 shows the Bone and muscle framework of the human body. This model is also taken from online source and aligned with the spinal structure we generated using 3D slicer. Since these framework is independent of the internal structure, general structures is used. This model is also converted to .OBJ file, integrated to Unity and is assigned with second least opacity and red color material file.

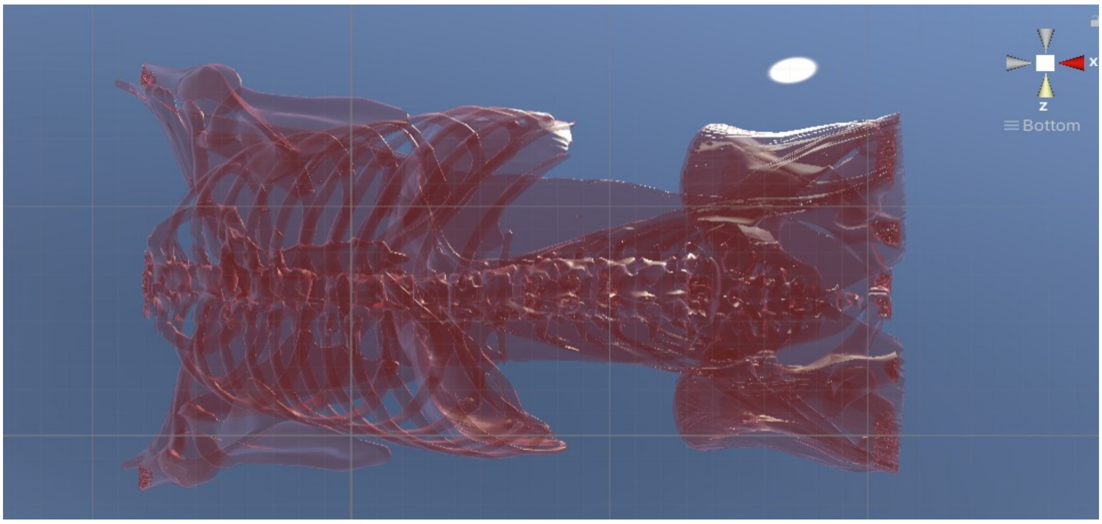

Figure 4.8: Muscle with reduced opacity

Figure 4.9 shows the 3D internal structures, developed from CT scan using 3D slicer. These structures are developed in the slicer using threshold values, then smoothed and merged in the MeshMixer. From Mesh, the models are converted to OBJECT files and are inserted into the Unity Project. Each structure is given particular opacity and color to highlight tumor mass in the kidney.

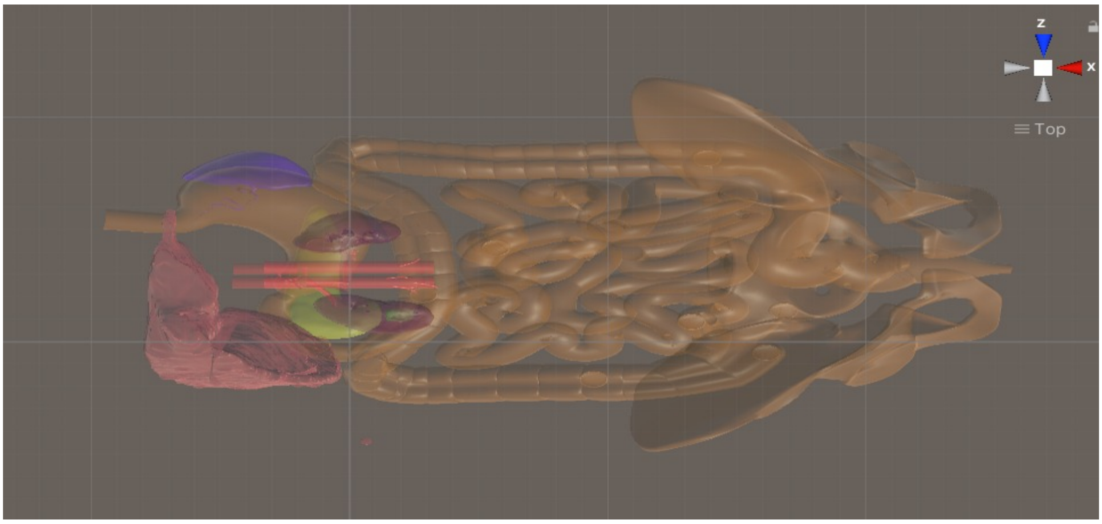

Figure 4.9: Total organs with reduced opacity

All the 3D models (body base, bone and muscle, internal organs) are combined to create a 3D patient model as shown in Figure 4.10 . All the models are arranged in hierarchical order such that all the models are within body base object. The front view after combining the human models is shown in Figure 4.10.

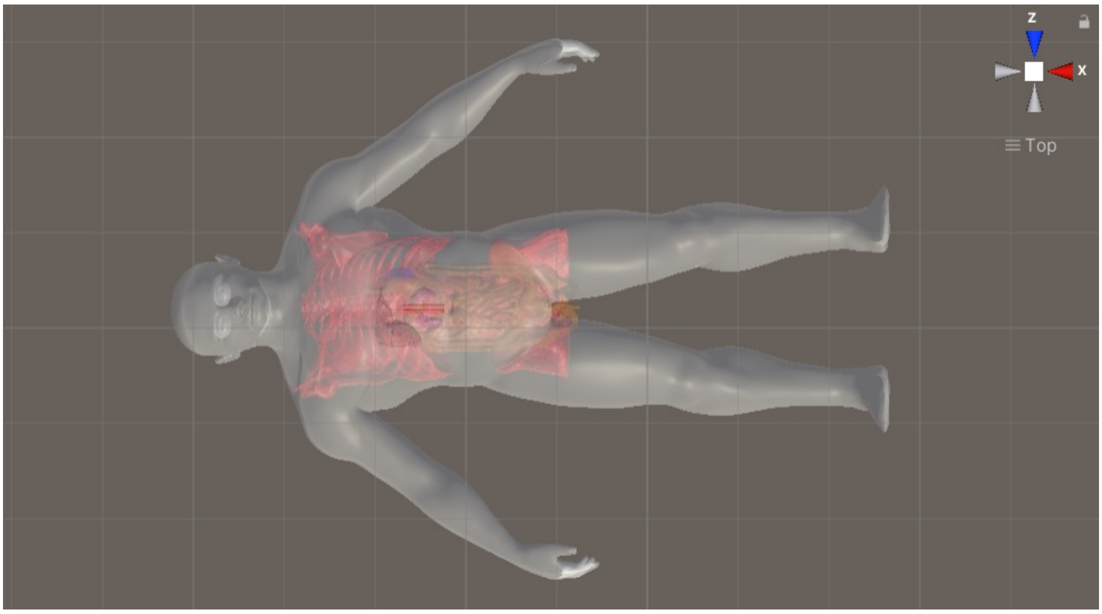

Figure 4.10: Front view of base body

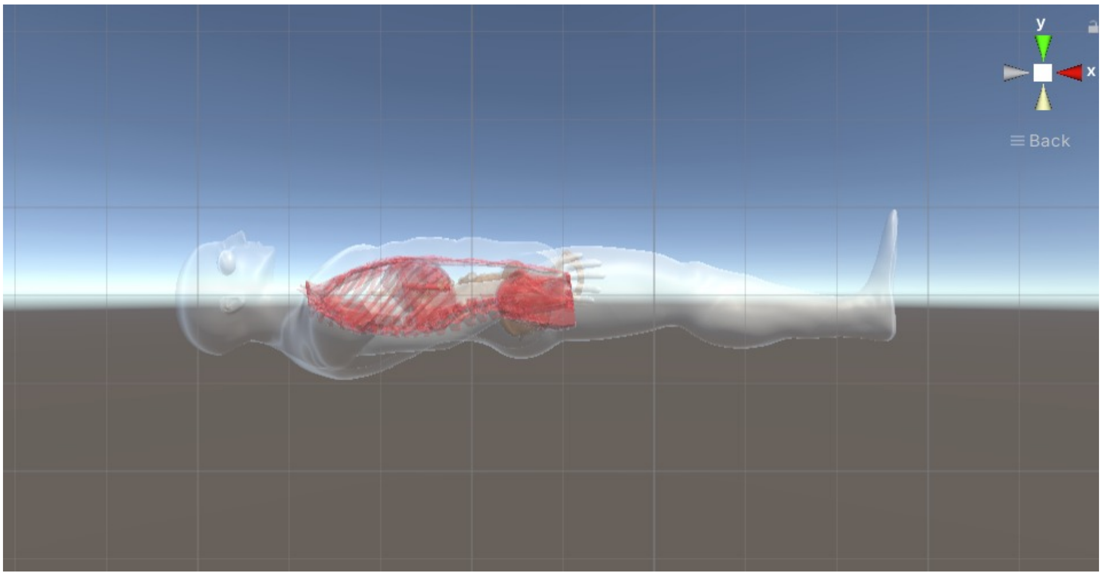

Figure 4.11: Side view of base body

The tumor is given full opacity and radiant color to make it highly visible. The Figure 4.12 shows such highlighted tumor which is on the back side of the kidney.

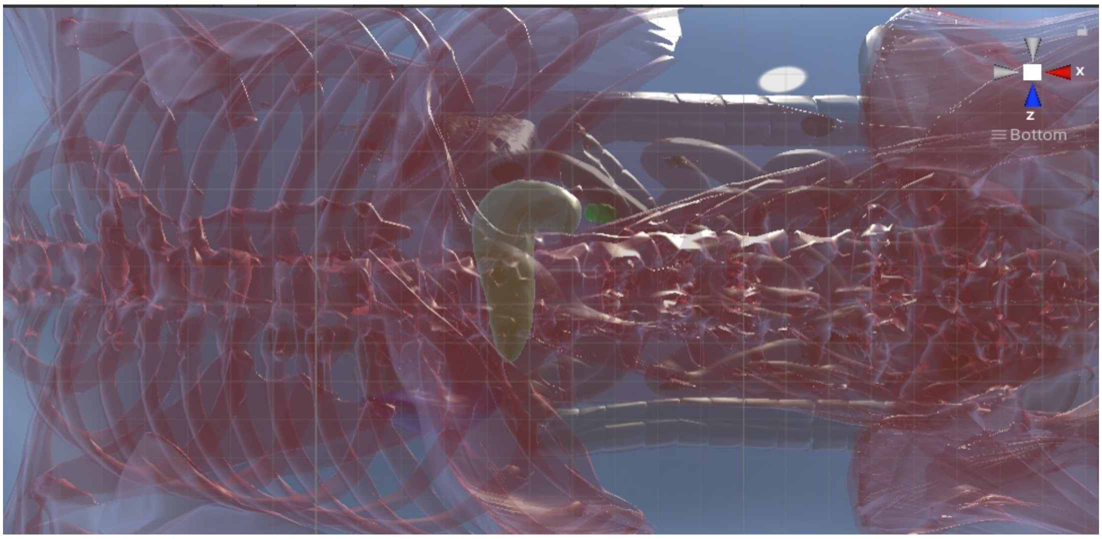

Figure 4.12: Tumour via seethrough body

The hospital scene setup and needle in hospital scene is shown in Figure 4.13 and Figure 4.14. This scene is taken from online as skp file and converted to dae file using sketchup pro application. Operation scene and needle is aligned in unity.

