Application of Virtual Reality for Teaching in the Dissection Room

By
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Declaration

I, the undersigned, declare that this thesis is my original work. It has never been presented for a degree in any other institution and that all sources of materials used in it have been duly acknowledged.

Name: ___________________________

Signature: ________________________

Date: ____________________________

This MSc. thesis has been submitted for examination with my approval as an advisor.

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Certificate of Examination

This is to certify that the thesis prepared by Alemseged Getachew entitled "Application of Virtual reality for Teaching in the Dissection Room" submitted in partial fulfillment of the requirements for the degree of Master of Science in Biomedical Engineering (Bioinstrumentation and Imaging) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Virtual reality (VR) is a computer graphics technology which can be used to develop applications to support teaching human anatomy. Using VR, virtual 3D models of various parts of the human body can be developed and interacted with. The present thesis work addresses the problem that medical students often encounter in their practice in wet specimens with the absence of cadavers, using kidney as an example. The main objective of the thesis is to reconstruct highly detailed 3D virtual model of the kidney based on small interval cross-sectional images (CT-DICOM dataset), suitable for undergraduate students teaching virtual dissection through animation using kidney as an example, to supplement the wet specimen dissection procedure.. A 3D slicer software is used to develop 3D model of the kidney from the imported CT-DICOM data. Output of the 3D slicer is high poly object which is exported in an STL file format to the T*ransmutr* software for simplifying the number of faces of the model by preserving the overall shapes of the original object which is used by Google sketch up & SimLab Composer software. Google Sketch Up is used for dissecting the kidney while SimLab Composer is used for rendering the 3D image and finally used for interactive VR viewing purpose. The final results of the developed 3D model of the kidney are used for interactive virtual reality viewing using desktop computer and virtually dissecting the kidney using Google sketch Up for visualization of the internal structure of the developed model. The developed 3D model allows students to perform detaching and interactively viewing a dissected kidney sequentially without the need of a supervisor. It can be also used inside the dissecting room to practice virtual kidney dissection by other medical practitioners.

Key Words: Virtual reality, CT-DICOM dataset, 3D Virtual model.

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List of Abbreviations

AR	Augmented Reality
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
HMD	Head Mounted Display
HD	High definition
MRI	Magnetic Resonance Imaging
PC	Personal Computer
ROI	Region of Interest
STL	Standard Tessellation Language/Stereo Lithography
3D	Three Dimensional
2D	Two Dimensional
US	Ultrasound
VR	Virtual Reality
VOI	Volumes of Interest

Chapter 1

Introduction

1.1 Virtual Reality

Educational technology is changing the way people engage and interact with learning materials. Its goal is to make a strong environment where scholars can use their innate abilities of learning to understand complex concepts and acquire knowledge through observation, imitation and participation [1]. Technology enhanced learning is best when it seamlessly integrates into the curriculum, mitigates the passive lecture experience and thus the sizable amount of students during a category, and also provides a tool within which students can engage in meaningful experiences and gain knowledge. The supply of multimedia technology, digital content and software empowers the fashionable day students because it provides opportunities to interact with learning materials more easily and effectively [2].

Virtual reality (VR) is often defined as a category of computer-controlled multisensory communication technologies that allow more intuitive interactions with data and involve human senses in new ways [3]. VR can also be defined as an environment created by a personal computer (PC) during which the user feels immersed, a perceptual and psychological sense of being within the digital environment presented to the senses [4].

Medical and health science students must gain many skills and acquire vast arrays of data throughout their time at the University to become competent practitioners, with anatomy especially being one of the cornerstones of health education. Without proper understanding of anatomy, no matter the world of healthcare, practitioners can’t be ready to perform investigations effectively as they require knowledge of organs’ and tissues’ precise locations [5]. Anatomy is traditionally taught at the beginning of a health science or medical course both in medical schools as well as in biomedical engineering to provide the fundamental knowledge in four main areas: gross anatomy, neuro-anatomy, histology and embryology [6]. It is commonly delivered in the form of lectures, which includes a slideshow presentation and a verbal description of the concepts, dissections and prosections, clinical cases and self-directed study using two dimensional (2D) images and multimedia resources [7]. Anatomical learning is best done in a setting where desired structures can be observed from all angles. This includes examinations of actual structures using cadavers or synthetic recreations, like silicone or plastic models. Surgeons stress the importance of dissections in anatomy teaching, because it provides an efficient method for learning anatomical details, familiarizing the scholars with variations in human physiology and appreciating structures of the body that cannot be examined during an operation [8]. On average, medical students can get approximately three hours of anatomy laboratory time each week where they share a cadaver between 10 – 12 students [9]. In Ethiopian teaching hospitals including AAU's Black Lion Medical College and St Paul Millennium Medical College, the average number of students per cadaver before the COVID-19 epidemic was 20-25; whereas during the epidemic, the number was reduced to the range 10-12 students per cadaver, which is in accordance with the international standards. These sessions are tightly structured and in many Universities, students are unable to gain access to the 'wet specimens' outside of scheduled times [10-11]. This means that the scholars only have a limited window during which they will learn anatomy effectively from a cadaver. Students are then required supplementary materials to reinforce their anatomical knowledge through self-directed study. This material most commonly consists of 2D supplementary resources such as lecture slides, textbooks and flashcards [12]. An issue with learning from static images is that anatomical structures are three-dimensional (3D) and it can be difficult to comprehend spatial relationships between structures. 2D images also limit the student's ability to rework these into 3D structures, which may be a challenging cognitive leap for those that find it difficult to see or mentally rotate anatomical structures [13]. With advances in educational technology, these traditional resources can be supplemented by interactive multimedia learning tools [14-15] and interactive software that can be accompanied by both auditory and visual information [16].

1.2 Statement of the Problem

Teaching and learning medical science courses is a difficult task, partially due to the complexity of the subject and limitations of traditional pedagogic methods: lectures, textbooks, laboratory, and anatomical dissections [17]. Virtual 3D models are powerful tools for teaching anatomy and there are a lot of different digital anatomy models, while most of these commercial applications are based on a 3D model of a human body reconstructed from images with a 1 mm-1.5 mm intervals. The use of even smaller intervals may result in more details and more realistic appearances of 3D anatomy models. The efficiency and applicability of teaching depends on the amount of available studying materials. A very important part of the teaching of anatomy is using human anatomical specimens that are of a high quality and that can realistically demonstrate the topographical relations of individual anatomical structures. Long-term usage of those specimens in teaching of anatomy courses causes the degradation of them. Students can use also anatomical literature, atlases, and scripts. Particularly anatomical atlases that are essential for their studies are very expensive for students. That is the reason 3D interactive anatomical models are great alternative studying tools for students and helping them to understand really complex topographical and functional relations of anatomical structures [18]. The problem the researcher want to address in the current study is that for medical students to become competent practitioners in their future carriers, the time allocated for dissection practices using wet specimen should be adequate, which is not the case in the current practice. One solution is to use interactive 3D virtual model of organs, using kidney as an example, to supplement the wet specimen dissection procedure. Even though different VR solution have been provided in previous literatures, the researcher wants to show that freely available software could be utilized to build one, making it a more cost effective approach. Using different software and DICOM data set, the 3D virtual model of the kidneys with their vessels are reconstructed. VR tries to restore reality through devices that permit us to “feel” that we are somewhere else, leap into a reality that does not exist, transport us to a built reality. 3D modeling of human anatomy provides students and doctors with the tools for advanced way of working with CT scanned pictures of human tissues and organs by means of 3D computer interactive simulation. The modeling is possibly used to analyze examined problems with the help of the scanned and modeled objects. For the student instead of being seated passively in a classroom for 1 or 2 hours, the use of VR technologies as teaching tools makes students fully and actively engaged in the activity.

1.3 Objective

1.3.1 General Objective

The whole purpose of this thesis is to reconstruct highly detailed 3D model of the human organ, using kidney as an example, based on small interval cross-sectional images (CT-DICOM dataset), label the external and internal parts of the model that is suitable for students when learning virtual dissection through animation.

1.3.2 Specific Objectives

- Identify the computing requirement for 3D reconstruction of the model;
- Identify the software used for the process of reconstructing 3D model of the kidney;
- Identify the anatomical sections of the human kidney based on CT-DICOM dataset;
- Isolate the various anatomical sections and label parts of the kidney by dissecting, and
- Test the interactive VR viewing application.

1.4 Materials and Methods

Human abdominal CT-DICOM dataset is collected from Osirx imaging library. A high speed computer with larger storage and workspace as well as different software required for the research work were used including 3D slicer, Transmutr, Google Sketchup and SimLab composer 9. Thresholding based approach was utilized for segmentation purposes. Transmutr software was used to change the file format so that it is compatible for the Google Sketchup and SimLab composer. Google Sketchup was used for dissection of the kidney and SimLab composer 9 for interactive VR viewing of the kidney. The details of materials and methods will be discussed in Chapter 3.

1.5 Relevance of the Research

Introduction of high speed computers and fast growing graphic software has helped the development of 3D models of different objects. Cadaver dissection is the gold standard in human anatomy classes. However, wet specimen is very expensive and not used again and again due to its limited time frame in usage. Therefore, students don't get ample time for practical laboratory work using wet specimens to become competent practitioners in their future carrier. This thesis research intends to alleviate the aforementioned problems and proposes a VR system making use of human abdominal CT–DICOM dataset, high speed computer and 3D graphic software. Standard DICOM dataset is imported and the 3D model of the kidney is reconstructed using a 3D slicer. The dissection process is done by Google Sketchup and interactive VR viewing is done using SimLab composer. Students can use the reconstructed model any time on their personal computers without the need for help of a supervisor.

1.6 Related Works

The work reported by S. Tan et al. develop a 3D model of the laryngeal for teaching anatomy and that showed a promising role in medical training [19]. Another work by J. Beermann et al. showed that 3D visualization improves understanding of surgical liver anatomy. VR is a self-learning tool that the practitioners use to reduce medical errors when practicing [20]. VR and augmented reality are technologies in computer graphics which can be used to create applications to aid the teaching of the human anatomy. Using these two technologies, virtual 3D models of various parts of the human body can be created and interacted with [21]. According to R. B. Trelease and Antoine Rosset, using clinical imaging data and special types of workstation software assist to speed up the production of VR simulations which is comparable with reconstruction based modeling from segmented cadaver cross-sections and it offers useful examples of normal structural distinction and pathological anatomy [22].

1.7 Organization of the Thesis

The rest of the thesis has been organized into four chapters. Chapter two discusses in detail about VR, types of VR as well as the benefits of VR and human anatomy. Different types of abdominal imaging modalities are explained and brief discussion on CT-DICOM imaging standard has also been included. Chapter 3 presents materials and methods followed in the current research including acquisition of abdominal CT-DICOM dataset, importing DICOM files to the 3D slicer software and segmentation in axial, sagittal and coronal planes for the reconstruction of 3D model using 3D slicer. Chapter four discusses how to reconstruct 3D virtual model of a human kidney using the 3D slicer while dissection of kidney is made by using Google Sketchup and interactive VR viewing is done using SimLab composer software. Finally, Chapter 6 presents the research conclusions and possible future works.

Chapter 2

Literature Review

2.1 Virtual Reality (VR)

Virtual reality (VR) allows an intuitive way of learning by focusing on first-person experience, which is particularly important in the learning process. Unlike third-person experience, first-person experience is subjective and helps students to generalize new knowledge in a more effective way to retain the knowledge [23, 24]. Besides, VR stimulates students to further investigate what they are learning [25].

To benefit from the VR technology, teachers should assess the nature of the teaching contents to decide when to use and when not to use VR in education [26]. The effectiveness of learning through the use of VR in 3D lies in its support for students to be more receptive to understand aspects of anatomy using 3D than using 2D [27]. While comparing the teaching of musculoskeletal anatomy through VR and traditional methods, VR can serve as a complement to traditional methods of teaching anatomy [28]. In anatomy classes, students need to rotate and manipulate structures from various views to spot anatomical structures. The concept of VR is creation of a digital world, in which a human user is placed and can interact with it in real time. VR is distinguished from other human-computer interaction methods by 3D graphics striving at realism, intuitive interaction and user immersion inside the digital scene. Visual-spatial ability has been defined as the ability to mentally manipulate objects in 3D [29]. Such ability is important for students taking medical courses to understand anatomical structures and is also important to surgical trainees and surgeons. Therefore, the power to see and mentally manipulate 3D structures and properly identify them and related structures are crucial skills to medical, dental, and biomedical engineering students when the anatomy is presented in various planes and positions [30]. Teaching anatomy using Virtual 3D model is easy and powerful tool for delivering skill and knowledge. Nowadays, there are plenty of digital anatomy models and most of those commercial applications support 3D models of a person's body reconstructed from images with 1 mm intervals. The use of even smaller intervals may result in more details and more realistic appearances of 3D anatomy models [31].

There are different types of VR: Desktop VR, Text-based VR and Immersive VR. In Immersive VR, the user becomes immersed in a virtual world. Desktop VR refers to computer programs that simulate a true or imaginary world in 3D format that is displayed on a screen as opposed to an immersive computer game. Text-based VR involves a real-time multi-person virtual environment using text description instead of graphics [32].

2.2 Augmented Reality (AR)

Augmented Reality (AR) is a type of display that allows a user to see the real world with virtual objects superimposed upon the real world. This is in contrast to VR, in which the user is completely immersed in the virtual world. AR superimposes virtual objects in the real environment by registering in 3D and giving real time interactivity to users [33]. AR is basically a variation of VR , therefore, both have the same fundamental elements, namely virtual objects, real-time response and visual equipment [34]. However, they are different in a few aspects. AR only superimposes virtual objects on the real objects, where the real environment can still be seen by users. In VR, the real environment is totally replaced with the virtual environment. Hence, VR will limit user activities within a room area because users cannot see the objects around them. Whereas, outdoor activities can be carried out by using AR, because the real environment still exists in AR [35].

2.3 What is similarity and difference between AR and VR?

The concept of VR is creation of a digital world, in which a human user is placed and can interact with it in real time. VR is distinguished from other human-computer interaction methods by 3D graphics striving at realism, intuitive interaction and user immersion inside the digital scene. Visual-spatial ability has been defined as the ability to mentally manipulate objects in 3D [29].

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2.4 Benefits of VR

The goal of VR is to improve, inspire and motivate students of certain events and at the same time allow students to experience hands-on learning [36]. But what is more appealing with regard to VR in education is the fact that it can allow learners to practice procedures without the risk involved. This can be applied in medical education without compromising the safety of a real patient [37]. Using VR technology in surgical educations can support surgeons to determine their capability level before actually operating on a patient [38]. The use of VR surgical simulation to succeed in specific target criteria significantly improved the operation room performance of residents. The transfer of training skills from VR to operation room sets the stage for more sophisticated uses of VR in assessment and training and allows for error reduction [39]. The stimulus and mindful commitment of the virtual environment come not only from the novelty but from interactivity, realism, and immersion [40]. VR is an empowerment technique that stimulates interest in any content matter, and it opens many new paths for learning [41]. A virtual environment allows for interaction with virtual objects similar to interaction with real objects [42]. For the case of anatomy learning, virtual environment promises versatility and flexibility in the presentation and exploration of anatomical objects, being less expensive than dissection facilities [43].

2.5 Human Anatomy

Human anatomy is the study of the human body structure. It is considered one of the oldest basic medical sciences which remains present in all curriculums of medical colleges until today [44]. Historically, the teaching of human anatomy in medical and allied health curricula using cadavers has been a source of serious social controversy, rivaling the foremost contentious medico-legal and ethical debates across other scientific disciplines. Many hold the view that cadaver dissection is the key component of teaching anatomy and therefore, the consequences for trainees/practitioners not having competent anatomical knowledge have recently been emphasized [45].

Anatomy is usually considered as the 'foundation of medical sciences', but it is also perceived to be a difficult and challenging subject in medical education [46]. Medical students got to acquire core anatomical knowledge to create a powerful foundation for future clinical encounters and professional practices. Anatomical models have applications in clinical training and surgical planning also as in medical imaging research. An important point of concern is that anatomy teaching within the medical and other health care education programs is on the decline and 'has fallen below a secure level' in recent years [47]. Students learn human anatomy in a structured way because anatomy is a corner stone of medical education. Anatomy is very important but difficult science for medical students when it is done by reading books only [48]. Modern computer software technologies can help to solve this problem by developing 3D human anatomy models and users can learn more detailed forms of anatomy through 3D computer generated models than just reading books [49].

2.6 Abdominal Medical Imaging Modalities

Advanced imaging techniques have a big role to enhance the standard of patients' medical care. Non-invasive medical imaging modalities assist the physician to render accurate diagnoses and precise required treatment. A vast amount of medical imaging modalities is accessible and subject to active and promising research. Each modality gives a range of data about the body's organ under investigation, which may be associated with possible disease/s. The imaging modality selection for a targeted clinical study requires medical insights specific to organs under study. . Figure 2.1 demonstrates different modalities that can be used for abdominal medical imaging based on the body part/s under investigation [50-51].

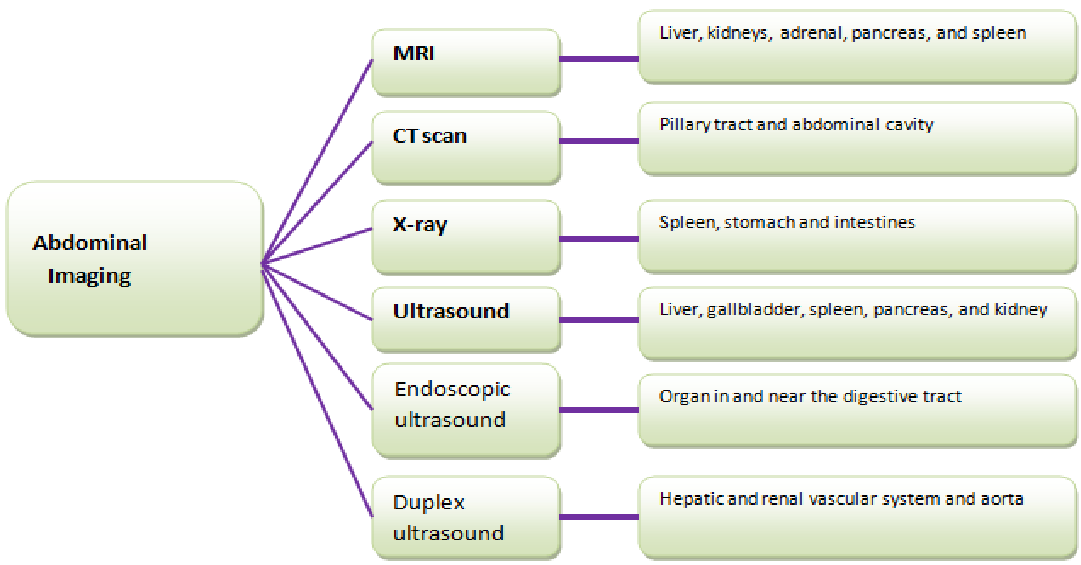

Figure 2.1: Medical image classification structure.