Figure 4.13: Hospital scene setup

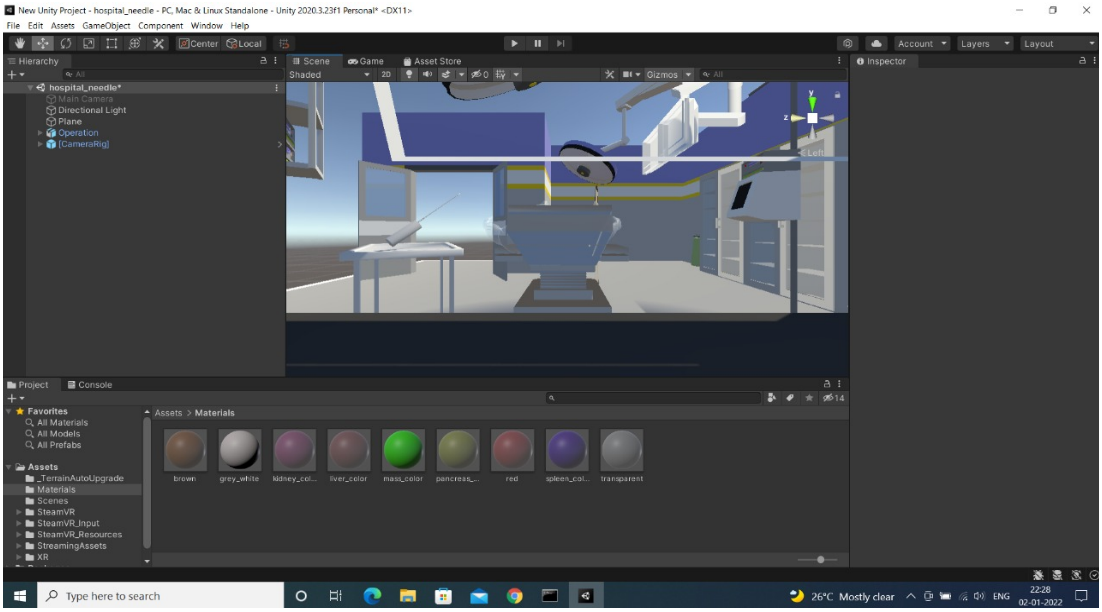

Figure 4.14: Needle

The 3d model of outer skin enclosing muscle and inner organs with the reduced opacity which is integrated in hospital scene whose side view is shown in Figure 4.15, upper view is shown in Figure 4.16, overall view is shown in Figure 4.17.

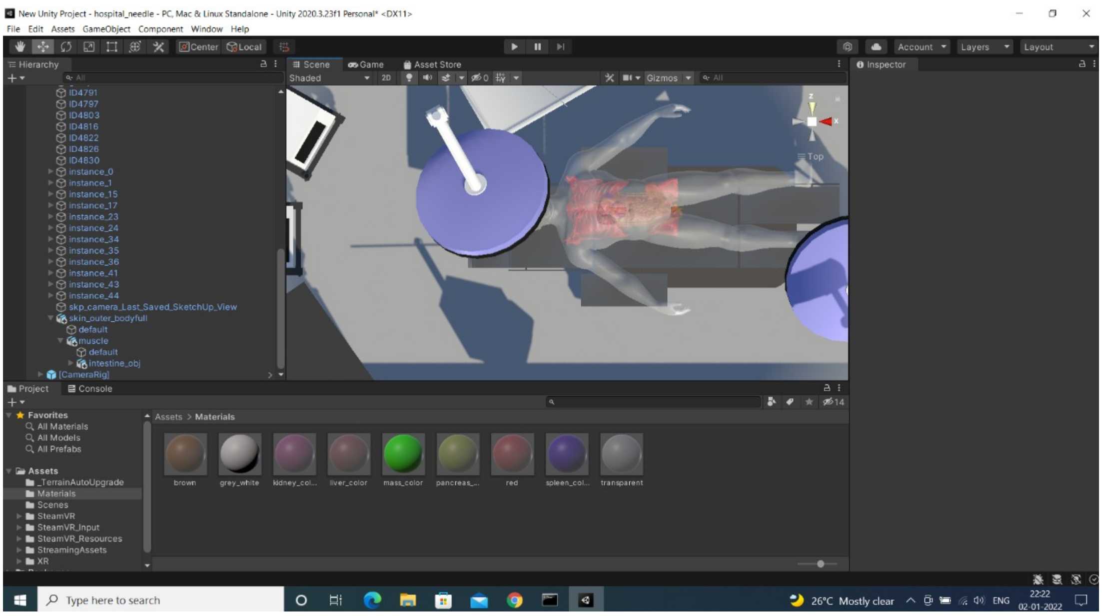

Figure 4.15: Hospital scene upper view

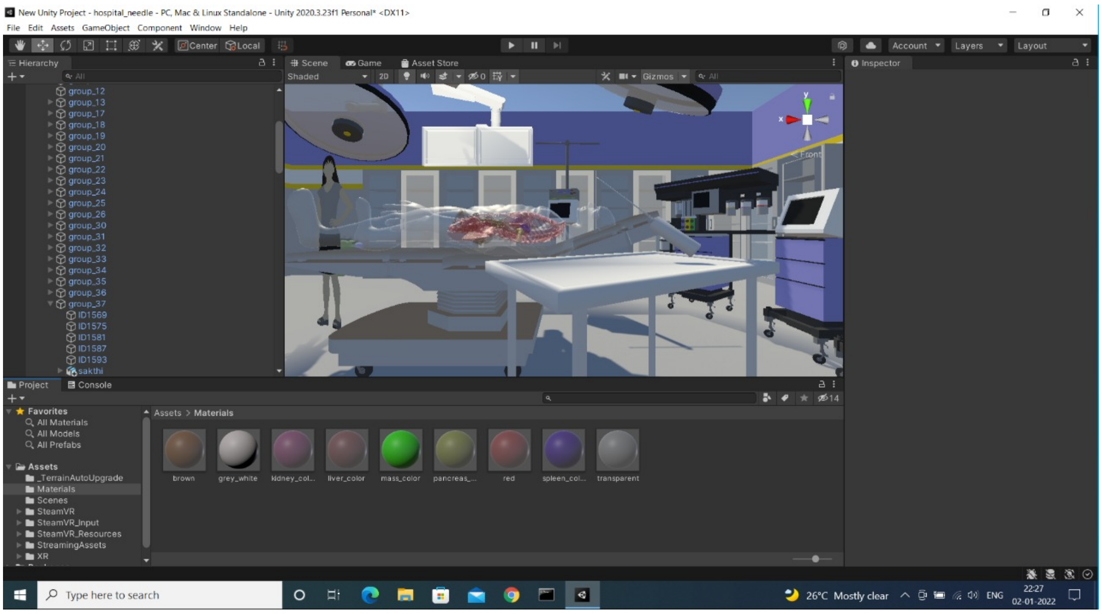

Figure 4.16: Hospital scene side view

After positioning the human body 3D model and needle model into the operation theatre, the entire scene is completed where the user can interact with the models. The overall scene view is shown on Figure 4.17.

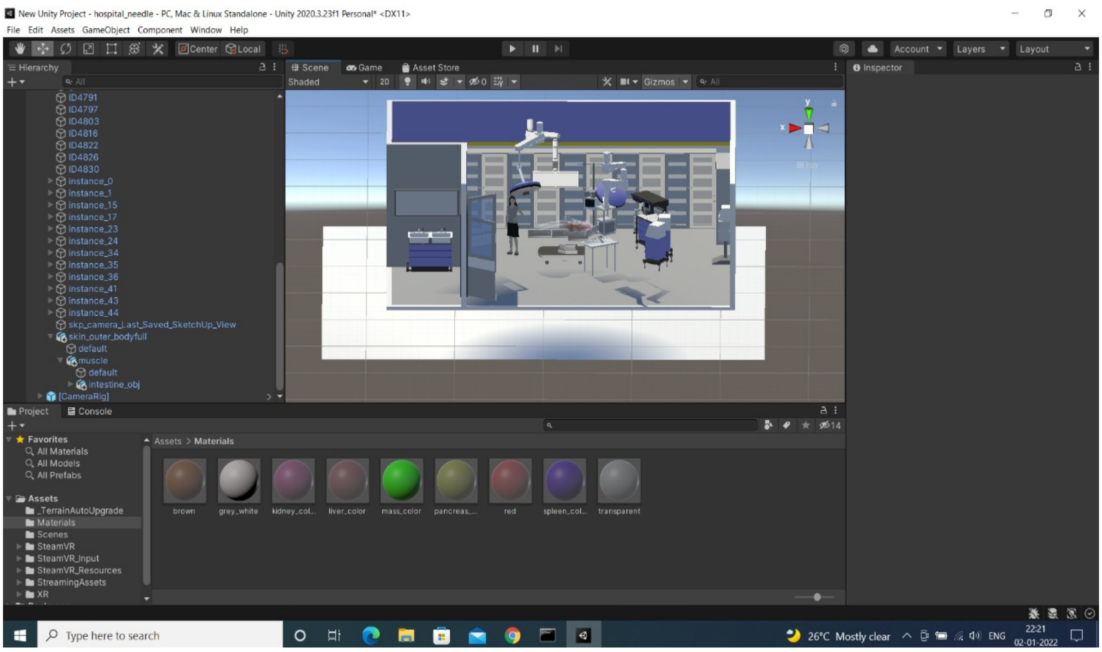

Figure 4.17: Hospital scene overall view

4.3 HTC VIVE INTEGRATION

Integrated HTC Vive hardware components and installed SteamVR. We connected the HTC Vive with the system and checked compatibility and connection errors. SteamVR is the ultimate tool for experiencing VR content of any hardware. Initially, we did the Room Setup in the SteamVR and saw the sample house setup provided by the application. Then we installed SteamVR plugin in the Unity and played the scene to see the operation theatre on the HTC Vive Headset. We saw the anatomy structures and the operation theatre scene we created on the headset.The HTC vive headset view of the room is shown in Figure 4.18.The HTC view of organ model in unity with controller in shown in Figure 4.19