2.6.1 Magnetic Resonance Imaging for Abdominal Diagnosis

Magnetic resonance Imaging (MRI) is a technique that uses dominant magnets and radio waves to make images of the within of the abdomen region. It is considered a non-invasive and non-ionizing device that provides 3D images, high spatial resolution and excellent soft-tissue contrast. MRI has the advantages of avoiding the dangers of an angiography and in providing better information about masses in the abdomen than CT in some cases. Differential contrast between soft tissues can be represented with high spatial resolution by varying the data acquisition parameters. In addition, the strong magnetic fields produced during the use of MRI can affect heart pacemakers and other implants attached to patients [52].

2.6.2 X-ray and Computed Tomography (CT) for Abdominal Diagnosis

X-ray imaging may be a transmission-based procedure during which X-rays source undergo the patient body. The X-ray is detected either by an ionization chamber or a film on the opposite side of the body. Differential attenuation of X-rays in the body leads to different contrast in the image between different tissues. Planar X-ray radiography generates 2D projection of the tissues lying between the film and the X-ray source. It is used to study the liver, kidney stones and structures in the abdomen including the stomach, spleen, and intestines [53].

Computed tomography (CT) is a type of specialized X-ray device that can display cross-sectional images of a precise area of the body. In the CT process, the X-ray source is compactly collimated to interrogate a skinny slice throughout the patient. To produce a series of 1D projections at different angles, the source and detectors rotate jointly around the patient. Afterword, these data are restructured to provide a 2D image with reasonable contrast between soft tissues. An abdominal CT is a relatively safe technique, but there are risks including exposure to radiation during the procedure (which is higher than the amount within an X-ray) and allergy to contrast dyes which can lead to kidney malfunctioning [54].

2.6.3 Ultrasound for Abdominal Diagnosis

Ultrasound (US) imaging produces images through the back scattering of mechanical energy from the interfaces between tissues and small structures within tissues. It operates at frequencies within the range of 1 to 10 MHz. At high frequencies, it has high spatial resolution and involves no ionizing radiation. The main clinical applications of US include intra-abdominal imaging of the liver, kidney, and the compromised blood flow detection in veins and arteries. Thus, US is considered a non-invasive, portable, and inexpensive diagnostic modality which has extensive use in the clinics [55].

Endoscopic US is a type of US which has thin, flexible tube devices that passes either through the mouth or through the rectum till it reaches the digestive tract. Sound waves are sent out to the end of the endoscopy's tube and bounce off the organs in the body. Afterward, a computer receives these waves and creates an image of the body inside. The technique is also used to get samples or biopsy by using a thin needle that can be passed through the tube to collect tissue/fluid. This technique does not produce harmful radiation [56].

2.6.4 Duplex Ultrasound for Abdominal Diagnosis

Typically, ultrasonic energy can be applied to interrogate vessels at a great depth as well as arteries in the abdomen. Duplex US combines the traditional US with Doppler US, where the traditional US uses sound waves that bounce off blood vessels to create images while the Doppler US records sound waves reflecting off blood (i.e. a moving object). There are no risks for using the Duplex US technique [57].

2.7 Overview of the DICOM Standard

DICOM stands for *Digital Imaging and Communications in Medicine*. It's a world standard associated with the exchange, storage and communication of digital medical images and other related digital data. The DICOM standard covers both the formats to be used for storage of digital medical images and related digital data, and therefore, the protocols to be adopted to implement several communication services which are useful within the medical imaging workflow. DICOM is a set of images in the form of layers that are generally integrated via a special system to show the results of the combined rays clearly, as also shown in Fig. 2.2 [58]. DICOM provides detailed engineering information that can be used in interface specifications to enable network connectivity among a variety of vendors' products. The standard describes how to format and exchange medical images and associated information, both within the hospital and also outside the hospital (e.g. for teleradiology and telemedicine applications).

DICOM interfaces are available for connection of any combination of the following categories of digital imaging devices: image acquisition equipment (e.g. CT, MRI, computed radiography, ultrasonography and nuclear medicine scanners); image archives; image processing devices and image display workstations; hard-copy output devices (e.g. photographic transparency films and paper printers). The main purpose of the DICOM standard is to permit cross-vendor interoperability among devices and knowledge systems handling digital medical images, as long as all the involved actors comply with the DICOM standard. DICOM is a comprehensive specification of information content, structure, encoding and communications protocols for electronic interchange of diagnostic and therapeutic images and image-related information [58].

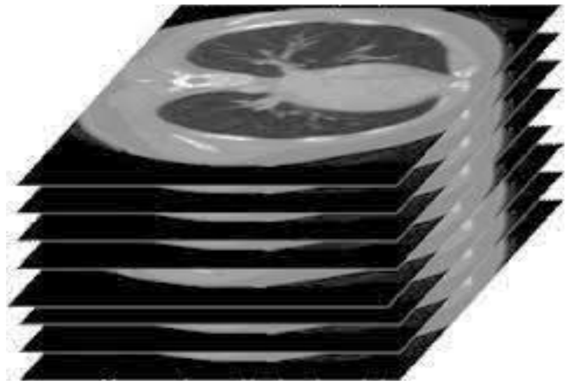

Figure 2.2: DICOM layers.

2.8 Image Segmentation

Image segmentation is dividing an image into parts having strong correlation with area of interest in the image. Image segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze [59]. Image segmentation is used to identify anatomical regions of interest for volume measurement, shape measurement, or creation of 3D models. Image segmentation is the foundation of object recognition and computer vision [60]. It is a process of subdividing a digital image into multiple regions or objects consisting of sets of pixels sharing same properties or characteristics which are assigned different labels for representing different regions or objects. Segmentation is done on the basis of similarity and discontinuity of the pixel values. It is also the initial step in image analysis and pattern recognition, and it refers to partitioning of picture into different regions that are homogeneous or similar in some characteristics.

Image segmentation is practically implemented in many applications such as medical imaging, content based image retrieval, object detection, feature recognition (such as face recognition, fingerprint recognition, iris recognition, object recognition, etc) and in real-time object tracking in video. Image segmentation is used to differentiate different objects in the image, while our image is divided into foreground and background. Whereas the foreground is related to the area of interest and background is the remainder of the image. In the 3D context, segmentation refers to the identification of volumes of interest (VOI) within the image by the classification of voxels into appropriate groups e.g. bones, tendon, fat, muscle, etc. In other words, the segmentation process is painting the voxels of interest and distinguishing them from the rest of the images [60].

Segmentation is a preliminary step that should be undertaken to reach a 3D representation of an organ and isolate it from the rest of the scanned volume [61]. Clearly, the accuracy of any resultant model will largely depend on the accuracy of the initial segmentation procedure. This process is also affected by the image resolution, noise, poor contrast between tissues, motion artifacts, and the user anatomical knowledge to interpret the images [62]. Different image processing software are used for segmentation of voxels of interest in different applications. The segmentation is done by a set of tools that the software provides the user to isolate the voxels of the region of interest from the rest of the images. Image processing software that uses medical images for generating computerized model uses the segmentation process as the initial step.

2.9 Modeling in Virtual Reality

Modeling of an object in the VR is a step-by-step process. The first step is creating a virtual environment that consists of virtual setting and a set of virtual objects that real people can manipulate in real time. In such an environment, virtual objects can then be used to demonstrate different kinds of skills and perform various actions. The next step is the multi modal interaction between virtual objects and users which includes speaking, eye contact, pointing at, gazing at and moving virtual objects. The last step involves recording user‘s body movements including objects, eye gaze and speech acts in real time [63].

2.10 Dissection of the Human Anatomy

Anatomy has been taught and learned through a spread of various tools. Some are traditional, such as dissection, others are clinically oriented such as medical imaging and surface anatomy. Some of the techniques are new and innovative and that include computer-assisted imaging (CAI) and body painting. Dissection is "the systematic exploration of a preserved human cadaver by the sequential division of tissue layers and thus , the liberation of certain structures by removal of the regional fat and animal tissue with the aim of supporting the training of macroscopic anatomy by visual and tactile experience" [64]. Historically, dissection has been practiced since the second century. Direct observation of the human body through dissection initiated the scientific method for learning medicine that included data collection, hypotheses generation, and further testing of these hypotheses [65]. Compared to other teaching alternatives, dissection has served medical students in different ways, including enriching their knowledge acquisition and integration, manual skills, and attitudes [66].

Chapter 3

Materials, Methods and Experimental Results

3.1 Methodology

This section explains the materials and methods used for the reconstruction of a 3D model of a region of interest using abdominal CT-DICOM dataset, dissection of the kidney using Google Skechup and finally the development of the VR model using SimLab composer software. It begins by acquisition of standard abdominal CT-DICOM dataset and then generation of a mask which is used for the reconstruction of highly detail 3D model of the kidney by the use of thresholding based segmentation algorithm of 3D slicer. The model is then exported to Transmutr, which is used for converting the file format for Google Sketchup and SimLab composer. Google Sketchup is used for dissection of the kidney using section plane. SimLab composer is used for animation and VR viewing for the region of interest. Figure 3.1 summarizes the conceptual framework followed in the development of the VR model.

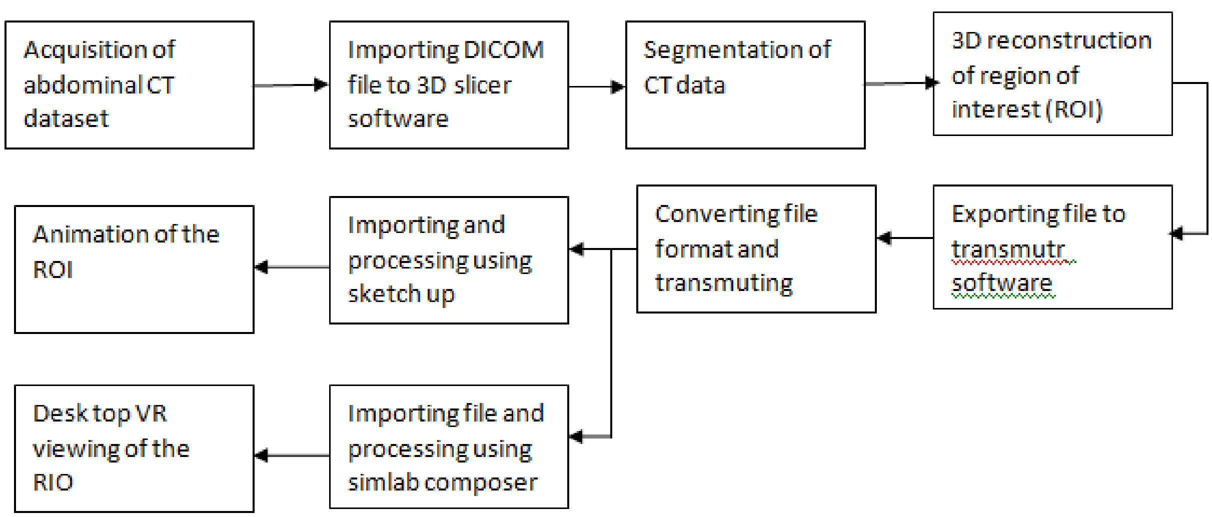

Figure 3.1: Conceptual frame work of the research methodology.

3.2 Acquisition of Data

The data for the research work is obtained from Osirix DICOM image library which is exclusively available for research and teaching purposes. The volume of CT abdominal (panoramix) dataset that comes from the Osirix DICOM imaging library is composed of 441 axial slices, 321 sagittal slices, and

215 coronal slices. The thicknesses (spacing) of the slices were 1.5 mm, 0.742mm and0.742mm for axial, sagittal and coronal slices respectively.

3.3 Computation

The computer needed for the work has the following minimum requirements: Intel (R), Core(TM) i5-6200U CPU @ 2.40 GHz, RAM: 4.00 GB, GPU: GT-540M, OS: Win10.

3.4 3D Slicer Software

3D Slicer is a free and open source, highly extensible, medical image processing, analysis and 3D visualization application platform originated jointly between Boston Brigham and Women's hospital surgery plan laboratory and AI laboratory at the Massachusetts Institute of Technology. The designers aim was to develop an easy-to-use software analysis and visualization tool. Slicer provides free research platforms for tutorial researchers and requires no special hardware devices. Over the past few decades, slicer has become a comprehensive platform for both clinical and preclinical research applications, also as for non-medical image analysis [36].

3.4.1 Importing DICOM files

DICOM stands for Digital Imaging and Communications in Medicine. It is a global standard associated with the exchange, storage and communication of digital medical images and other related digital data. The DICOM data of a CT image is usually in serial form and consists of a sectional section image of a neighborhood of the physical structure. DICOM is used as a clinical messaging syntax to exchange medical images between medical equipment and knowledge systems. Using the import menu of the 3D slicer, the axial, sagettal and coronal sections of the abdominal CT DICOM dataset are loaded to the software. Figure 3.2 shows a snapshot taken while importing a DICOM dataset obtained from the Osirix imaging library to the 3D slicer work space in the axial, sagittal and coronal workspace of the software.

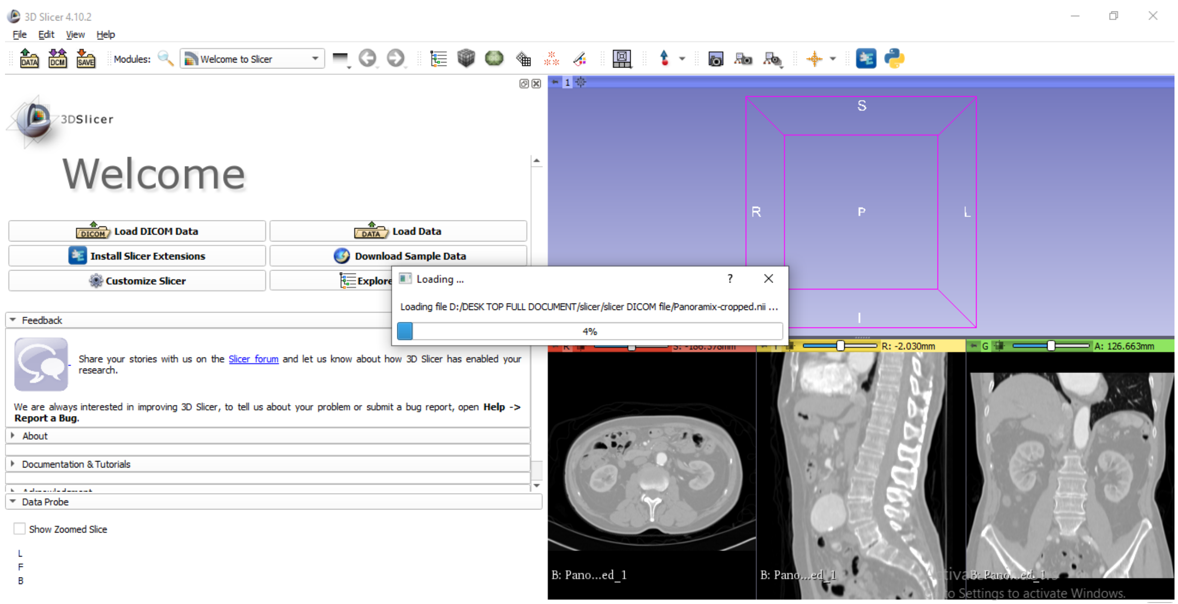

Figure 3.2: Importing DICOM files to the 3D slicer.

3.4.2 Generation of the Mask

Before using the thresholding algorithm, the primary task is the generation of the mask which is employed for reconstruction of the region of interest (ROI).

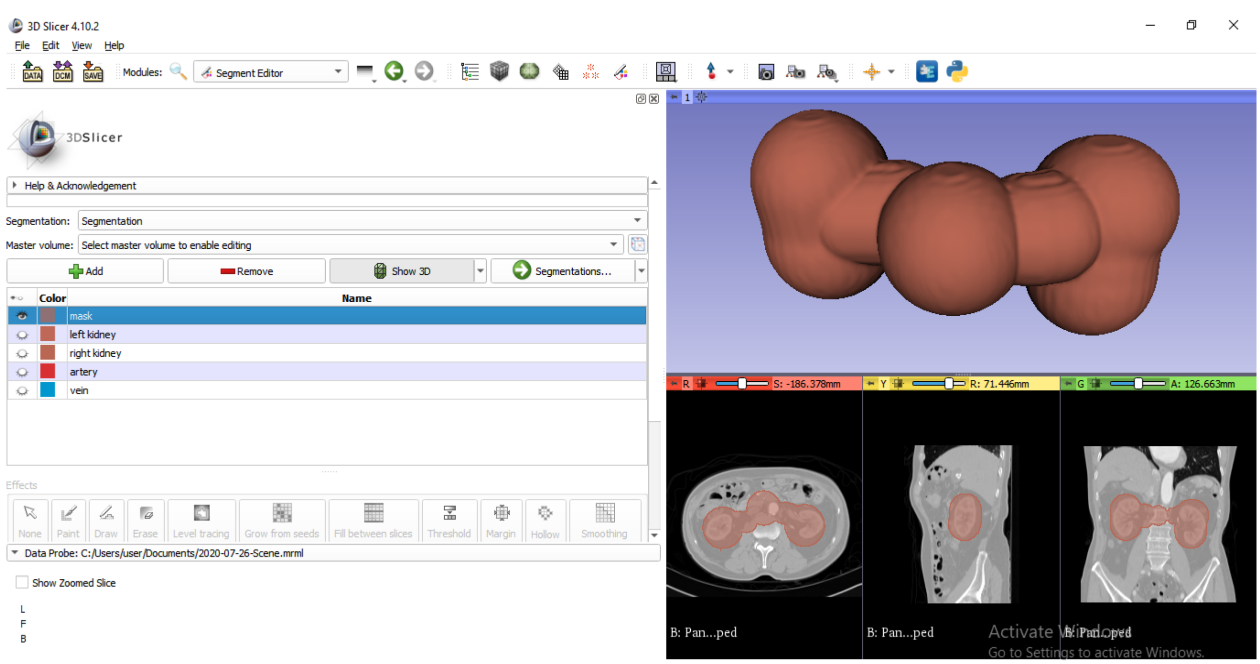

Figure 3.3: Generation of mask for the region of interest.