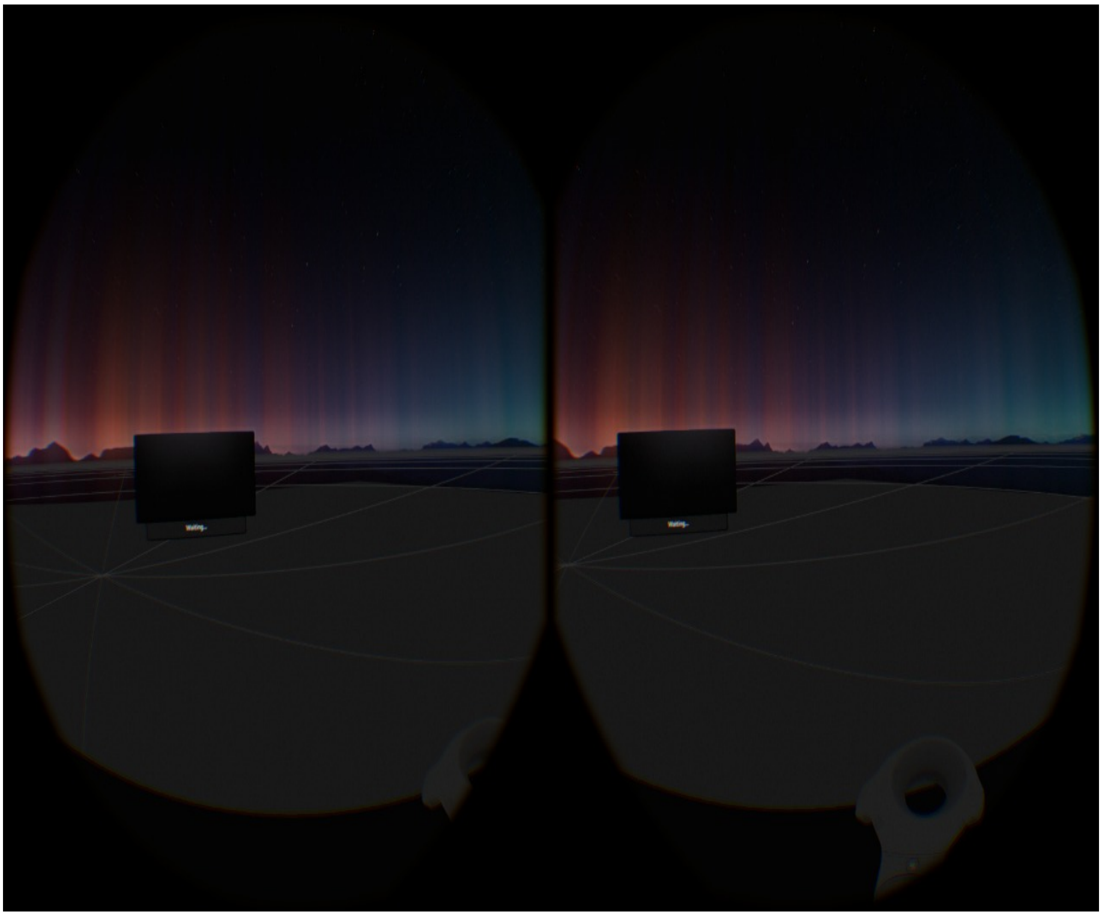

Figure 4.18: HTC vive headset view of room setup

When the HTC Vive CameraRig is connected successfully and the scene is played, the scene starts playing on the HTC Vive Headset. The HTC Vive Headset display can be viewed on the Unity Engine as well as shown in Figure 4.19.

Figure 4.19: HTC vive view of organs model in unity with controller

4.4 INTERACTION AND LOCOMOTION

Locomotion in HTC Vive happens via teleportation and interaction in the virtual environment include grabbing.

Teleportation:

- The Teleport action is activated.
- Shoot a ray from the controller. If it hits something, make it store the point where it hit and show the laser.
- Hide the laser when the Teleport action deactivates.

The following process is shown in Figure 4.20.

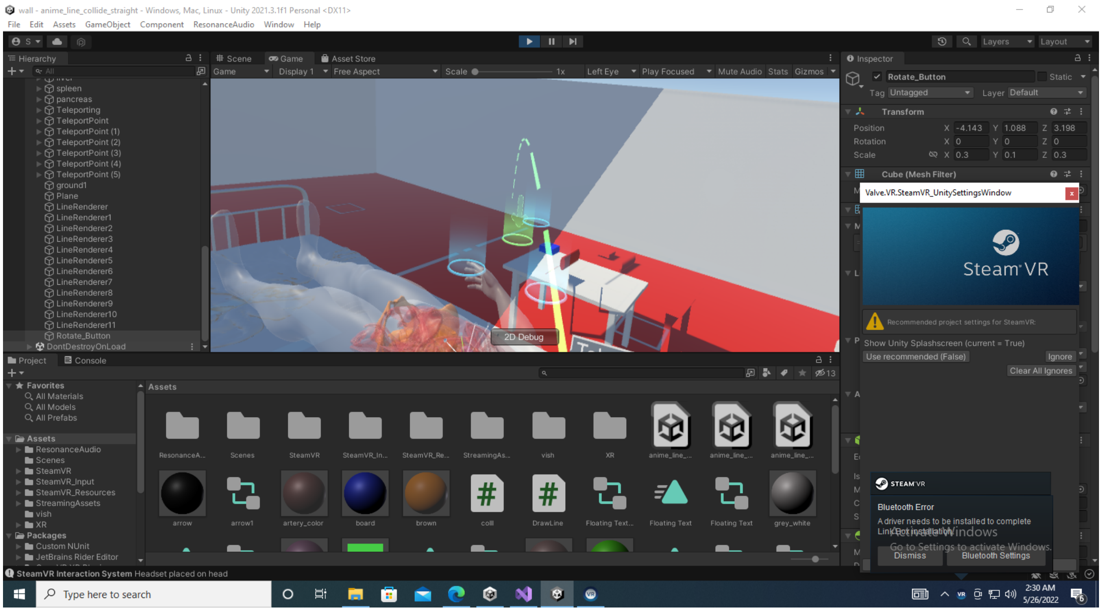

Figure 4.20: Teleportation in HTC Vive

Grabbing: As the collider goes right over the top part of the controller helps to pick up objects, the trigger which is on the controller, is currently colliding with, have the ability to grab the object which is shown in the Figure 4.21

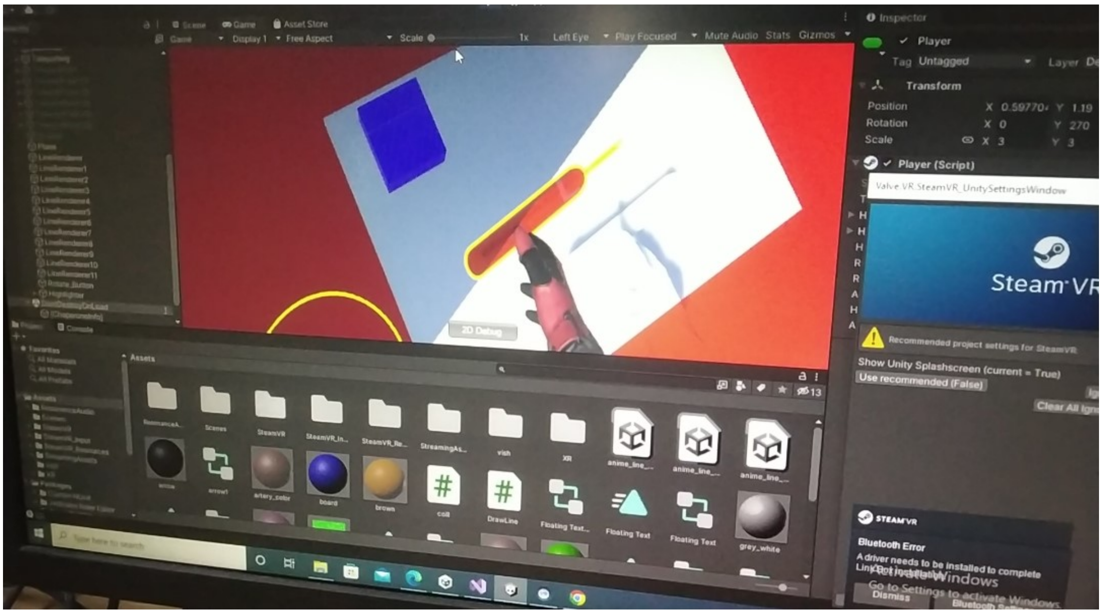

Figure 4.21: Grabbing Object

Rotation of body: Unity calls OnCollisionEnter event when the object (which is pink cuboid in our case) collides with any collider (player's hand) which is shown in Figure 4.22. When this event is called, transformation of body happens which is shown Figure 4.23

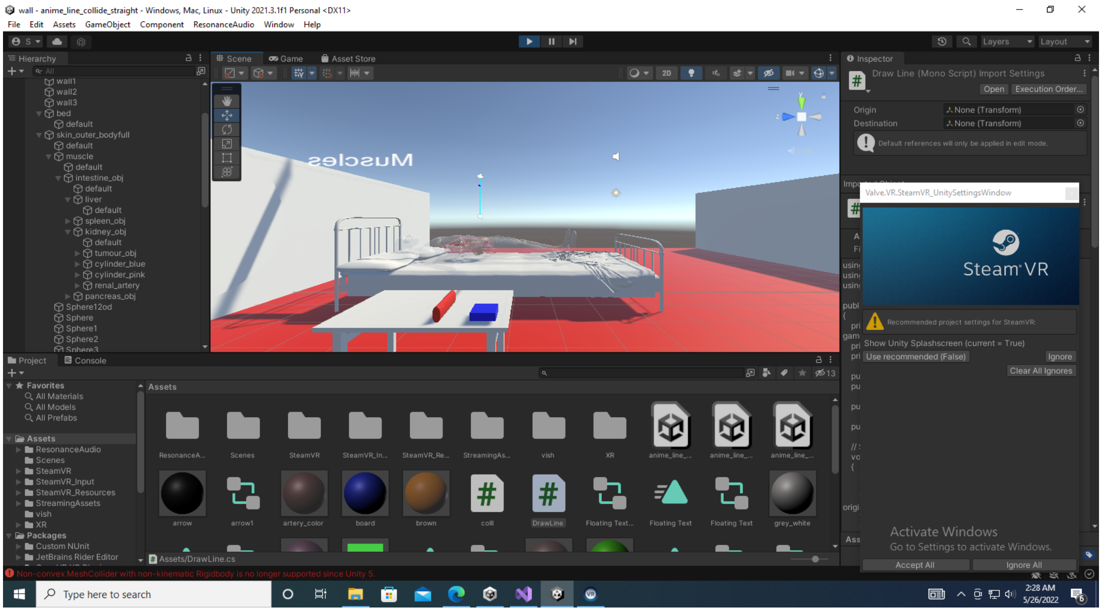

Figure 4.22: Cuboid for rotation

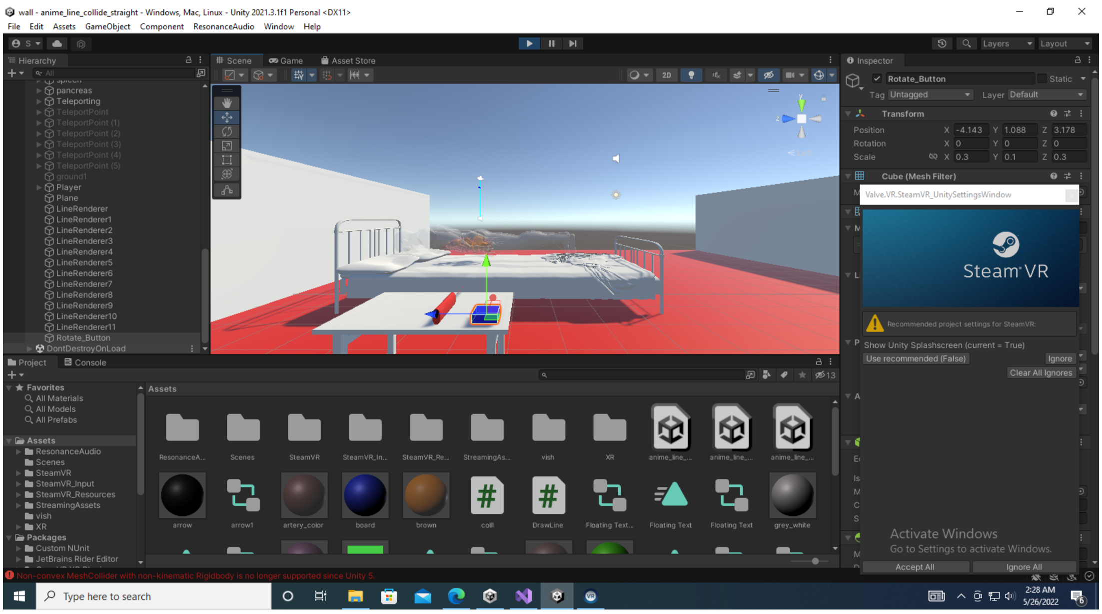

Figure 4.23: Body after rotation

4.5 ANIMATION

An Animator Controller must be used by the Animator component in order to specify which animation clips to utilise and how and when to mix and transition between them.

- Controller: The character's associated animator controller.
- Update Mode (Normal): The animator is updated in-sync with the Update function, and its pace is adjusted to fit the current timescale. Animations will likewise slow down as the timescale does.
- Culling Mode (Always Animate): Never cull, even when off-screen.

The following components of animator is shown in Figure 4.24.

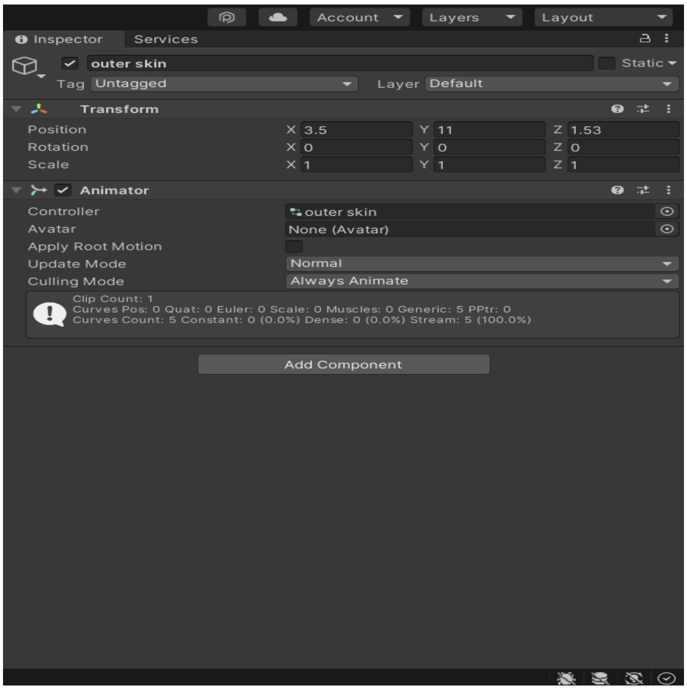

Figure 4.24: Animator components

For animation within a following frames some features are enabled and disabled, so that finally we have different changing name board when the scene is played. Features included are mesh renderer and mesh collider for arrow and plane and mesh renderer for floating text. Time frame displaying name board for kidney is shown in Figure 4.25 and name board for all organs are shown in Figure 4.26. Time frames for displaying differnt nameboards are:

- 0-300 for outer skin
- 420-600 for muscle
- 720-900 kidney
- 1020-1200 for tumor
- 1320-1500 for liver
- 1620-1800 for spleen
- 1920-2100 for pancreas

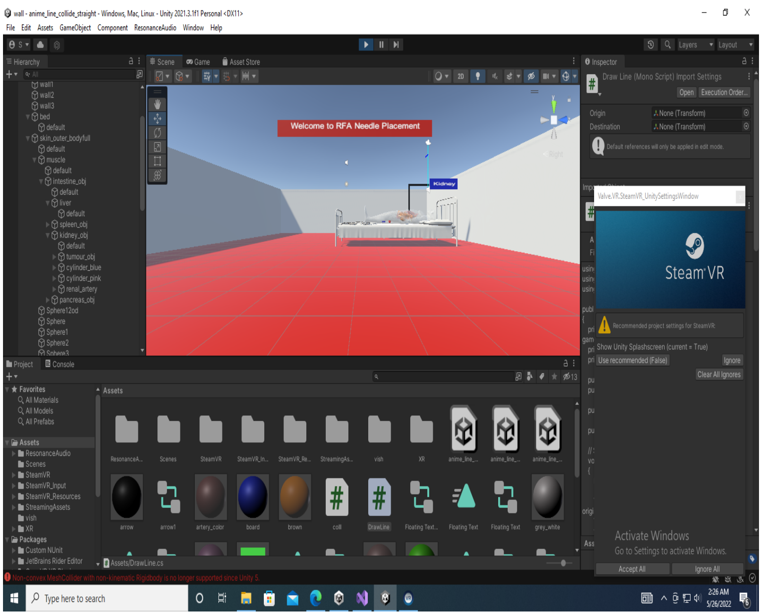

Figure 4.25: Animation with a nameboard

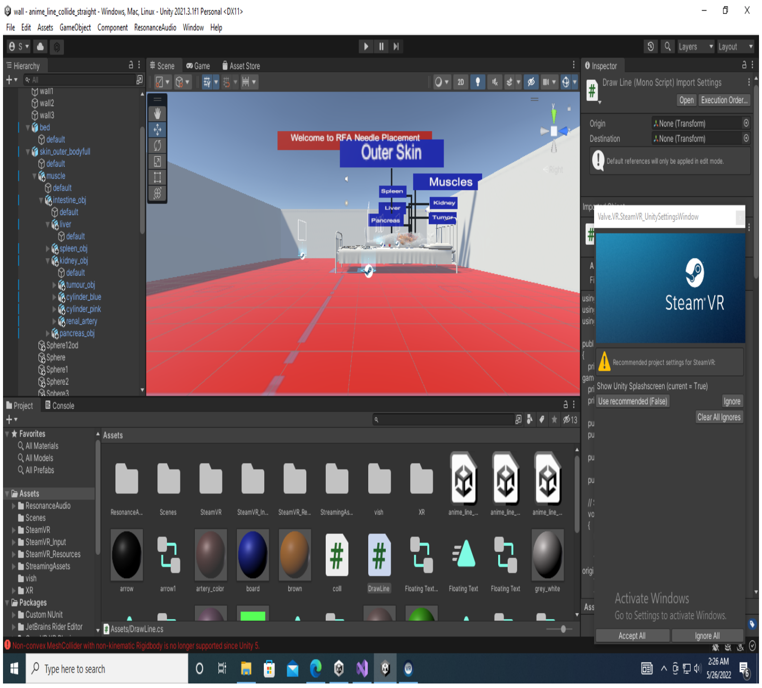

Figure 4.26: Full animation setup

4.6 LINE RENDERING

A straight line is drawn between each point in a set of two or more 3D points using the Line Renderer component. Since the line is always continuous, using numerous GameObjects, each with its own Line Renderer, is recommended if you need to render two or more entirely distinct lines. One-pixel lines are not rendered by the Line Renderer. It renders billboard lines, which are polygons that constantly face the camera and have a width measured in world units. The components used in line rendering in shown in Figure 4.27, Figure 4.28 and explained below.

- Cast Shadows: This option determines whether the line should cast shadows, whether they should be cast from one or both sides, or whether they should be drawn at all.
- Receive Shadows: The line receives shadows if receiving shadows is enabled.