Figure 3.3 shows the generation of a mask to create the ROI out of the 3D reconstructed human abdominal region. Certain steps are employed subsequently to generate the mask. The first step is importing the CT scanned data, which is obtained from the Osirix imaging library to the 3D slicer. The second step is using the segment editor menu, we create the segment and rename it as Mask. The third step is to use the segmentation tool called paint and select the region under study using paint brush. By varying the paint brush diameter, one can select all the slices of the axial, segittal and coronal planes of the DICOM data. If we then click on 'show 3D' at this point, the mask is visible within the 3D space of the software.

3.4.3 Segmentation of CT data

Image segmentation is that the process of identifying and labeling of the regions of interest within the entire region of the study. It is the process of partitioning an image into multiple labeled regions locating the objects, and limits in images [59]. For this study thresholding segmentation method is employed because thresholding segmentation algorithm uses similarity of a particular feature attributes within the image area under study. 3D slicer is employed for the reconstruction of 3D image using thresholding segmentation algorithm for the reconstruction of 3D image of the kidney.

3.4.3.1 Segmentation of Region of Interest (ROI)

Segmentation can be used to create 3D model of an organ and tissue from a given DICOM dataset. There are a number of image segmentation techniques, for the reconstruction of 3D model of the organ and tissue and the one adopted in the current study is thresholding based. Thresholding approaches rely on the principle that each tissue type has a characteristic range of pixel intensities. Hence, it is possible to differentiate between tissues and identify boundaries. 3D Slicer as a 3D visualization software package enables segmentation of DICOM images using semi-automated algorithms to demarcate regions of interests. The thresholding algorithm reconstructs the 3D model of the human kidney, the aorta and inferior vena-cava. Figure 3.4 and Fig. 3.5 present 3D reconstruction results for the left and right kidney of a sample subject, respectively. Figure 3.6 presents segmented abdominal aorta and renal artery while Fig. 3.7 presents a segmented inferior vena cava. Figure 3.8 presents the two kidneys together with the abdominal aorta and renal artery segmented together. Figure 3.9 shows segmentation result for the two kidneys, inferior vena cave and renal vein together. Figure 3.10 and 3.11 present the front and back sides of the entire segmented ROI, respectively.

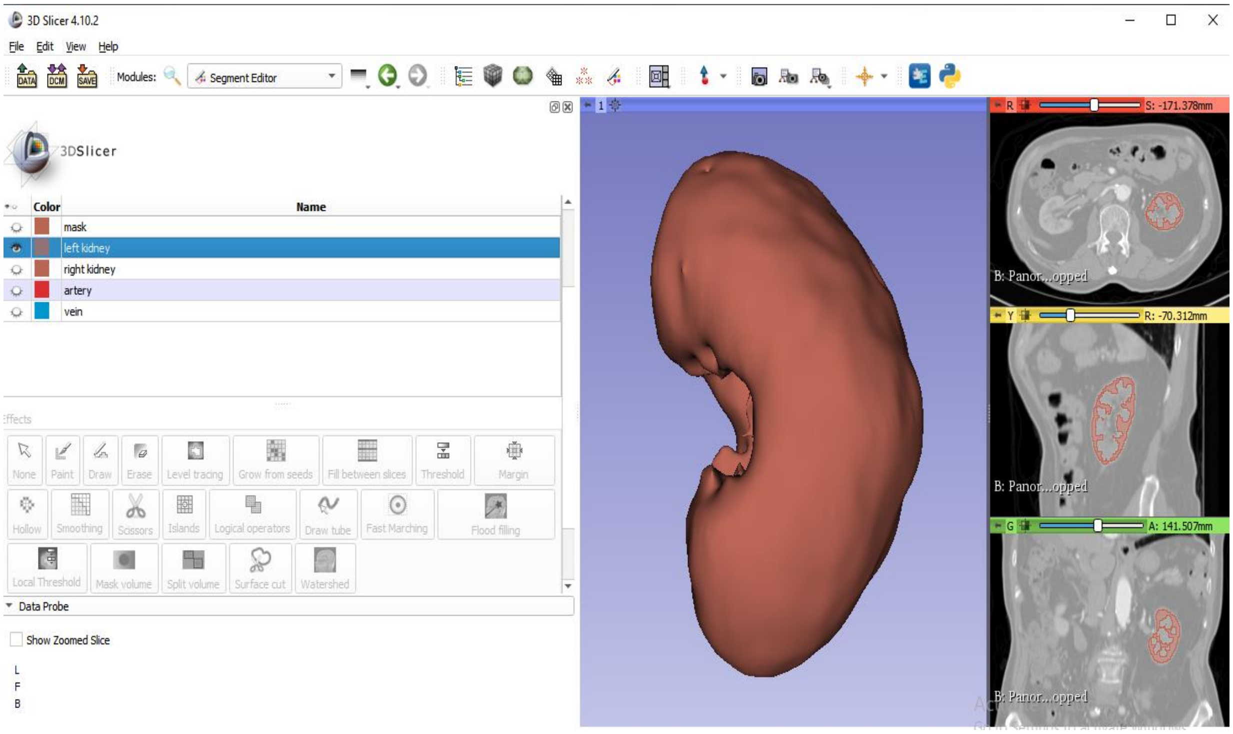

Figure 3.4: 3D Reconstruction of the left kidney.

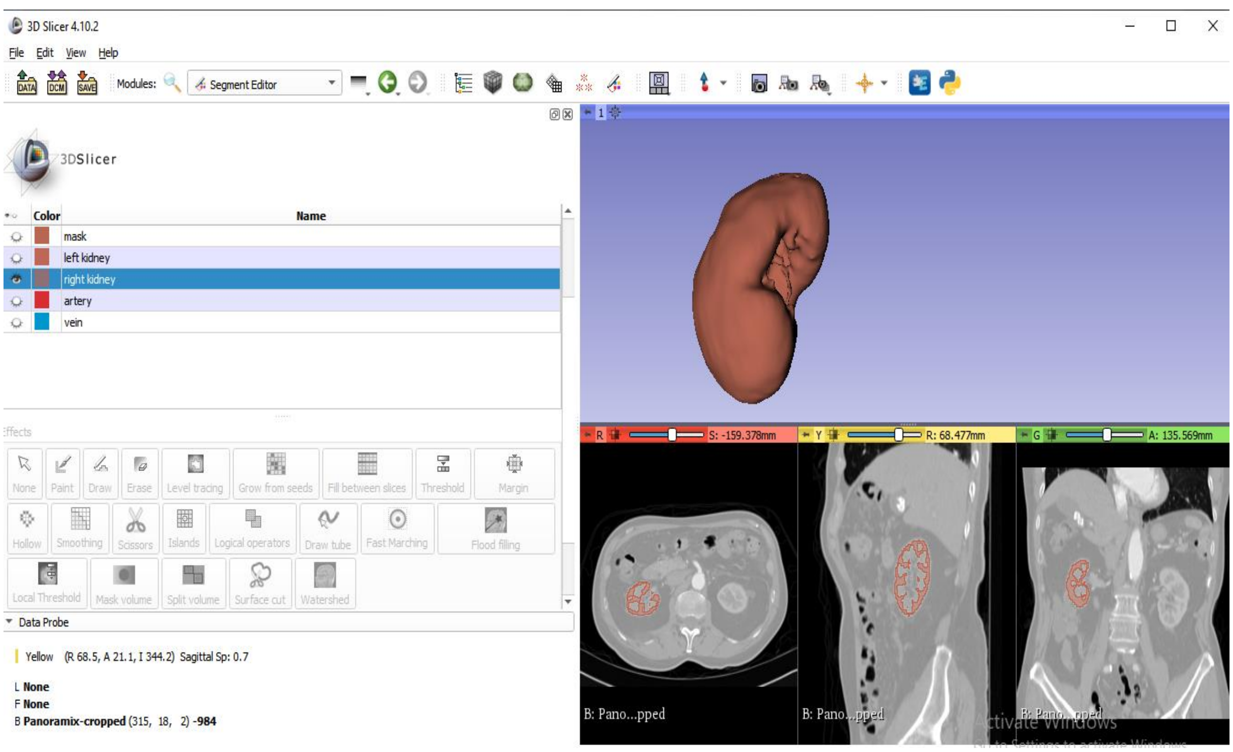

Figure 3.5: 3D Reconstruction of the right kidney.

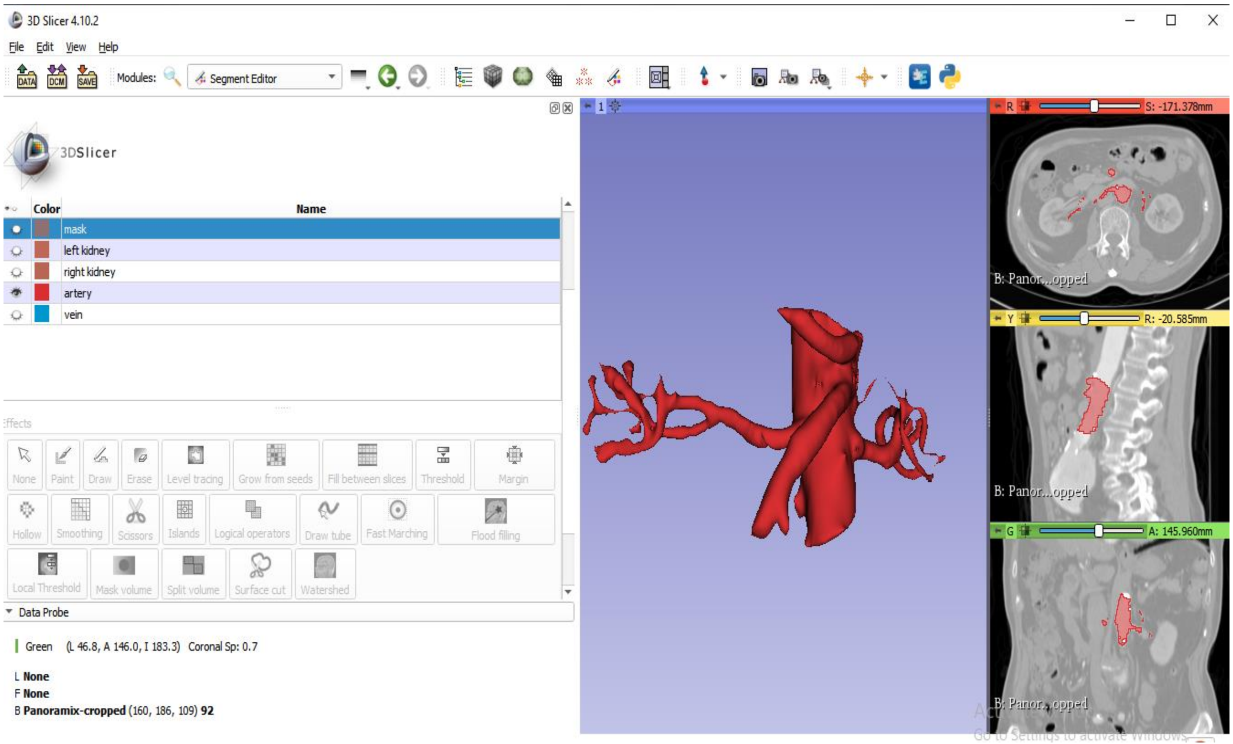

Figure 3.6: 3D Reconstruction of the abdominal aorta and renal artery.

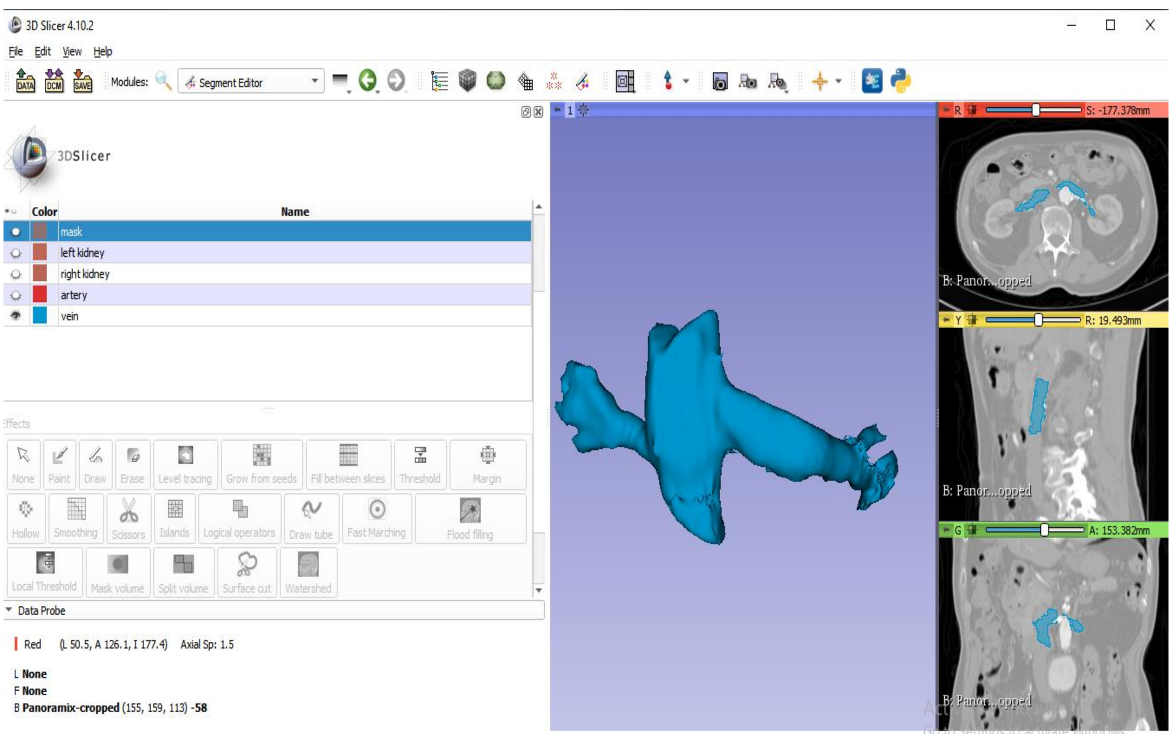

Figure 3.7: 3D Reconstruction of the inferior vena cava.

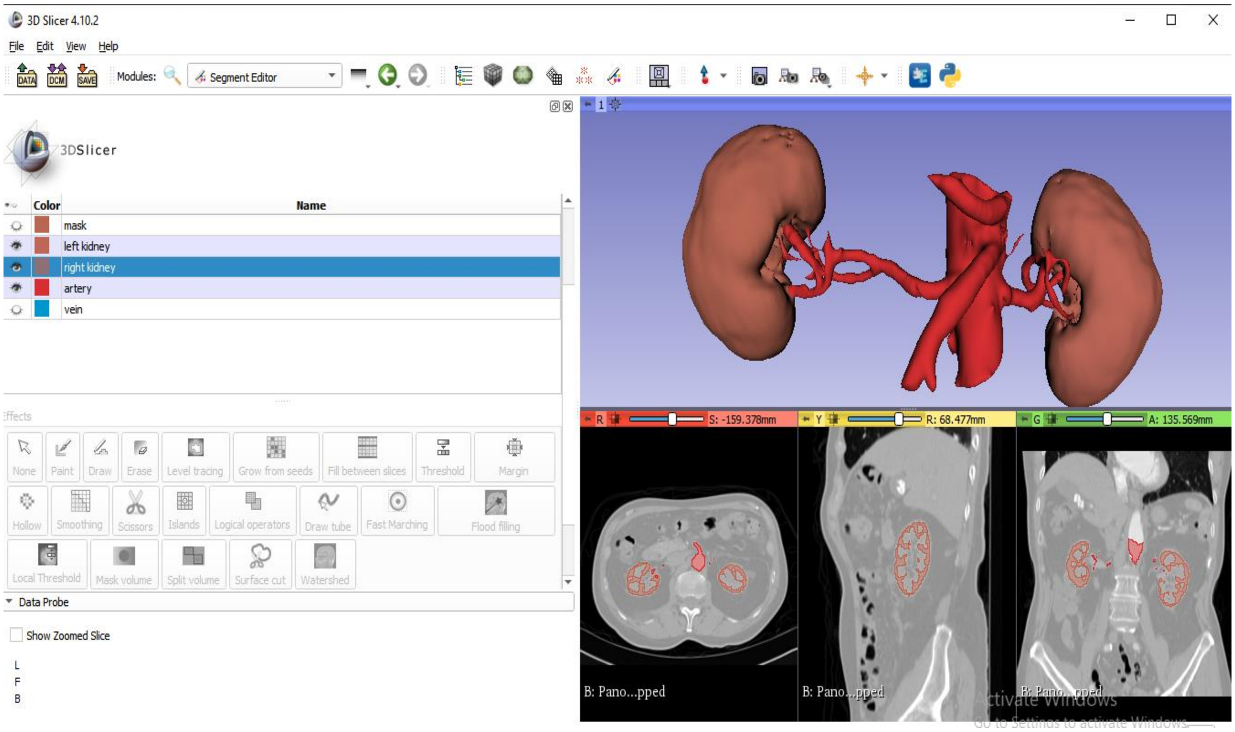

Figure 3.8: 3D Reconstruction of kidney, abdominal aorta and renal artery.

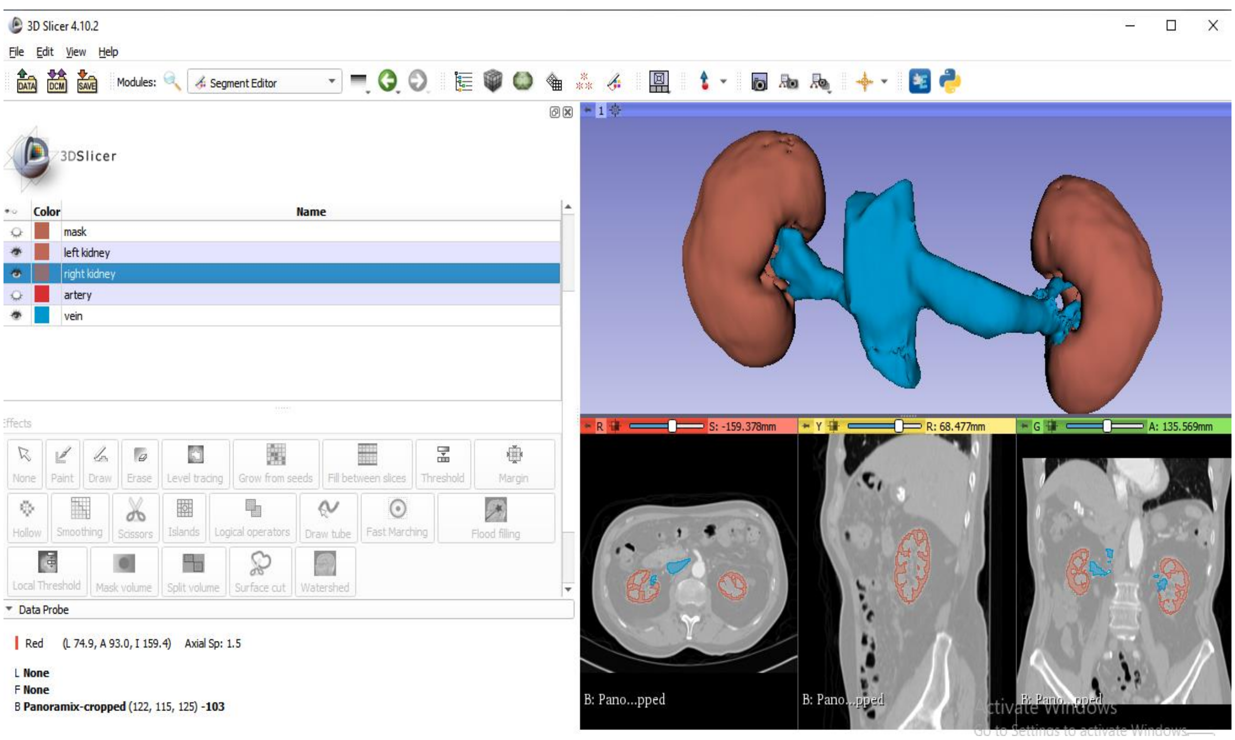

Figure 3.9: 3D Reconstruction of kidney, inferior vena cava and renal vein.

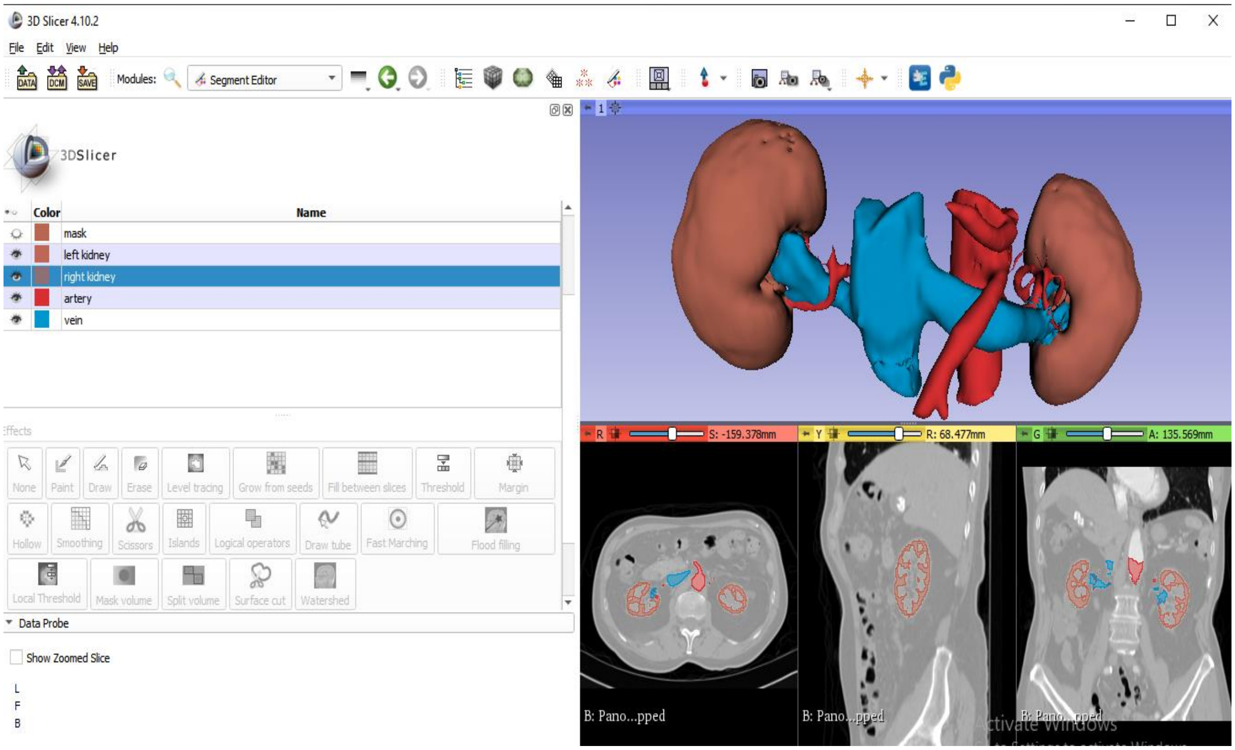

Figure 3.10: Front side image of the 3D Reconstruction of the region of interest.

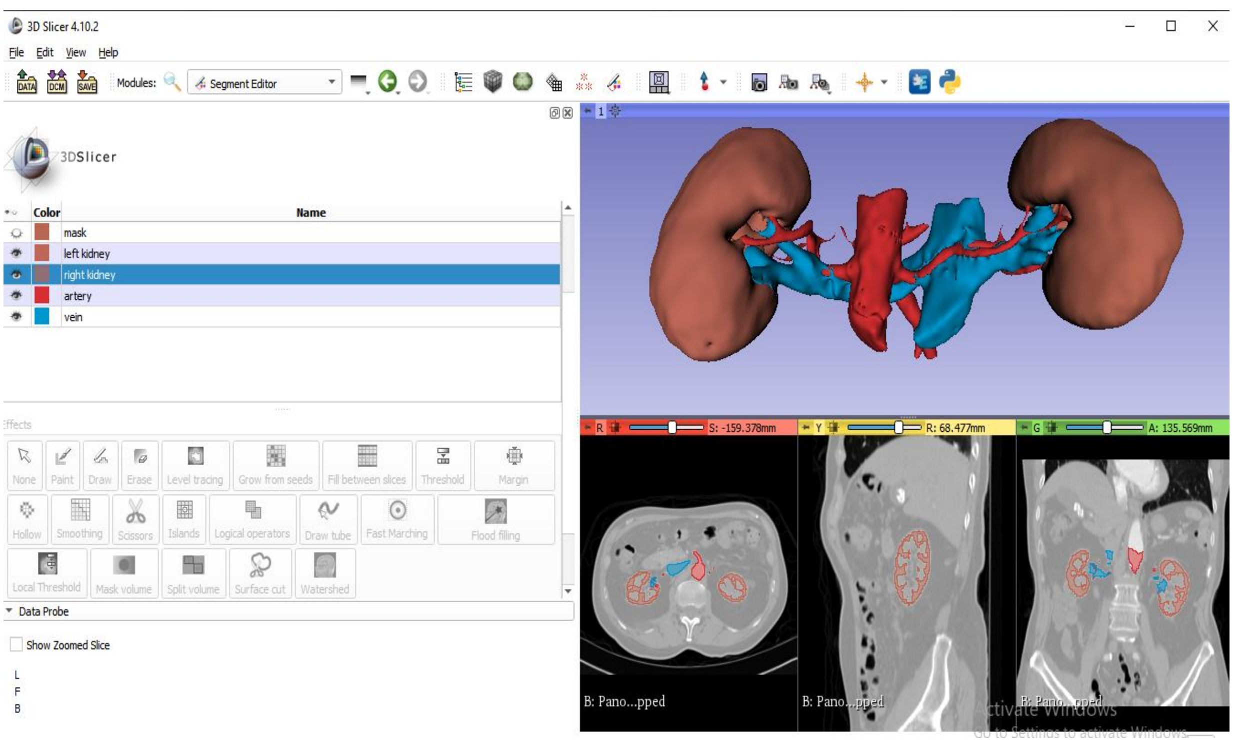

Figure 3.11: Back side of the 3D Reconstruction of the region of interest.

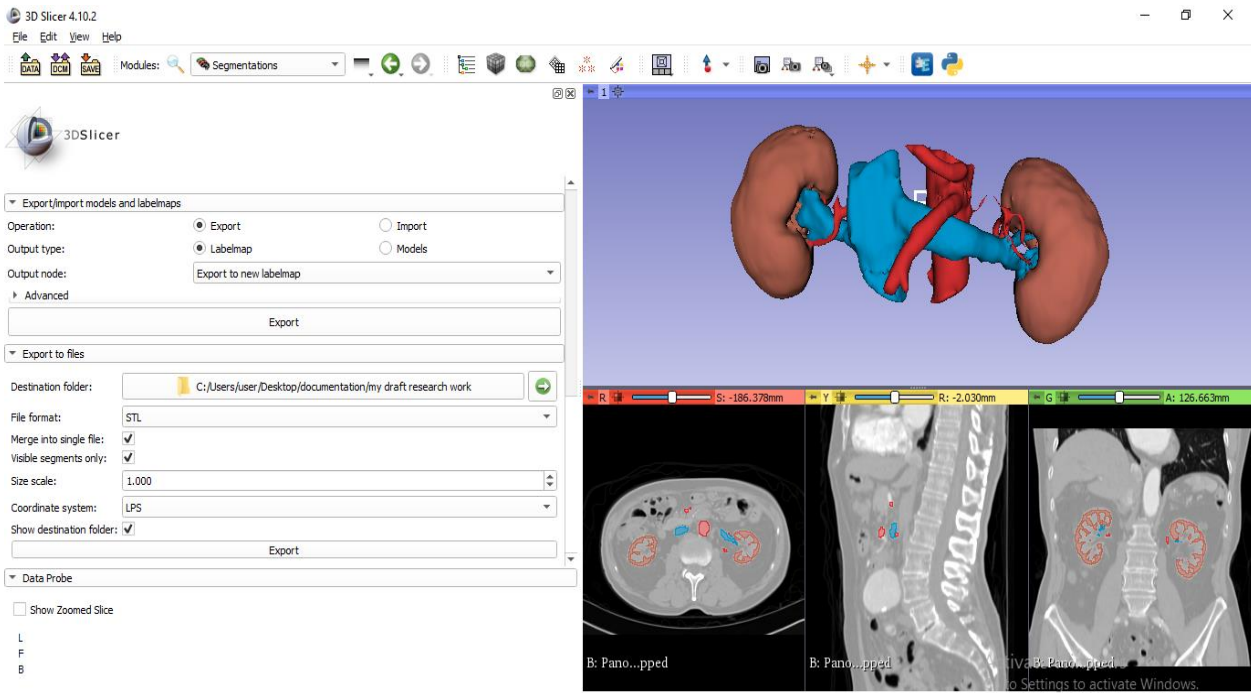

Figure 3.12: Exporting the files in STL format from 3D slicer to the destination folder.

Once the segmentation is completed, the resulting ROI will be converted to STL format and exported from the 3D slicer to the destination folder. Figure 3.12 presents a snapshot of the exporting process.

3.5 Transmutr Software

Google Sketch Up cannot handle very high-poly objects that is reconstructed from the 3D slicer. Due to this limitation, transmutr software is used. Transmutr has the fine-tuning ability to simplify (reduce) the number of faces by preserving the overall shape of the original object. Transmutr is utilized to convert the different 3D file formats to Google Sketch Up files, with powerful features like programmed render-ready materials, geometry simplification and essential options like scaling, unit conversion, and axes/origin transformations. Transmutr is a program designed to help the conversion of different 3D model formats used for Google Sketch Up. The developed 3D virtual model using the 3D slicer and saved in STL format cannot be recognized by Google Sketch up. Therefore, transmutr is used for the conversion of the file format which can be used by the Google Sketch Up [67]. Figure 3.13 presents the appearance when while the kidney is being loaded to the transmutr while loading of the entire model to the transmutr is depicted in Fig. 3.14. One can adjust the axes and do rendering within the transmutr and load it back, as depicted in Fig. 3.15 and Fig. 3.16, respectively.

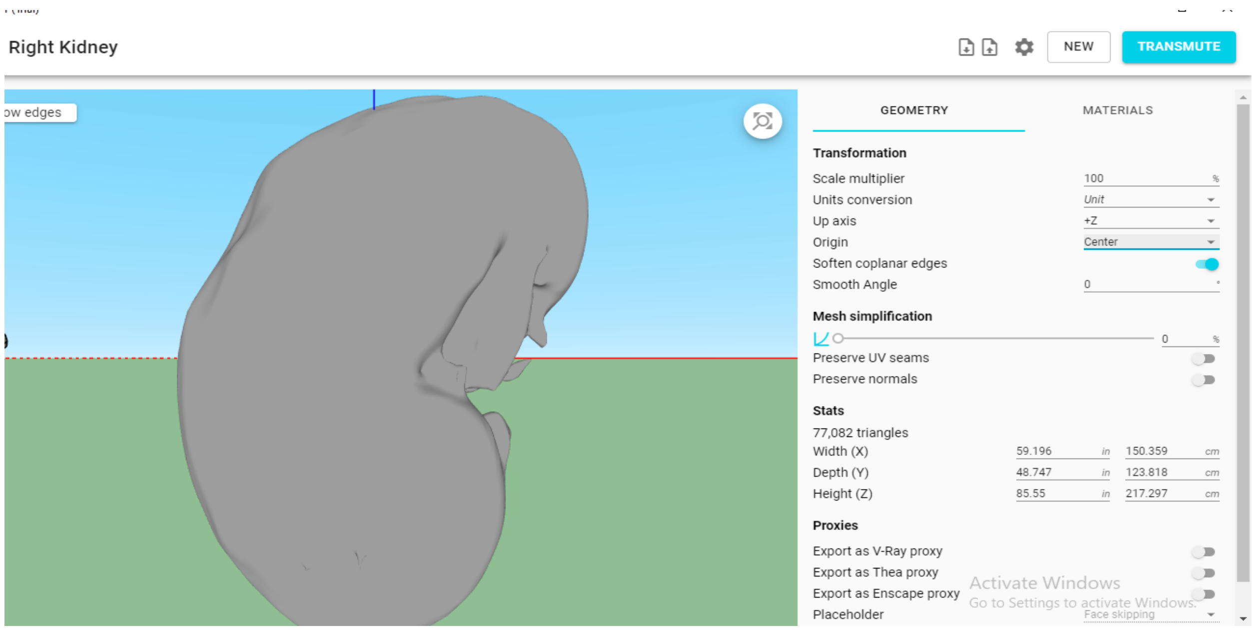

Figure 3.13: After loading the kidney to the transmutr..

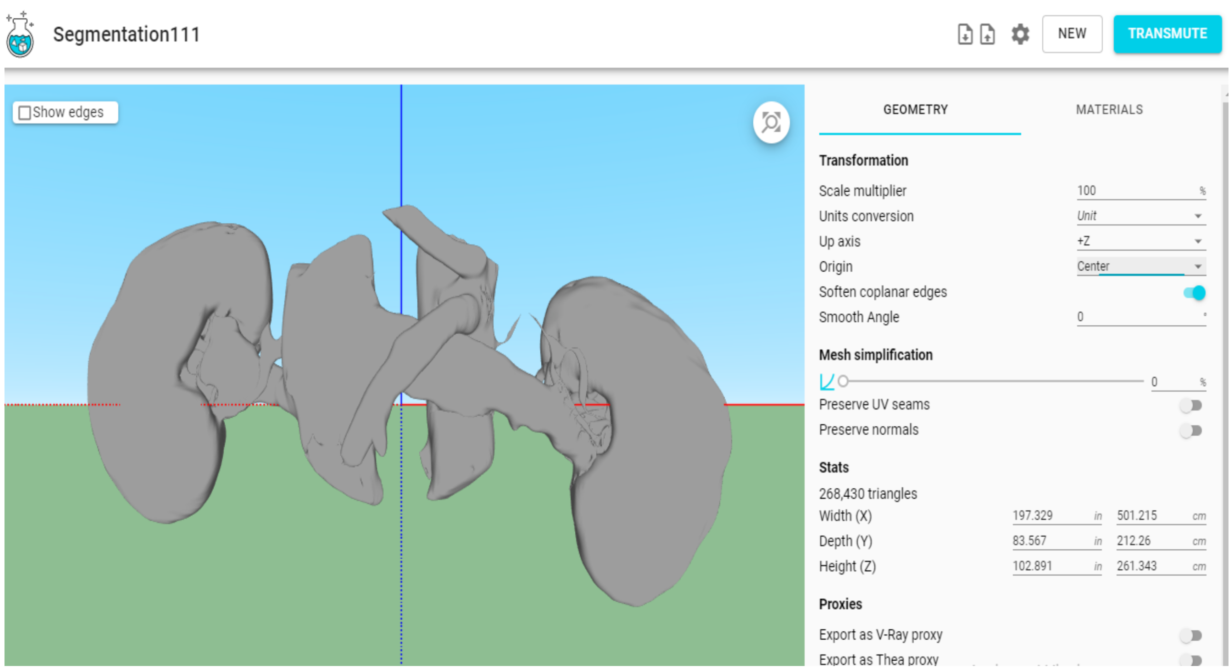

Figure 3.13: After loading the model to the transmutr.