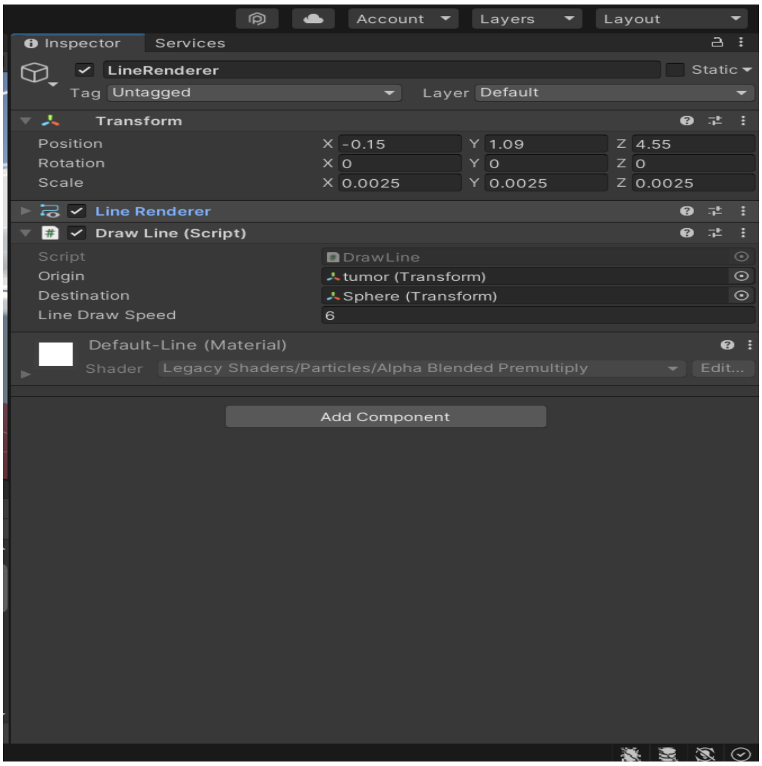

Figure 4.27: Line Renderer Part 1

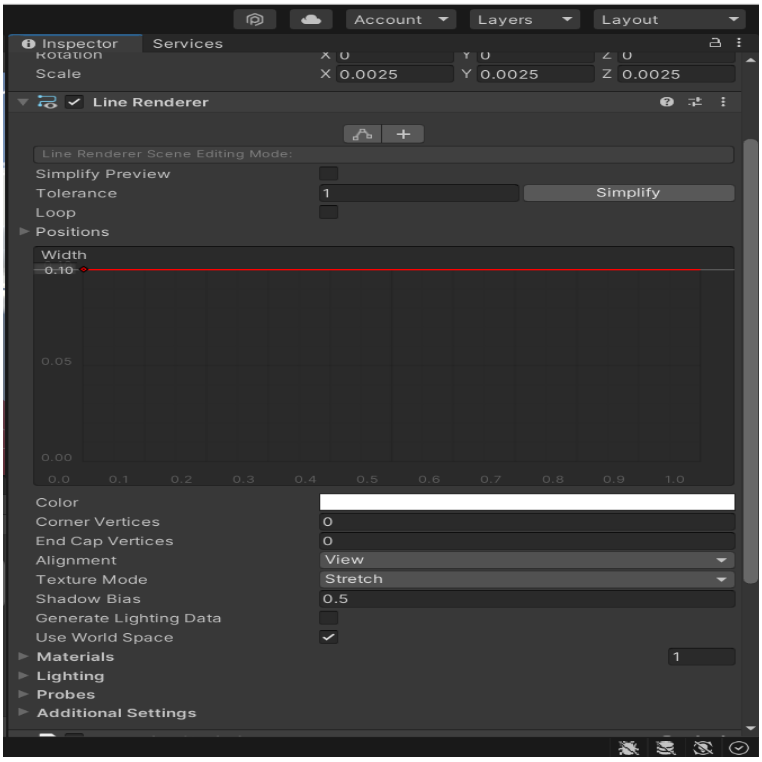

Figure 4.28: Line Renderer Part 2

- Materials: These attributes list a variety of materials that were utilised to render the line. For each material in the array, a single line will be drawn.
- Positions: An array of Vector3 points to link is described by this property. Origin and destination are among these positions.
- Use World Space: When this option is selected, the points are taken into account as being in world space coordinates rather than being impacted by the transform of the GameObject to which this component is linked.
- Width: Define a width value and a curve to control the width of your line at various points between its start and end. The curve is only sampled at each vertex, so its accuracy is limited by the number of vertices present in your line.
- Color: Create a gradient to regulate the line's colour along its length.

Here in the below image 4.29 you can see 13 lines have been drawn. Keeping source as spots and destination as mass. The lines collide with the other objects also.

4.7 COLLISION DETECTION

When a collider or rigidbody starts to touch another with collider or rigidbody, the collision detection method calls OnCollisionEnter. Information concerning contact sites, impact velocity, etc. is contained in the Collision class. An object's motion will be managed by Unity's physics engine after a Rigidbody component is added to it. A Rigidbody object will experience gravity's pull downward and will respond to collisions with arriving objects if

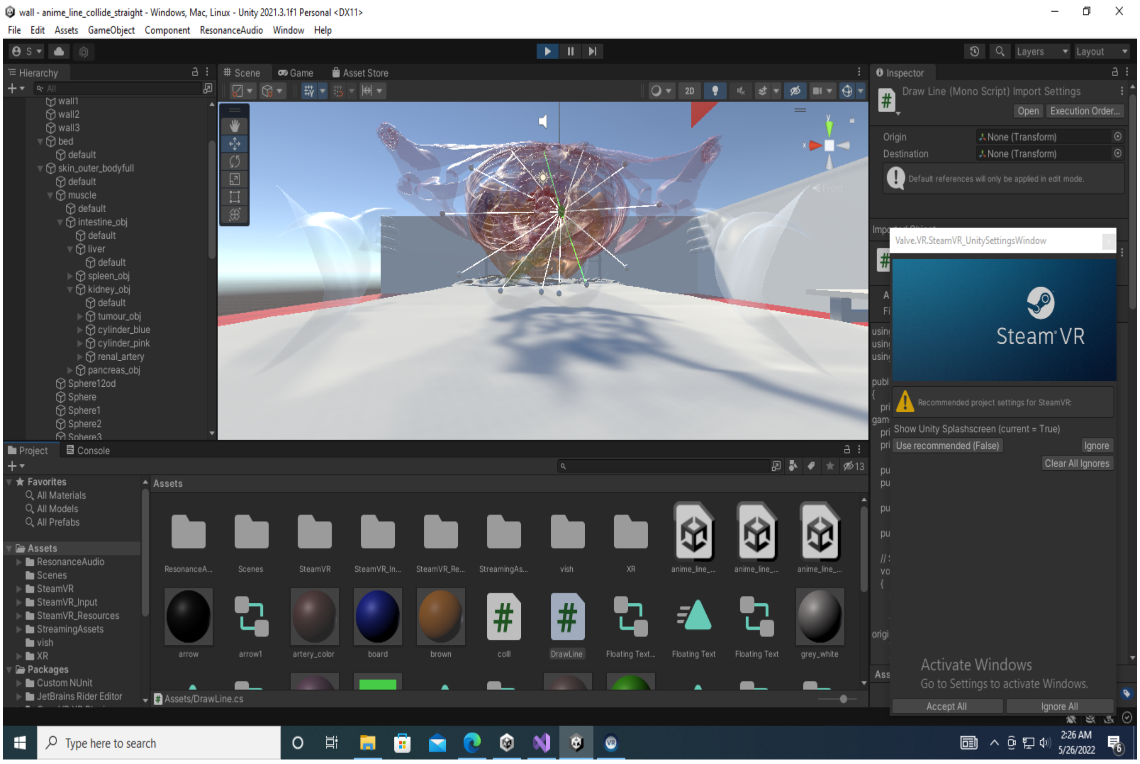

Figure 4.29: Line Renderers to mass before collision detection

the appropriate Collider component is also present. This happens even without the addition of any code. Additionally, the Rigidbody provides a scripting API that enables you to manipulate the object physically realistically by applying forces to it. For instance, the behaviour of a car can be described in terms of the forces generated by the wheels. With this knowledge, the physics engine can manage the majority of the other components of the car's motion, allowing it to accelerate properly and react to collisions appropriately. Figure 4.30 displays the rigidbody component reference.

- Mass: The object's mass (in kilogrammes by default).
- Use Gravity: If selected, gravity has an impact on the object.
- Interpolate: Only use one of the choices if your rigidbody's motion appears jerky.

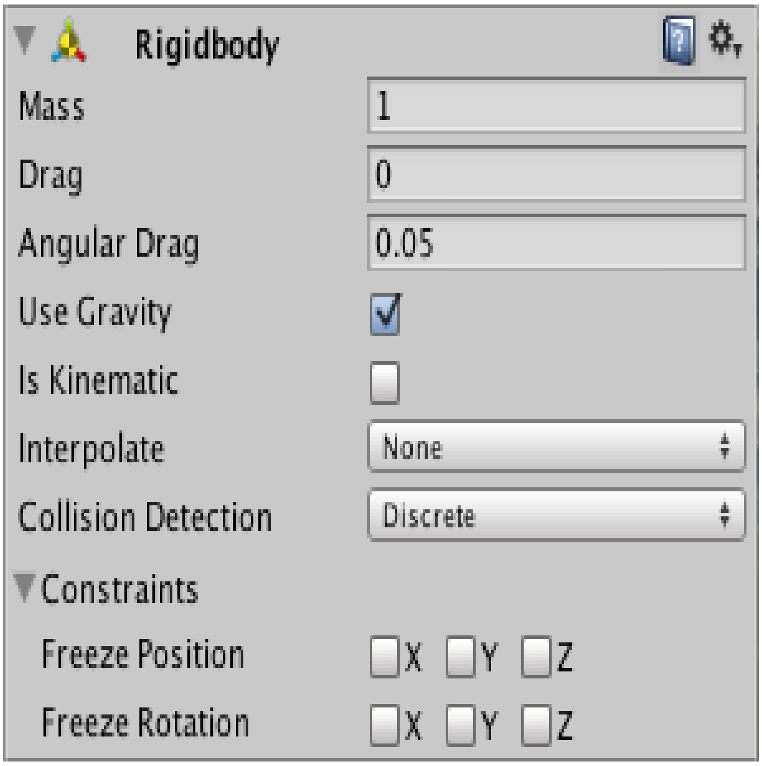

Figure 4.30: Rigidbody components

- Collision detection: Used to stop quickly moving object from crashing into one another without being noticed.
- Discrete: Use discrete collision detection to compare yourself to every other collider in the scene. When checking for collisions against it, other colliders will employ discrete collision detection.

Here in the given image Figure 4.31 you can see only one path without any collision with other objects. We can also have more non-collidable paths if we have more uniformly distributed spots.

4.8 CONTACT MOTION COMPENSATION

To accurately model the mechanical behavior of the heterogeneous kidney with high efficiency, we propose the unified particle-based

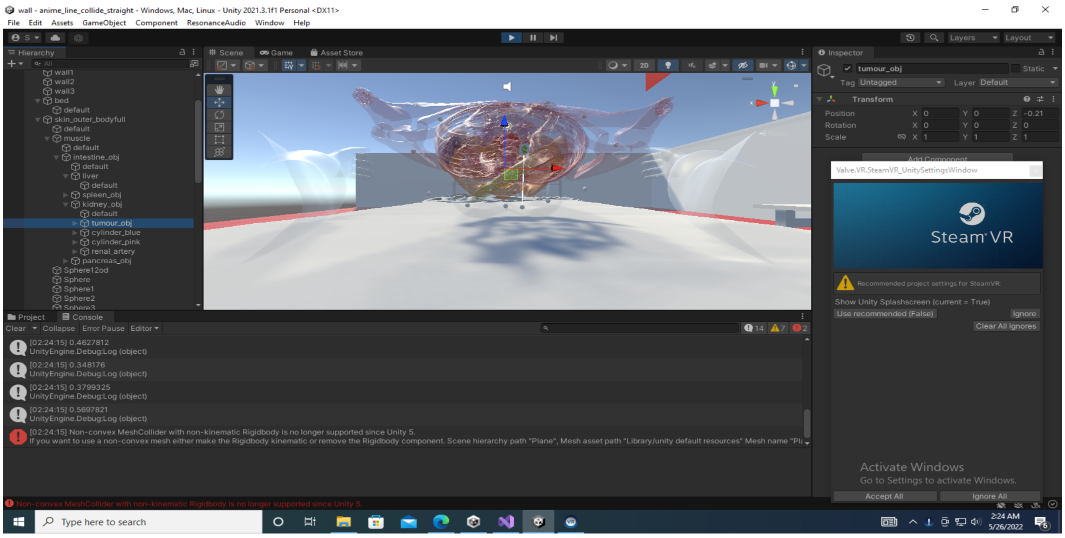

Figure 4.31: After Collision detection

heterogeneous deformable model, which represents the kidney soft tissue and tumor with unified particles. Each kinds of particles are assigned with different attribute for position correction in the position-based dynamics. For a single kind of particles (such as tissue), C is a constraint for n particles P=p1,p2,p3,. . . ,pn , which satisfies C(P)=0 . When the external force f exerts on the particles, the constraint C will not satisfy C(P)=0 due to the updated position of all particles. To make all the particles satisfying the constraint again, we need to give a correction P to the position of the particles, which satisfies C(P+P)=0. The correction factor for the different organs are calculated through various experiments and are available on the online source.

The mean displacement of Kidney surface fiducials are on :
`https://www.liebertpub.com/doi/10.1089/end.2010.0249.`

The mean displacement of liver are on:
`https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7314378/.`

The mean displacement of pancreas are on:
`https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6927045/.`

The mean displacement of intestine are on:
`https://pubmed.ncbi.nlm.nih.gov/22075437/`

CHAPTER 5

RESULTS AND PERFORMANCE EVALUATION

5.1 DICE SIMILARITY METRICS (PLASTIMATCH DICE ALGORITHM)

The Dice statistics class computes a Dice statistic for the overlap between two regions.
0 = X and Y have no overlap and 1 = two regions are the same.

$$D = \frac{2|X| \cup |Y|}{|X| + |Y|}.$$

Inputs

- Reference Segment : Ground Truth Segmentation
- Reference Segmented Structure : Human Segmented organ structure to be compared
- Compare Segment : Segmentation done based on threshold values
- Compare Segmented Structure : Segmented organ structure to be compared

Outputs

- Dice Coefficient : Similarity of two samples
- Confusion Matrix metrics
- Reference and compare centre
- Reference and compare Volume

The Dice Similarity Metrics for Kidney and Tumor is shown in Figure 5.1 and Figure 5.4.

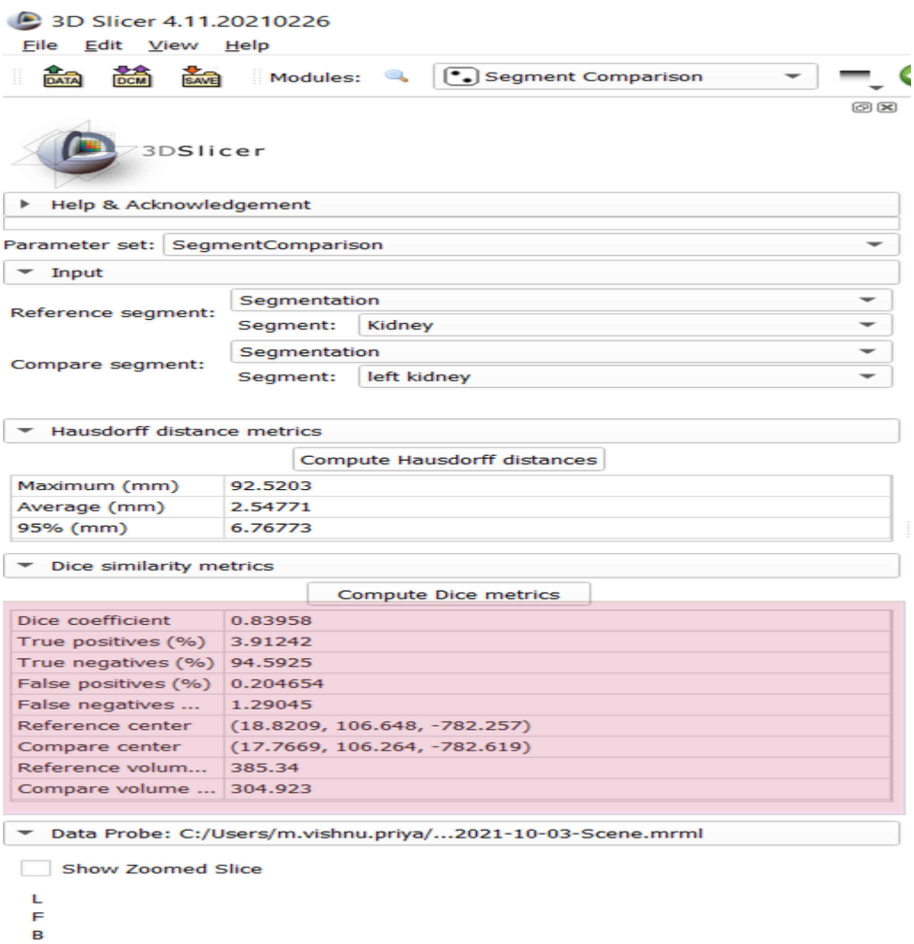

Figure 5.1: Dice Similarity Metrics for Kidney

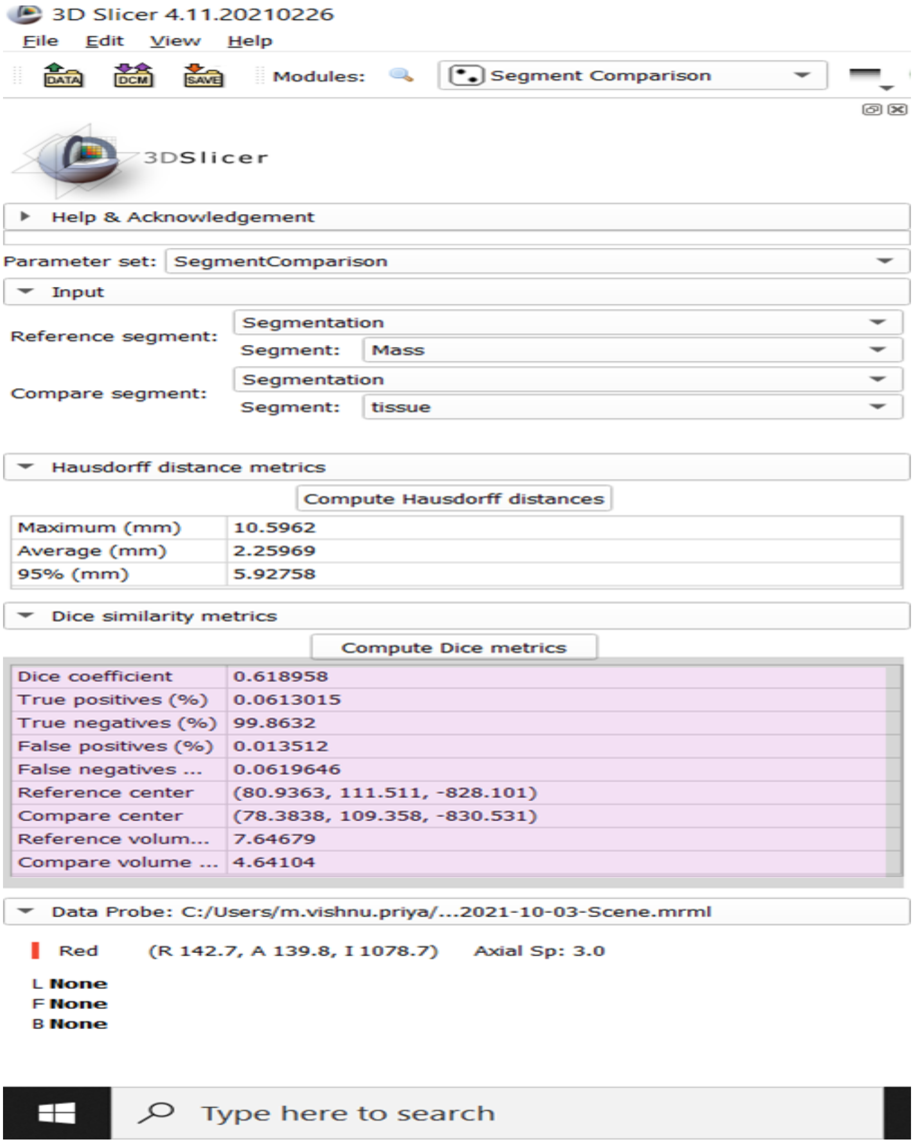

Figure 5.2: Dice Similarity Metrics for Tumor

5.2 HAUSDORFF DISTANCE METRICS [PLASTIMATCH HAUSDORFF ALGORITHM]

The Hausdorff class computes the worst-case distance between two regions.