The above figure shows that the 3D model is imported into the work space of transmutr from the destination folder where the geometry and the rendering action should be takes place in the plat form.

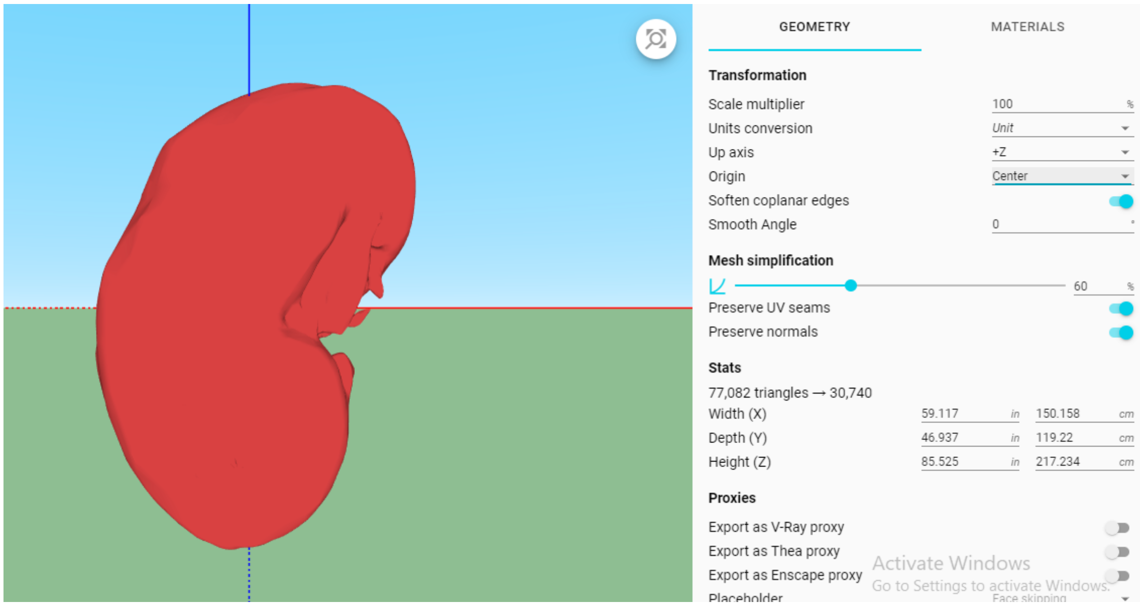

Figure 3.14: Adjusting axis and rendering the kidney in the transmutr.

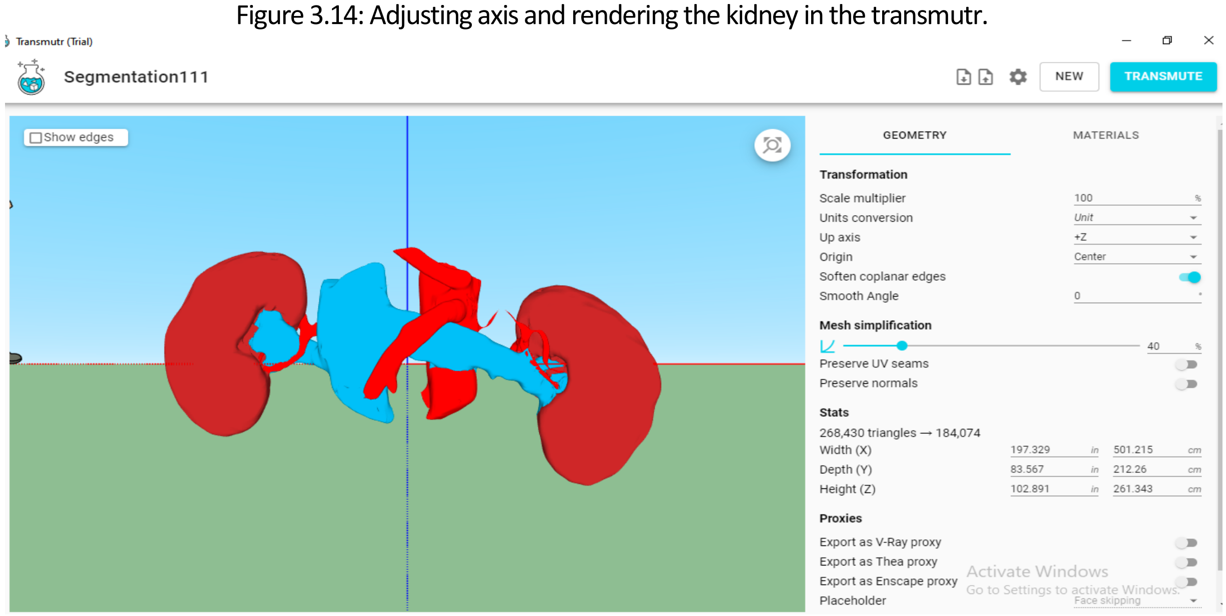

Figure 3.15: After loading adjusting axis and rendering of model in the transmutr.

Figure 3.15 and Fig. 3.16 show that after the model is imported into the work space of the plat form, the model geometry is adjusted and the model is partially rendered. Now the model is ready to be exported to the other platform for further action.

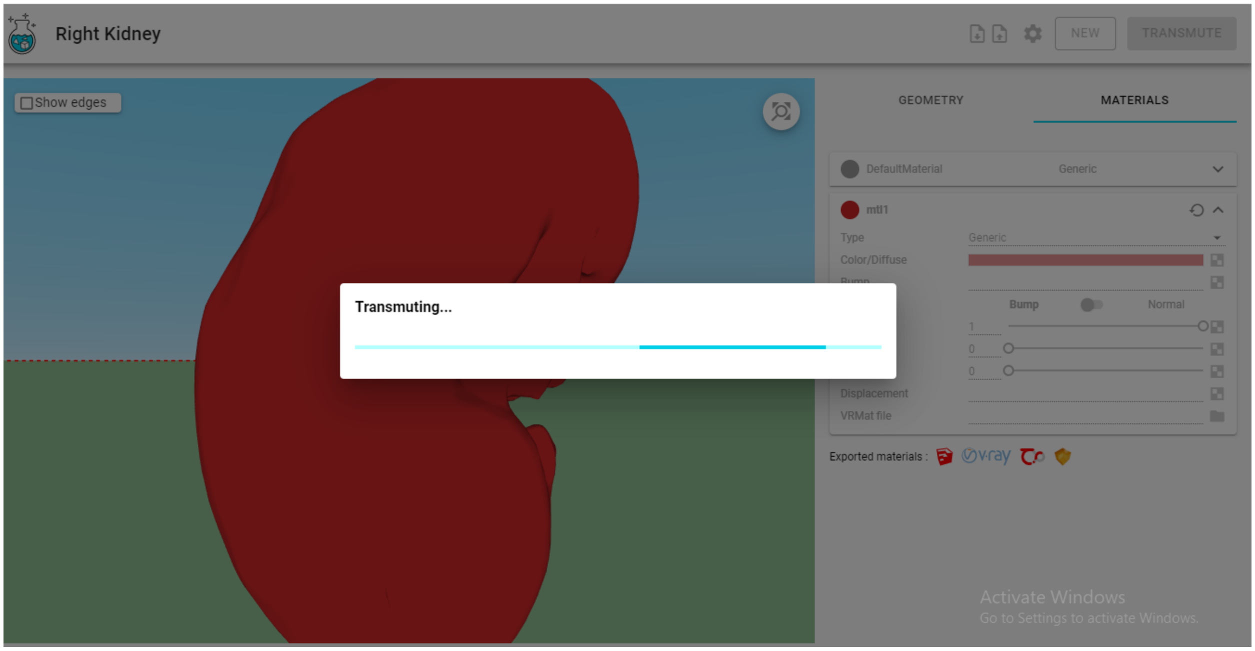

Figure 3.16: Transmutting the kidney to the destination folder.

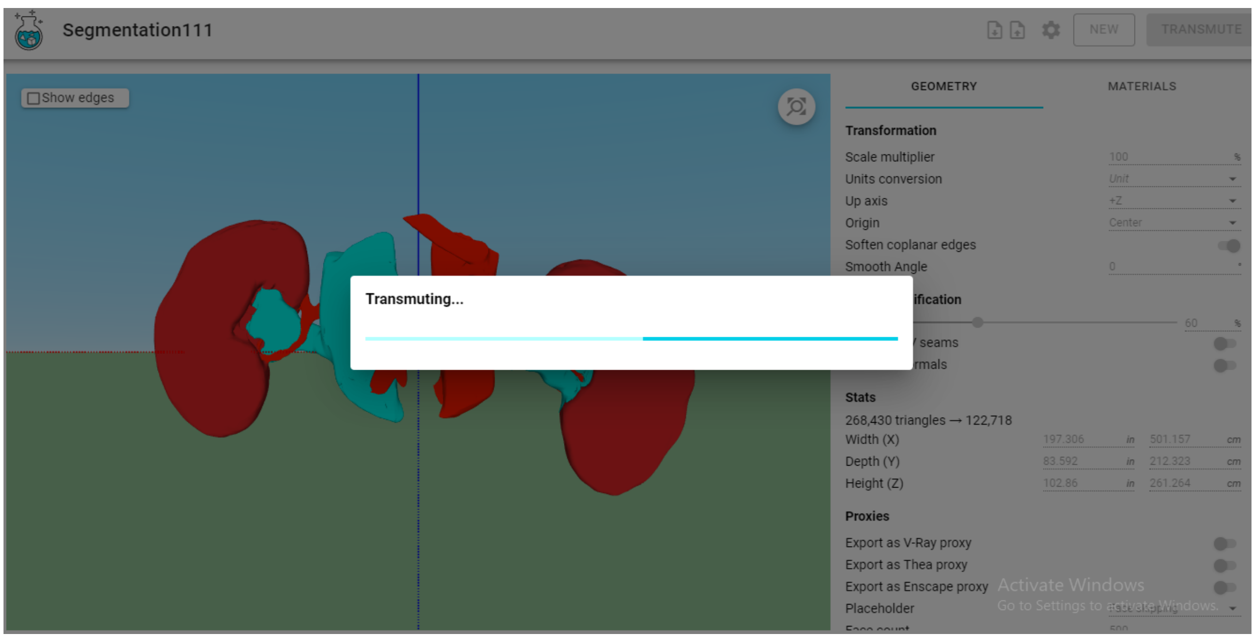

Figure 3.17: Transmutting the model to the destination folder.

Once everything is in place, the model can be transmutted back to the destination folder. Figure 3.17 and Fig. 3.18 present snapshots taken while the kidney alone and the entire model are being transmutted back to a destination folder.

3.6 Google Sketch up

Google Sketch Up is a 3D modeling program marketed by Google to create and modify models. It is free software and can be easily downloaded from the internet [68]. Figure 3.19 shows the imported 3D model of kidney from the transmutr software to the Google Sketch Up software and the arranged 3D model in the work space for the dissection processes. The imported model is tilted backwards from top side in nature. Hence, in order to visualize the internal structure using the software, the model should be adjusted using rotating tools from the top towards the front side of the 3D model for visualizing the internal structure during the dissection process.

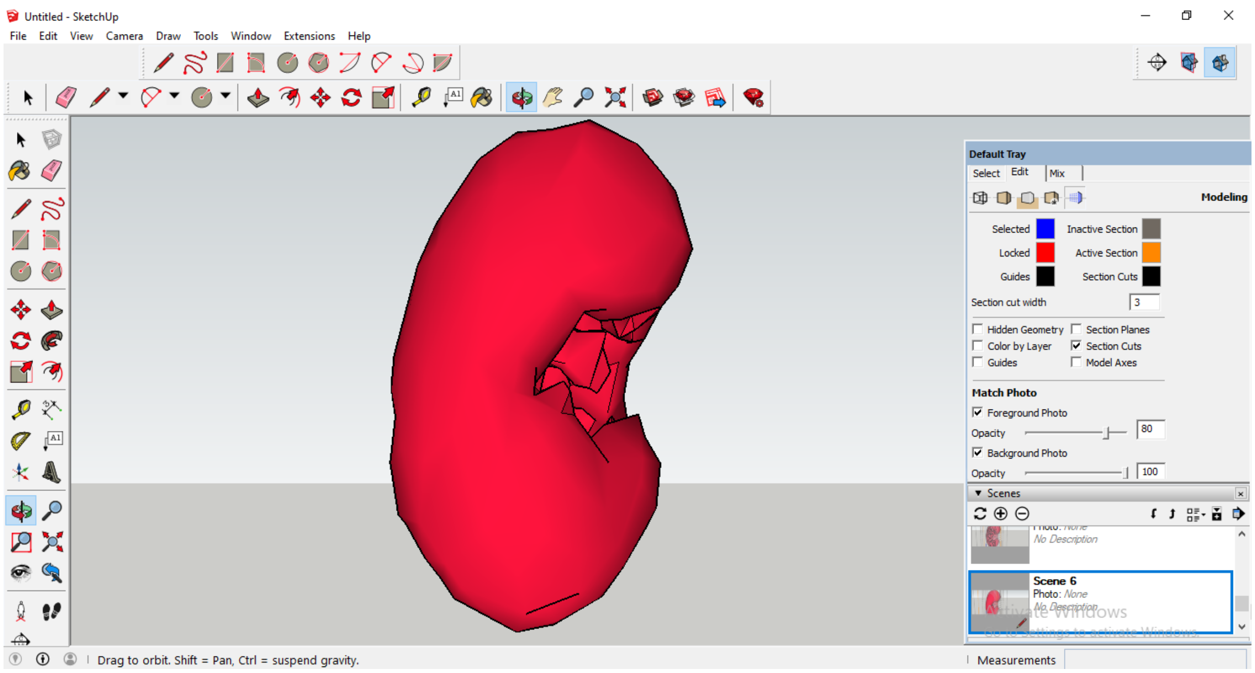

Figure 3.18: Importing the transmuted kidney to Google Sketch Up.

3.6.1 Dissecting Kidney

Google Sketch Up is used for the dissection of the kidney and for developing sequentially animated scene sequence of internal structure of the kidney by using section plan as a cutting tool. The section plan is arranged from back to front in 15 mm gap. A total of five scenes are used for dissection and the scene transition time is 20 seconds for each scene and this is used to develop the animation for the dissection processes. Figure 3.20 and Fig. 3.21 depict the arrangement and scene sequence of the dissection processes respectively.

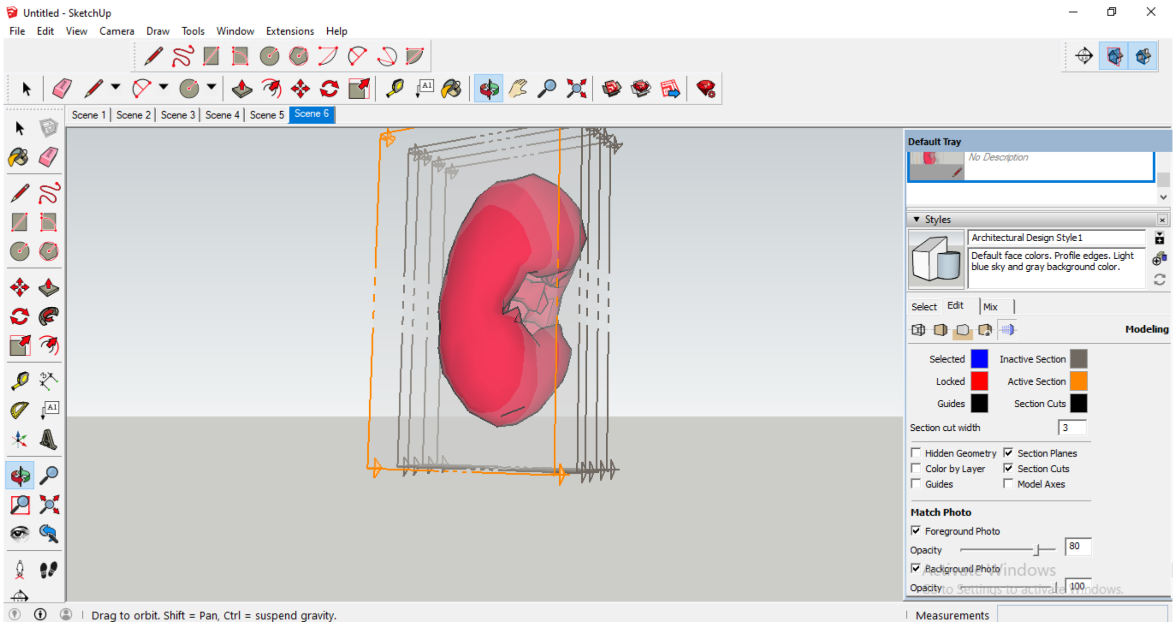

Figure 3.19: Setting section plan and scene for dissection of the Kidney.