Directed Hausdorff = measure from X to Y is defined as the maximum distance, for all points in X, to the closest point in Y.

$$\vec{d}_H(X,Y) = \max_{x \in X} \min_{y \in Y} d(x,y)$$

Hausdorff distance(undirected) = the maximum of the two directed Hausdorff measures.

$$d_H(X,Y) = \max\left\{\vec{d}_H(X,Y), \vec{d}_H(Y,X)\right\}$$

Directed average Hausdorff measure = average distance of a point in X to its closest point in Y

$$\vec{d}_{H,\text{avg}}(X,Y) = \frac{1}{|X|} \sum_{x \in X} \min_{y \in Y} d(x,y)$$

Average Hausdorff measure(undirected) = average of the two directed average Hausdorff measures

$$d_{H,\text{avg}}(X,Y) = \frac{\vec{d}_{H,\text{avg}}(X,Y) + \vec{d}_{H,\text{avg}}(Y,X)}{2}$$

Directed percent Hausdorff measure = for a percentile r, is the rth percentile distance over all distances from points in X to their closest point in Y. For example, the directed 95 percent .Hausdorff distance is the point in X with distance to its closest point in Y is greater or equal to exactly 95 percent of the other points in X.

$$\vec{d}_{H,r}(X,Y) = K_r\left(\min_{y \in Y} d(x,y)\right) \forall x \in X$$

Percent Hausdorff measure(undirected)

$$d_{H,r}(X,Y) = \frac{\vec{d}_{H,r}(X,Y) + \vec{d}_{H,r}(Y,X)}{2}$$

In Figure 5.3, the results of kidney segmentation hausdorff distance metrics between the ground-truth [CT segmented by Experts] and the image segmented using threshold effects in 3D Slicer is shown. The maximum deviation of distance is 92.52. The overall average distance is 2.54 and about 6.76 percent of points have greater distance than 95 percentile of the total points.

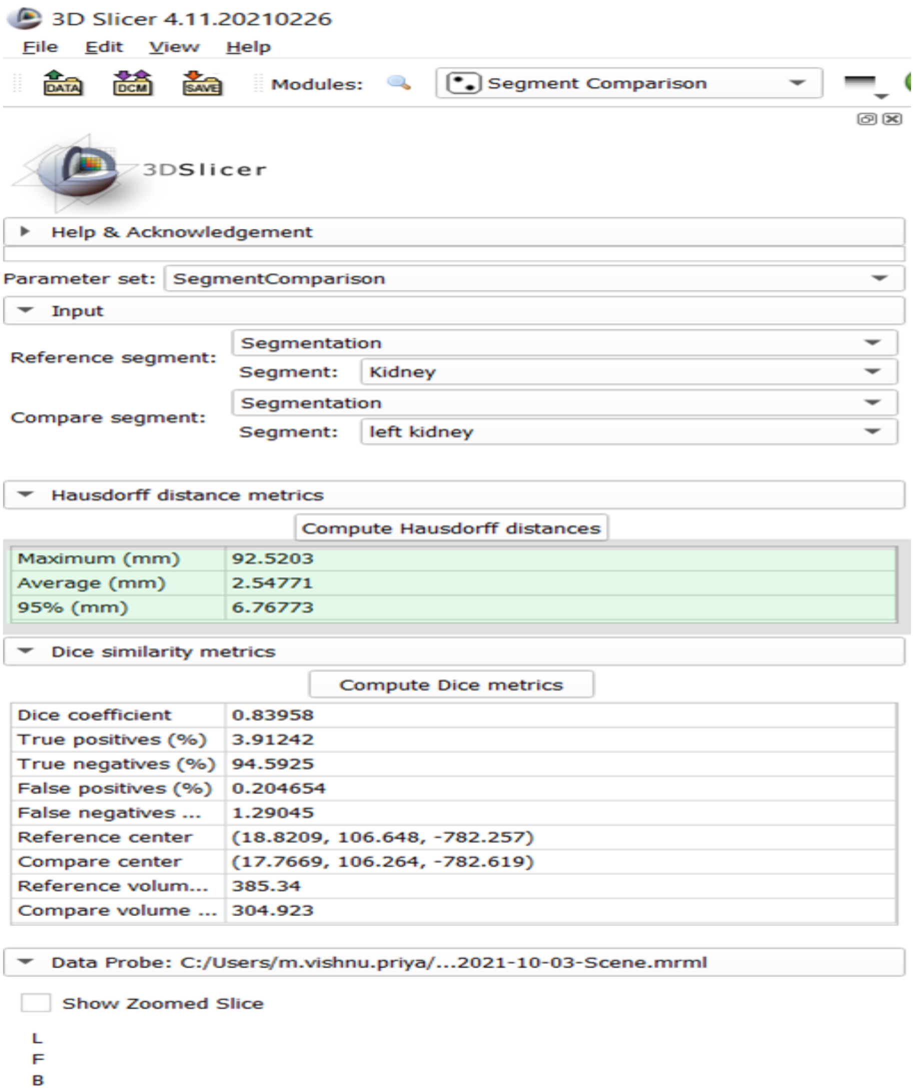

Figure 5.3: Hausdorff Distance Metrics for Kidney

In Figure 5.4, the results of tumour mass segmentation hausdorff distance metrics between the ground-truth [CT segmented by Experts] and the image segmented using threshold effects in 3D Slicer is shown. The maximum deviation of distance is 10.59. The overall average distance is 2.25 and about 5.92 percent of points have greater distance than 95 percentile of the total points.

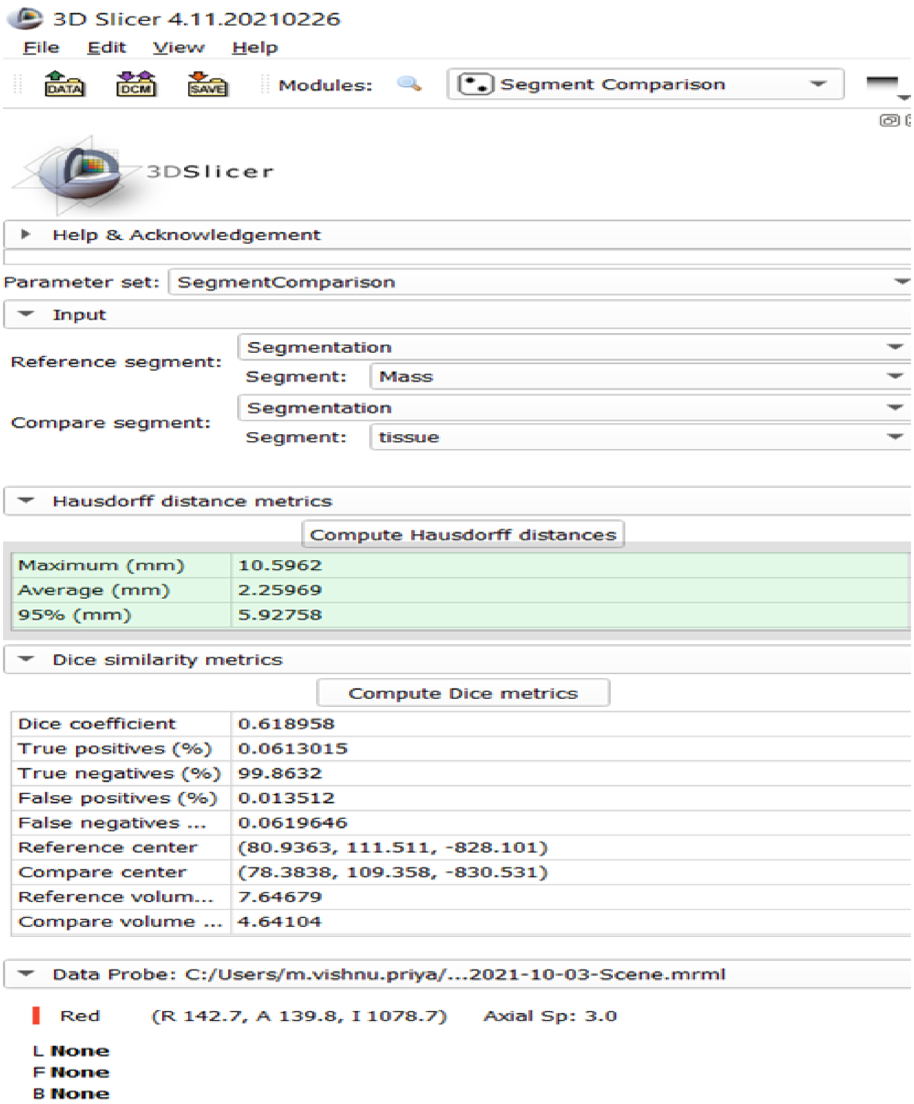

Figure 5.4: Hausdorff Distance Metrics for Tumor

5.3 COMPARING VOLUME

In Figure 5.5, the segment of one of the image with a simple global thresholding in Segment Editor module is shown and is superimposed over the other image [ground-truth : CT scan segmented by Medical Experts] then there will be a very clear view of what moved and how much. If the object is segmented based on interest, there will be a quantitative metrics about their displacement by using Segment Comparison module in SlicerRT extension.