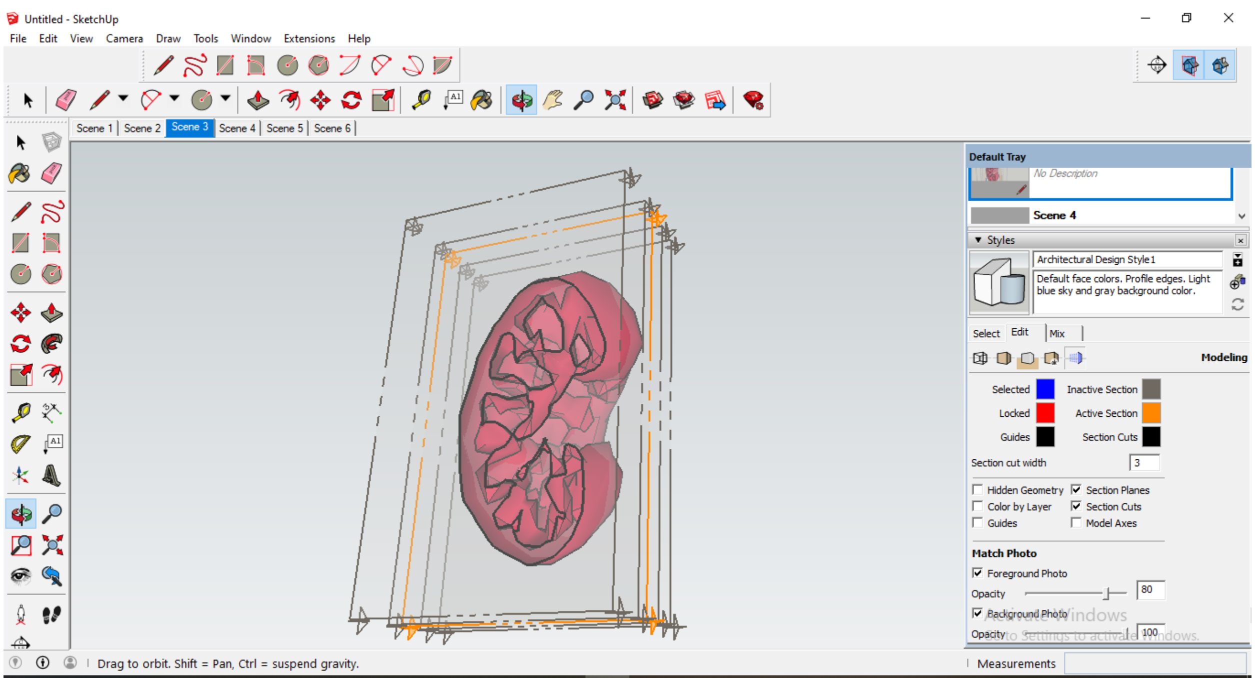

Figure 3.20: Process of dissecting and developing scene for sequential animation of the kidney.

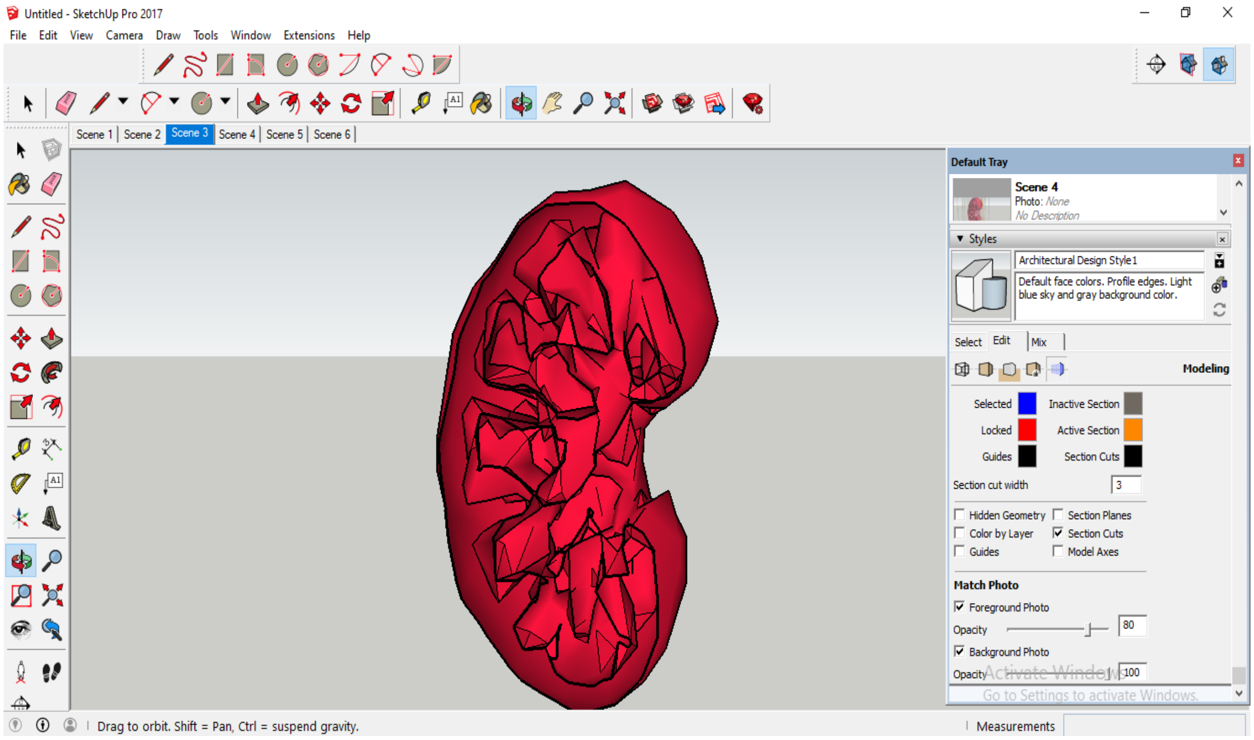

Figure 3.21: After removing the section plans.

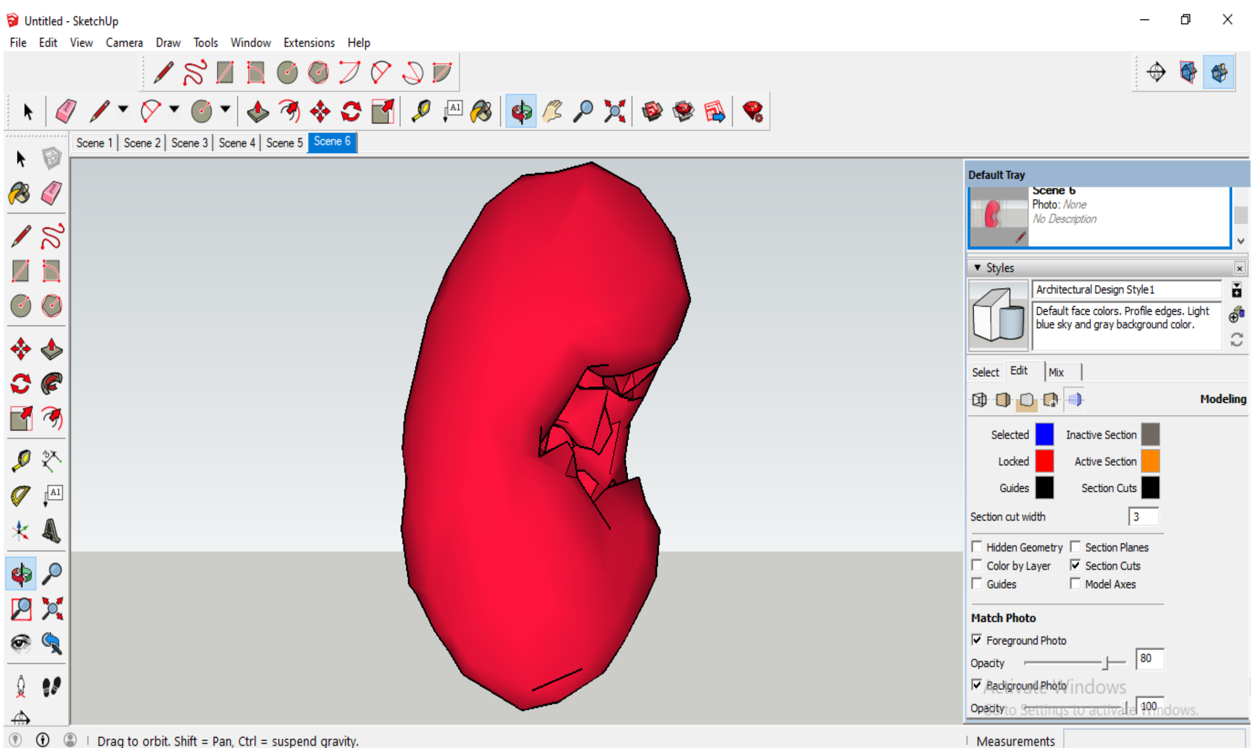

Figure 3.22 Full animation of the kidney after removing the section plans in Google Sketch Up.

Once the section planes are removed, the kidney appears like the one shown in Fig. 3.22 while Fig. 3.23 presents the full animation of the kidney after the sections planes are removed in Google Sketch Up. Figure 3.24 shows that after setting the scene sequence, the cutting plane is removed and the internal structure is visualized without the section plane and sequential animation is obtained at the end. The scene transition delayed time of 1 second to 20 seconds video is obtained and the final animation sequence is combined with a video resolution of 1080 with full HD with 25 frames per second. The final output video is then saved in a video format (see Fig. 3.24, Fig. 3.25 and Fig. 3.26).

Figure 3.27 shows that the video obtained from the output of the Google Sketch Up is imported into the adobe premium pro video editing software. With this software, the internal section of the dissected kidney is labeled and the description of each section is explained.

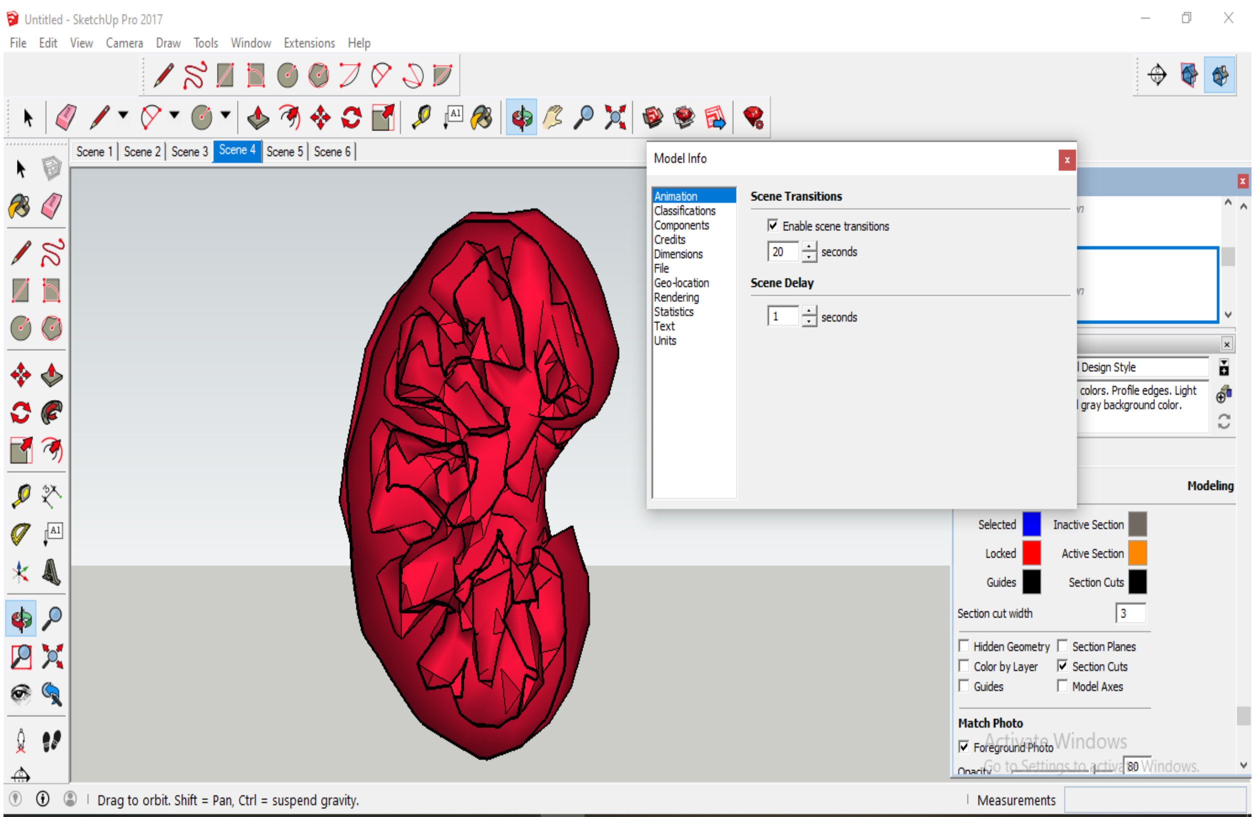

Figure 3.23: Scene transitions.

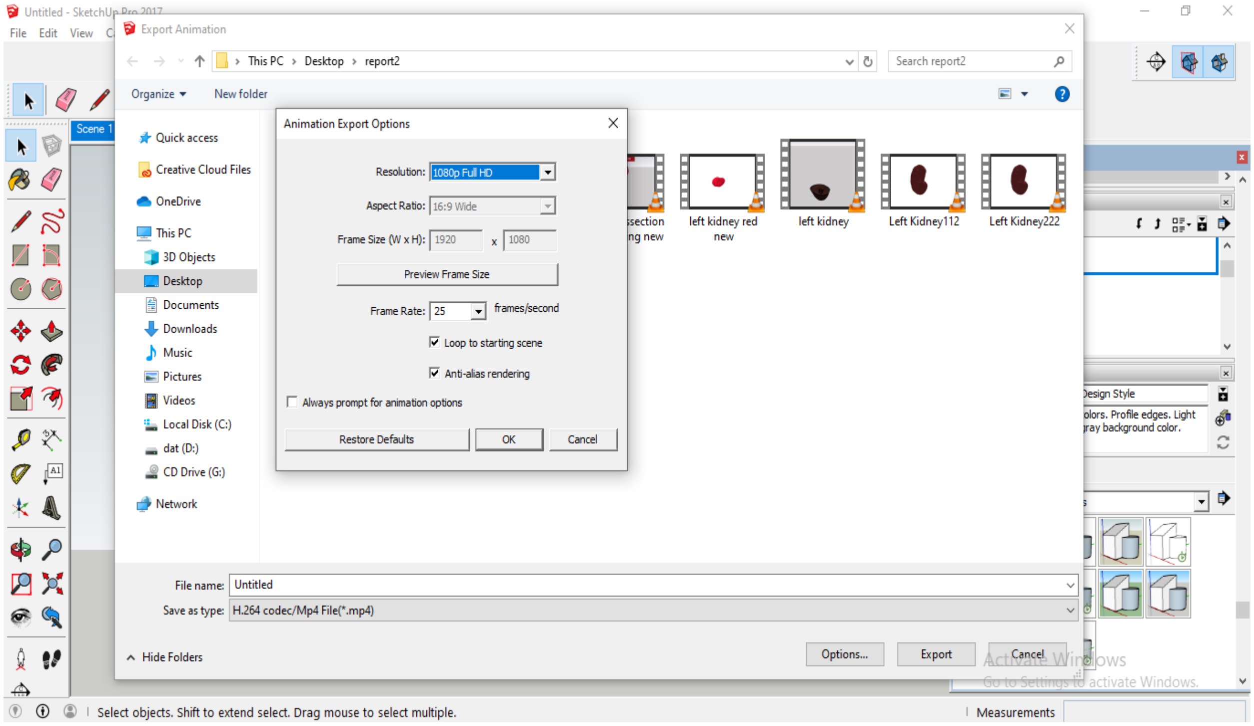

Figure 3.24: Exporting animation scene sequence.

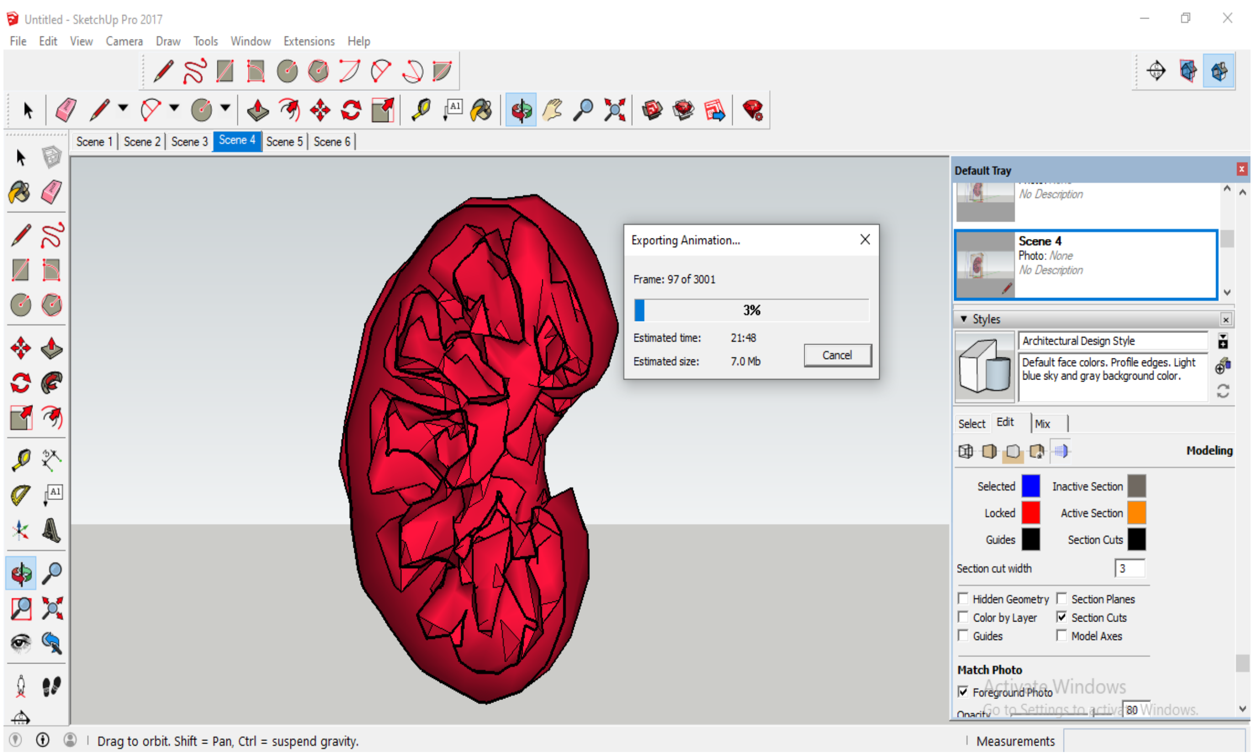

Figure 3.25: Exporting and saving video in the destination folder in video format.

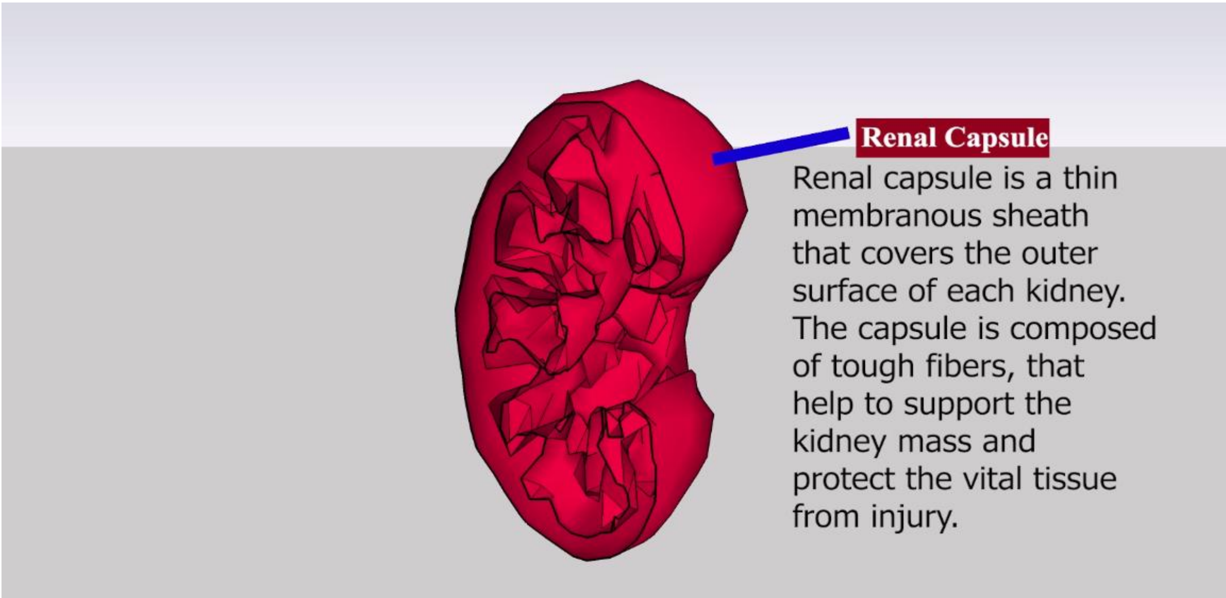

Figure 3.26: Dissected and labeled 3D video animation of the kidney.

3.7 SimLab Composer

SimLab Composer is a huge tool for designers, covering a vast importing/exporting support, lighting, animations and several advanced visualized outputs. The VR version can turn job into a viewable VR scene on various devices such as HMD, Oculus Rift, Desktop or a Mobile device [69]. Using SimLab Composer, the imported 3D model of the ROI will be rendered and animation time line should be set and the time line sequence is attached to the object for visualizing the 3D model using the interactive desktop VR viewer. This is sequentially done as follows.

The start position (see Fig. 3.28) is used to load the human model into the scene. The human model is the representative of the camera in the VR experience. Then the animation time line is set as also been shown in Fig. 3.29. Then follows attaching animation time line for each parts of the model with the time line for desktop VR viewing mode (Fig. 3.30). Once the model is exported, it is possible to run the VR experience either in Desktop Mode or in VR Mode to test it out. Figure 3.31 shows that when the VR viewer is selected, under this menu, another option is displayed. Then, when the VR show is triggered, another dialogue box pops up with Desktop & VR mode options. In the current work, Desktop mode is selected. If someone wants to use the VR mode instead, that requires an oculus rivet to use VR mode option. When the Desktop mode is selected then the entire work is exported for interactive VR viewing animation action.

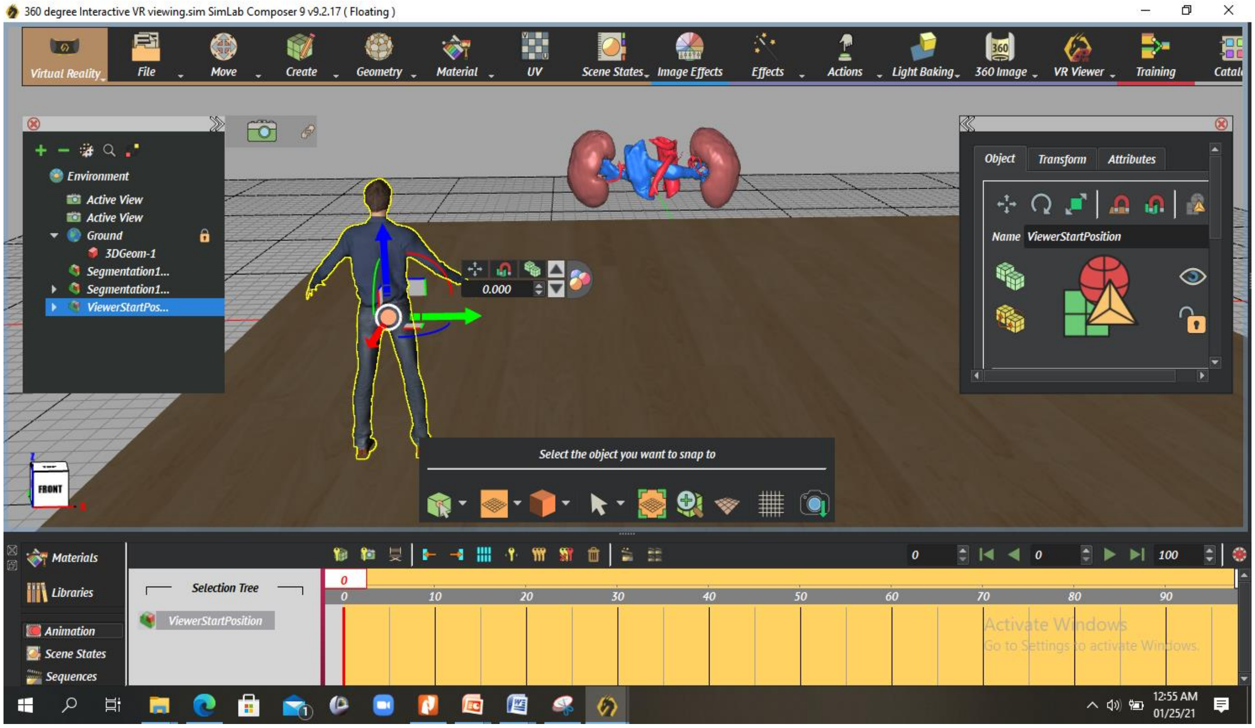

Figure 3.27: Importing the 3D model and set start position.

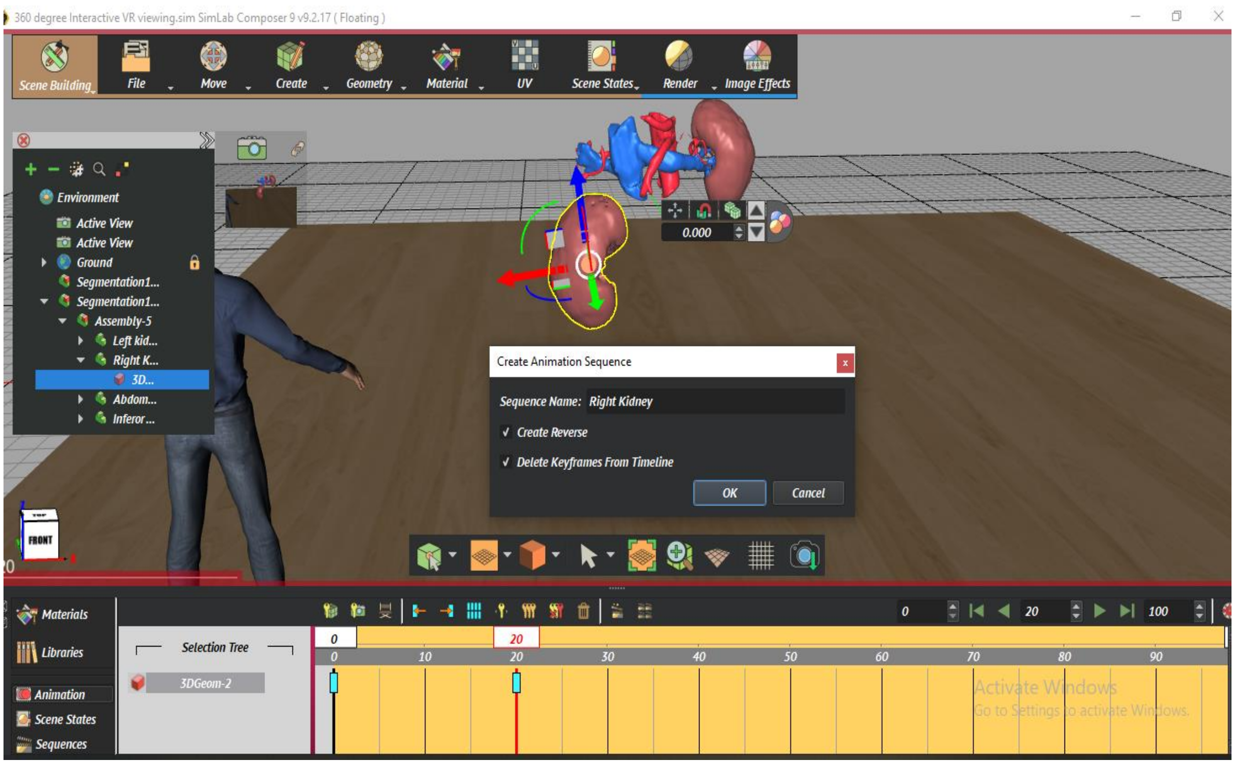

Figure 3.28: Setting animation time line.

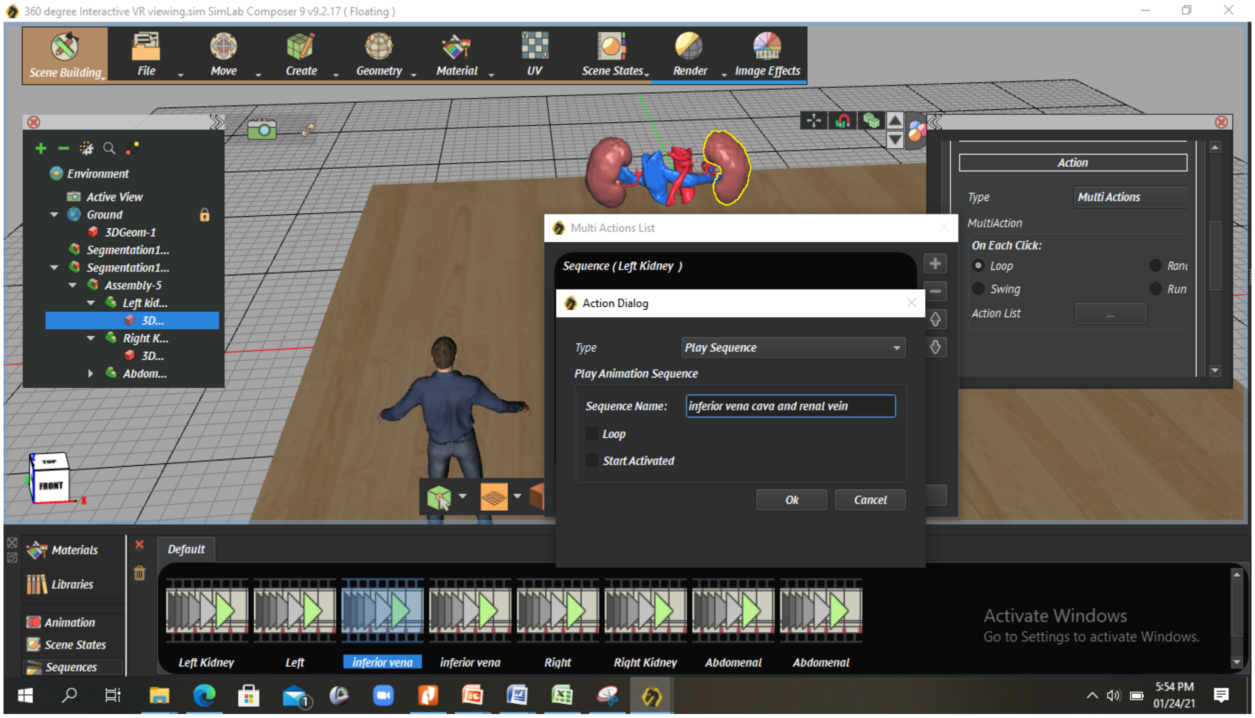

Figure 3.29: Attaching animation sequencing.

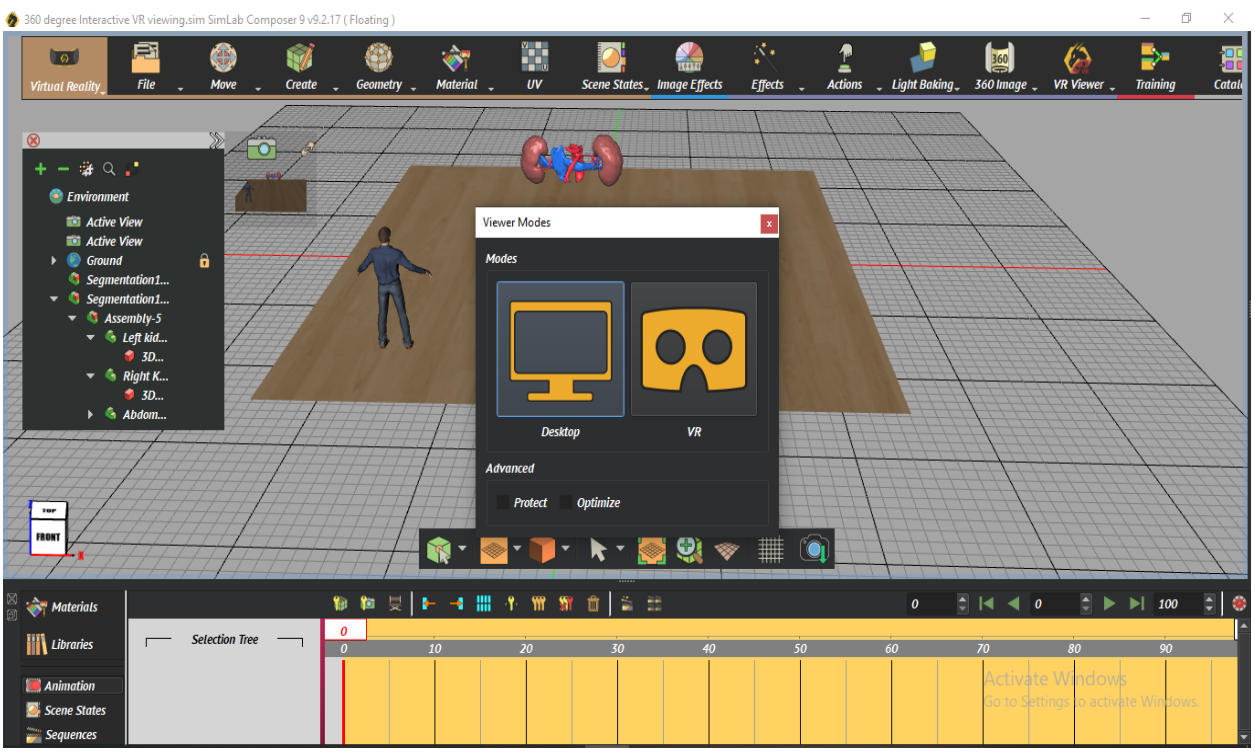

Figure 3.30: Interactive VR viewing model.

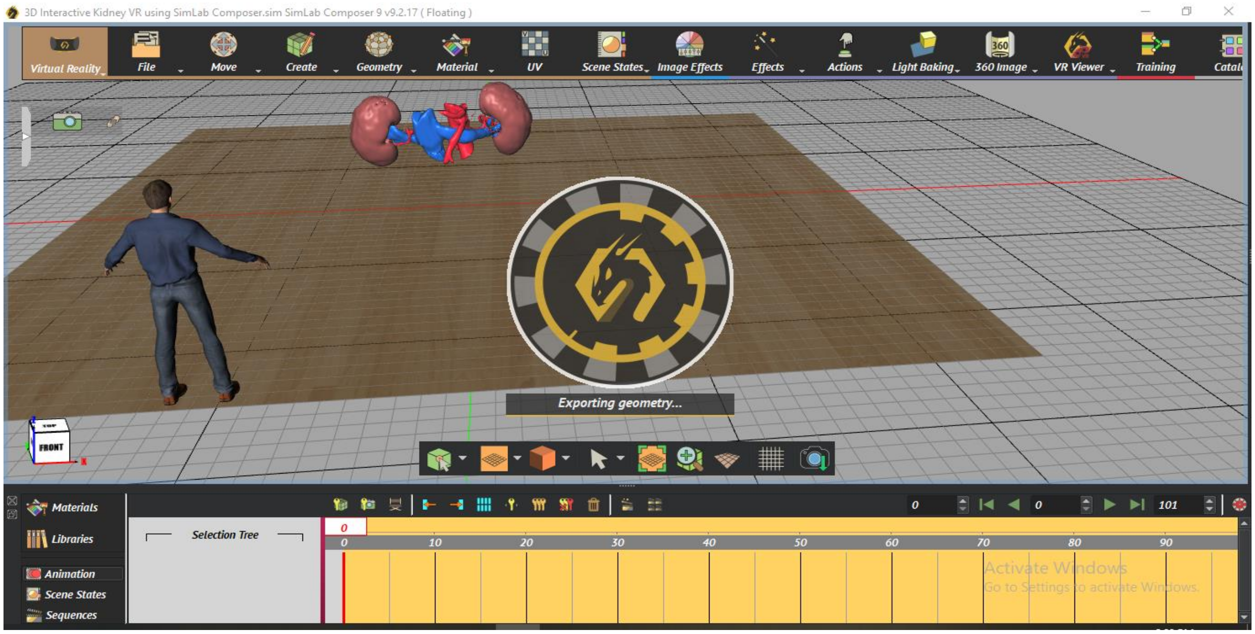

Figure 3.31: Exporting files to the interactive VR viewer.