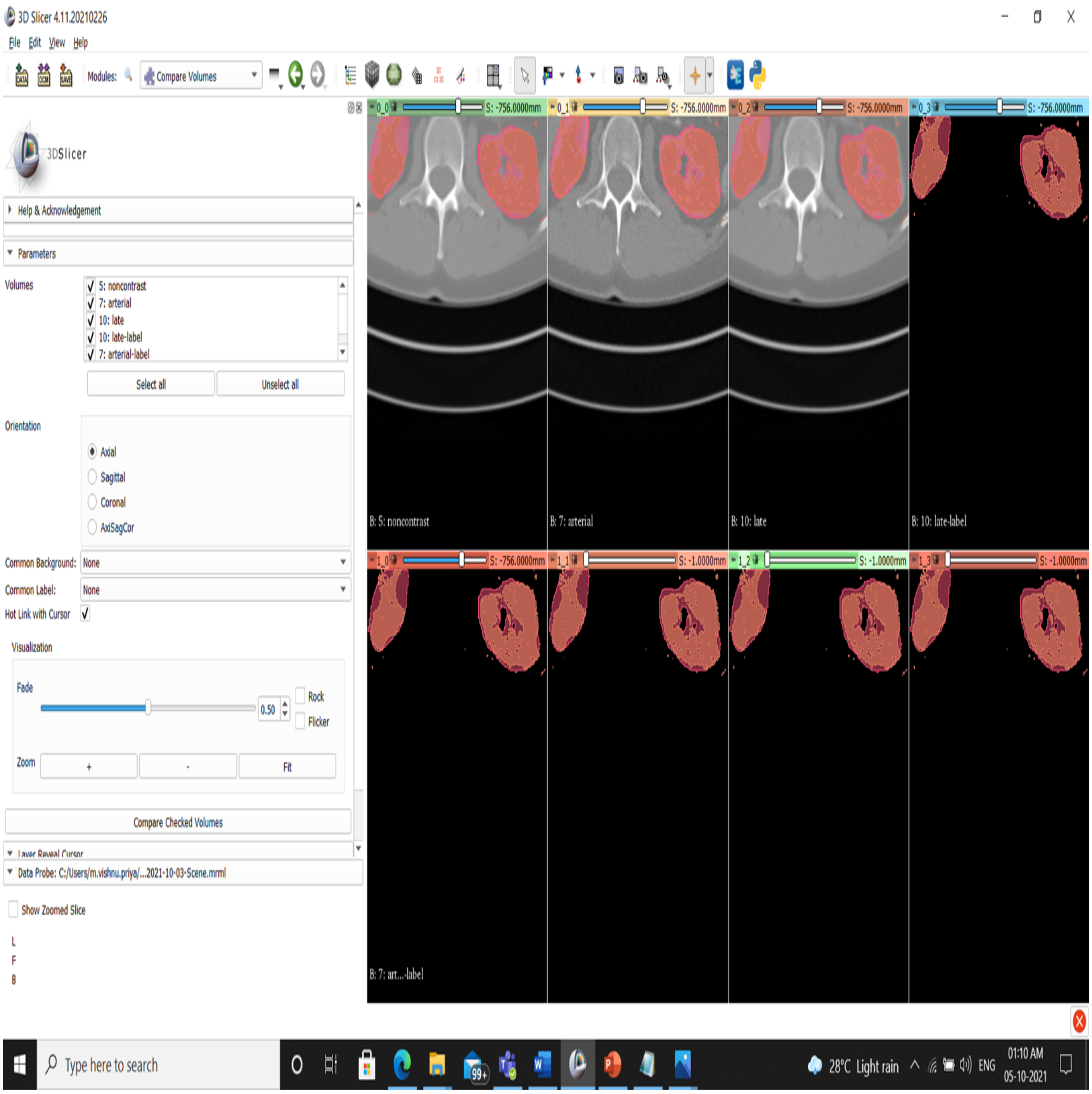

Figure 5.5: Comparison of Volumes

5.4 ANALYSIS ON LINE RENDERER

The Line Renderer component provided by Unity Engine takes Vector3 arrays as input to draw a straight line between them. It is used to draw free-floating lines in 3D spaces. Also, the drawing of the line can be animated by calculating the points along the way. The points along the line can also be stored in arrays so that it can be further used for trail tracking or for automated movement along the drawn line.

The results of line renderer we tried are presented here in Figure 5.6

NUMBER OF SPOTS	UNIFORM DISTRIBUTION	NUMBER OF LINES WITHOUT COLLISION	NUMBER OF LINES WITH COLLISION HIT
5 SPOTS	NO	-	5
5 SPOTS	YES	-	5
7 SPOTS	YES	-	7
10 SPOTS	YES	-	10
13 SPOTS	YES	1	12

Figure 5.6: Analysis on Line Renderer

In this project, line renderer is used to draw a straight line from the outer skin to the tumor mass. For this, 13 different spots are created on the outer skin around the body. The spots are nothing but 3D spheres. From these spheres (as origin) straight line path are checked for tumor center (as destination). Using Physics RayCast, any hit on the path is checked. If collision is detected, the line renderer is disabled. Else, the line is drawn. The line with minimum distance is suggested for the user. The line without collisions can be found with increase in spots and it's uniform distribution around the body. The number of spots is directly proportional to the probability of finding non-colliding lines. The placement or distribution of spots also plays a major role in concluding efficient path.

5.5 DEFORMATION RESULTS

The deformation of models is done based on the depth of the needle inside the body. When the minimum distance line is fixed by line renderer component, the distance of that line is divided into three ranges. Instead of making a abrupt change on the models on needle insertion, we deform the models by slowly in three phases. Also, this range can be specified according to the displacement values. In these surgeries, all the organs displacement in terms of .00mm So we decided 3 phases on the basis of VR experience. Initially, we did the displacement on insertion of needle and it was not giving a real-time like simulation. Then we tried mesh deformation but the deformation was slow and it was not compatible with controller movement. We moved onto position based dynamics and changed the vertices of the organs directly. Displacement is done using Transform.Position() function of Unity Engine.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

Our projects creates a reliable environment for medical trainees to practice and perform RFA needle placement. With this system, any person can train any number of times without the need for an actual phantom. This helps in developing psycho-motor skills and provides easiness compared with the CT scan based heads-up procedure. By developing structures using CT scan, procedures can be done in virtual environment and any complications possibly to occur can be predicted and can be avoided. This project is very useful as it eliminates the traditional procedure completely and provides navigation and guidance with respect to each of the user action.

Beyond the rehearsal and refinement of procedures, VR lends itself to being an excellent teaching tool, providing trainees of all level access to a range of techniques that accurately replicate real-life environments, without risk to the patient or even a necessary need for supervision.

6.2 FUTURE WORK

If this project extended to mixed reality, that would create a huge revolution on the medical field. Because of insufficient facilities, we did this project in virtual reality though it is cost effective and reliable. If the structures are mapped into phantoms and are made to assist the trainee then the system would be an actual replica of the surgery and needle placement along with the guidance from the system. The surgeons would agree that holographic guidance can provide more comprehensive patient-specific target region data for surgical navigation, which benefits them to precisely locate the tumor inside the abdominal phantom with right pathway.

We can also create VR/MR systems for many other surgical and medical procedures. By including these technologies into teaching, the skills and the knowledge learnt in these platforms can be transferred onto actual surgeries which will lead to better patient outcome.

REFERENCES

[1] Weixin, Xiangyun Liao, Yinling Qian, and Qiong Wang. Mixed reality guided radiofrequency needle placement: A pilot study. *IEEE Access*, 6:31493–31502, 2018.

[2] C. Ruiz B. Lorea V. Delmas P. Rosset L.R. Le-Nail J.F. Uhl, G.D. Prat. 3d-modeling of sternal chondrosarcomas from angio-ct-scan: Clinical application and surgical perspectives. *Annals of 3D Printed Medicine*, 1:2666–9641, 2021.

[3] Dan, Yu Zhang, and Ruiying Zhao. Study on deformation technology of virtual surgery simulator based on liver puncture. In *2018 3rd International Conference on Robotics and Automation Engineering (ICRAE)*, pages 176–179, 2018.

[4] Vuthea, Vikram Apilla, Patrick Saalfeld, Christian Boedecker, Tobias Huber, Florentine Huettl, Hauke Lang, Bernhard Preim, and Christian Hansen. Collaborative vr for liver surgery planning using wearable data gloves: An interactive demonstration. In *2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pages 768–768, 2021.

[5] Koosha, Qi Sun, Krishna C. Gurijala, Bireswar Laha, and Arie E. Kaufman. Benefits of 3d immersion for virtual colonoscopy. In *2014 IEEE VIS International Workshop on 3DVis (3DVis)*, pages 75–79, 2014.

[6] Sara Daniela, Miguel Esteban Mora Gonzalez, and Ricardo Alonso Espinosa Medina. 3d reconstruction of organ from ct images and visualization in a virtual reality environment. In *2021 IEEE Colombian Conference on Applications of Computational Intelligence (ColCACI)*, pages 1–5, 2021.

[7] Mujun, Jinwen Deng, Yue Wang, Xuejun Zhang, and Xuejun Zhang. Virtual surgery system for abdominal organs based on vr helmet. In *2018 International Workshop on Advanced Image Technology (IWAIT)*, pages 1–4, 2018.

[8] Jonas, Sebastian Misztal, Beniamin Roth, Leonard Flock, Thomas Luiz, Dieter Lerner, Markus Herkersdorf, Konstantin Weaner, Markus Neuberaer, Andreas Franke, Claus Kemp, Johannes Pranqhofer, Sven Seele, Helmut Buhler, and Rainer Herpers. Applying multi-user virtual reality to collaborative medical training. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pages 775–776, 2018.

[9] Zhang, Minyong Shi, and Chunfang Li. Research and application of path-finding algorithm based on unity 3d. In *2016 IEEE/ACIS 15th International Conference on Computer and Information Science (ICIS)*, pages 1–4, 2016.

[10] Diego Chala and Luis Vives Garnique. Development of a simulator with htc vive using gamification to improve the learning experience in medical students. In *2018 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI)*, pages 1–6, 2018.

[11] Mirko, Matija Mandurov, and Maja Matijasevic. Performance and qoe assessment of htc vive and oculus rift for pick-and-place tasks in vr. In *2017 Ninth International Conference on Quality of Multimedia Experience (QoMEX)*, pages 1–3, 2017.

[12] Meng, Sandeep Ganni, Jeroen Ponten, Armagan Albayrak, Anne-F Rutkowski, and Jack Jakimowicz. Analysing usability and presence of a virtual reality operating room (vor) simulator during laparoscopic surgery training. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pages 566–572, 2020.

[13] Shuheng, Yining Chen, Pengjie Sun, Denghong Liao, and Xiaojun Chen. Development of a patient-specific surgical simulator based on virtual reality. In *2017 10th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI)*, pages 1–5, 2017.

[14] Cosmina. A glance into virtual reality development using unity. *Informatica Economica*, 22:14–22, 09 2018.

[15] Iago, Rafael Torchelsen, and Anderson Maciel. Efficient surgical cutting with position-based dynamics. *IEEE Computer Graphics and Applications*, 37(3):24–31, 2017.

[16] Timothy Hedstrom Alexander Wu Siddharth Atre Jürgen P. Schulze Shea B. Yonker, Oleksandr O. Korshak. *3D Medical Image Segmentation in Virtual Reality*. PhD thesis, University of California San Diego, La Jolla, CA, 2019.

[17] Anna University PhD-Regulations 2015. `https://cfr.annauniv.edu/research/regulation/PhD-Regualtion-2015.pdf`. Accessed: 20 March 2015.