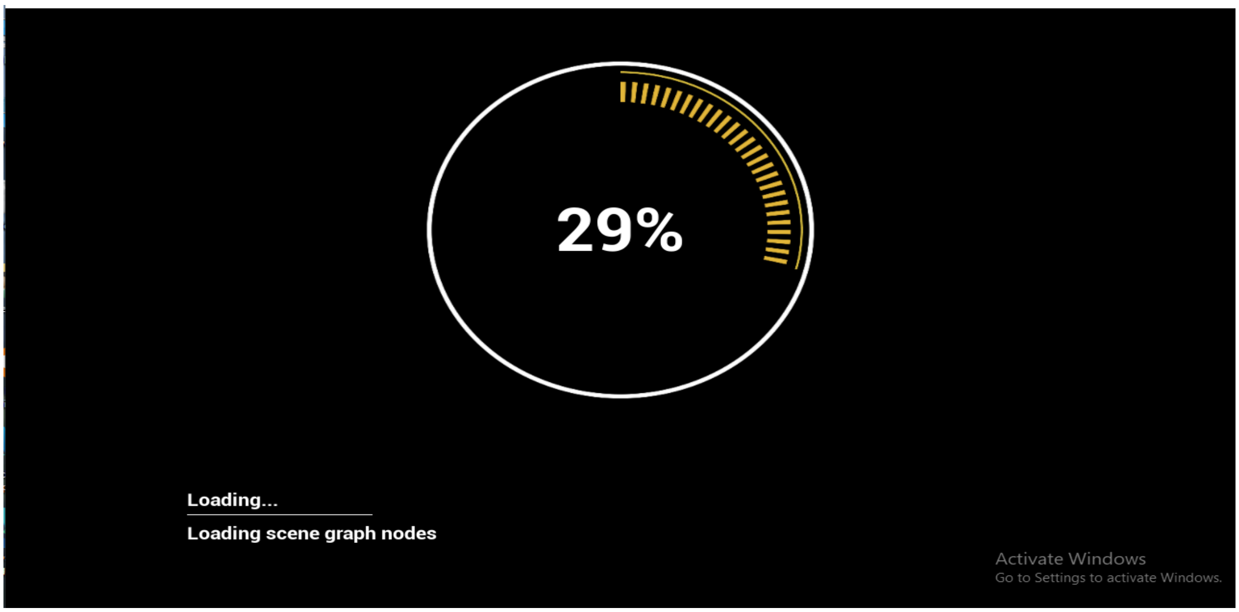

Figure 3.32: The progress of exporting for VR viewer.

Once the model is exported it is possible to run the VR experience either in Desktop Mode or in VR Mode to test it out. A snapshot is presented in Fig. 3.32 to show the process of exporting files to the interactive VR viewer while Fig. 3.33 the progress of exporting to the VR viewer. Figure 3.34 depicts the VR viewing in the Desktop mode.

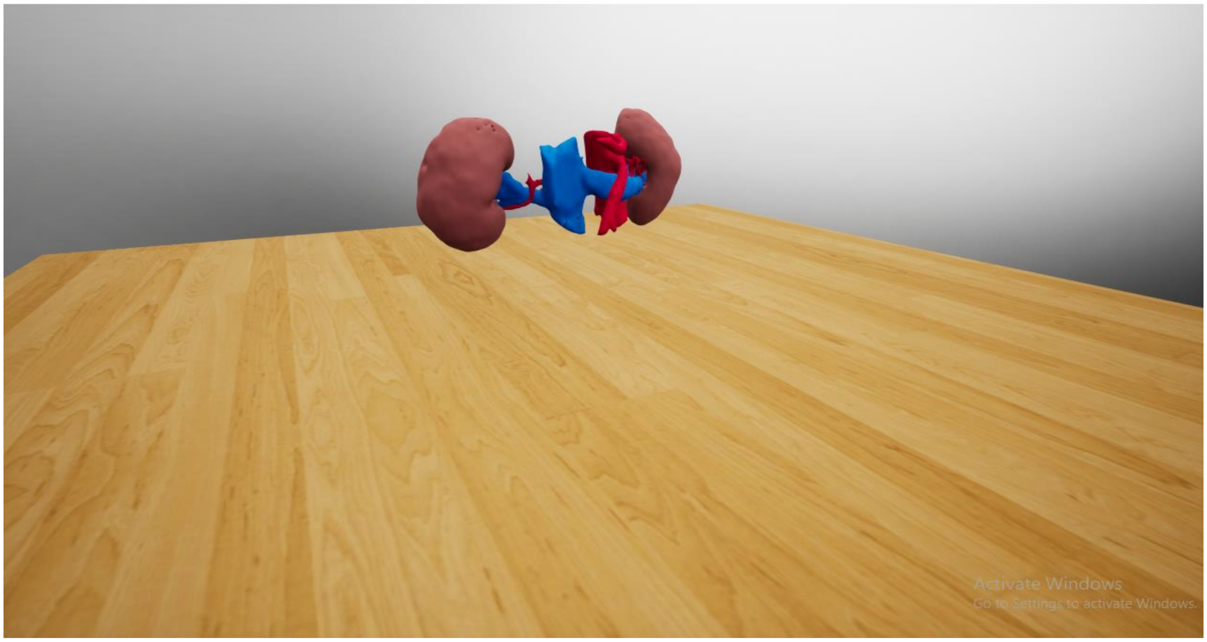

Figure 3.33: VR viewing in desktop mode.

Figure 3.35 depicts that when the model is selected, its color will be shaded yellow showing the model is in interactive VR mode. The yellow part of the model is selected for interactive VR viewing mode in such a way that the entire model is in VR viewing mode. The subsequent pictures presented in Fig. 3.36, Fig. 3.37, Fig. 3.38, Fig. 3.39 and Fig. 3.40 show different regions of interest displayed in VR viewing mode for visualization of the 3D models in different directions.

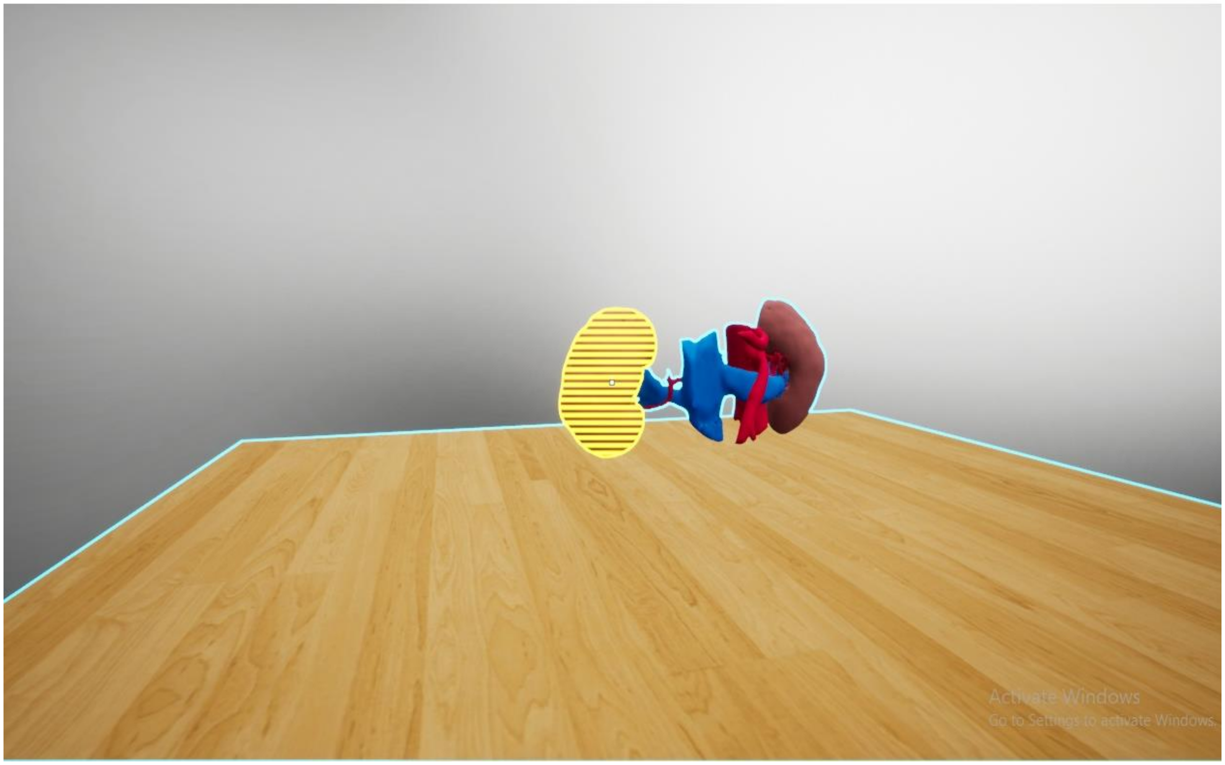

Figure 3.34: The yellow color painted part is interactive VR part.

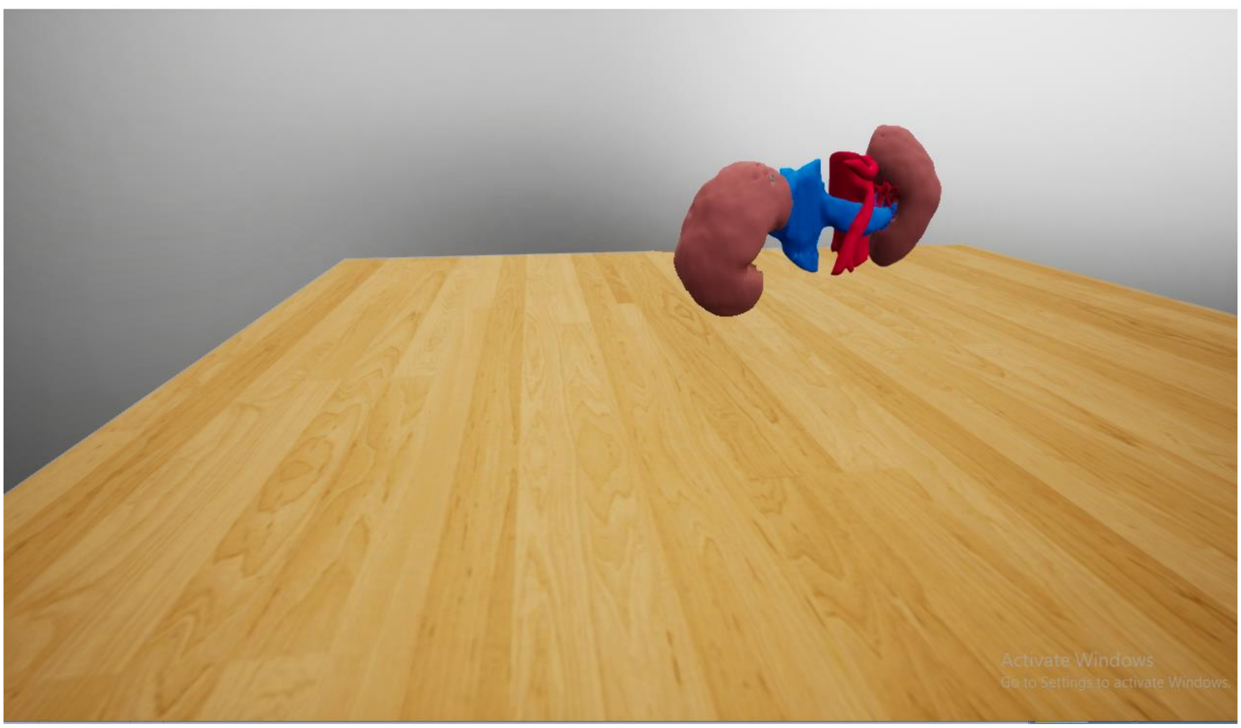

Figure 3.35: The right kidney in VR mode.

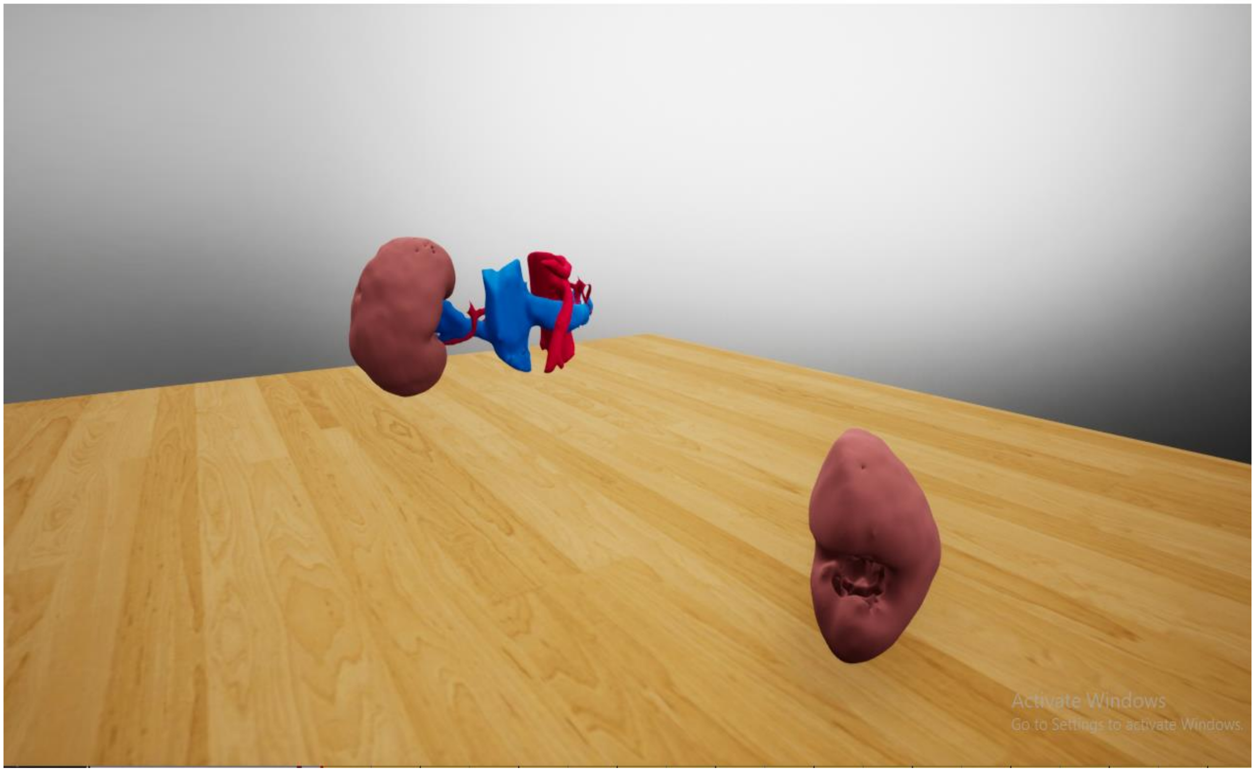

Figure 3.36: The left kidney in VR mode.

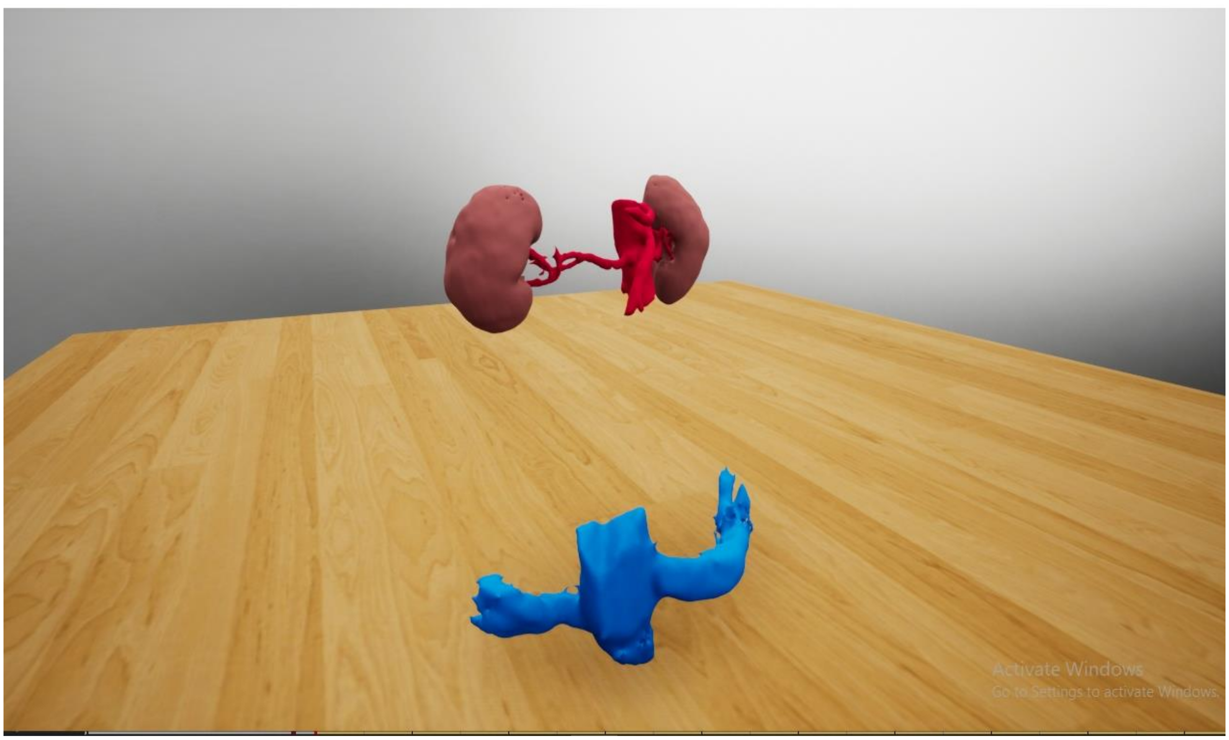

Figure 3.37: The inferior vena cava in VR mode.

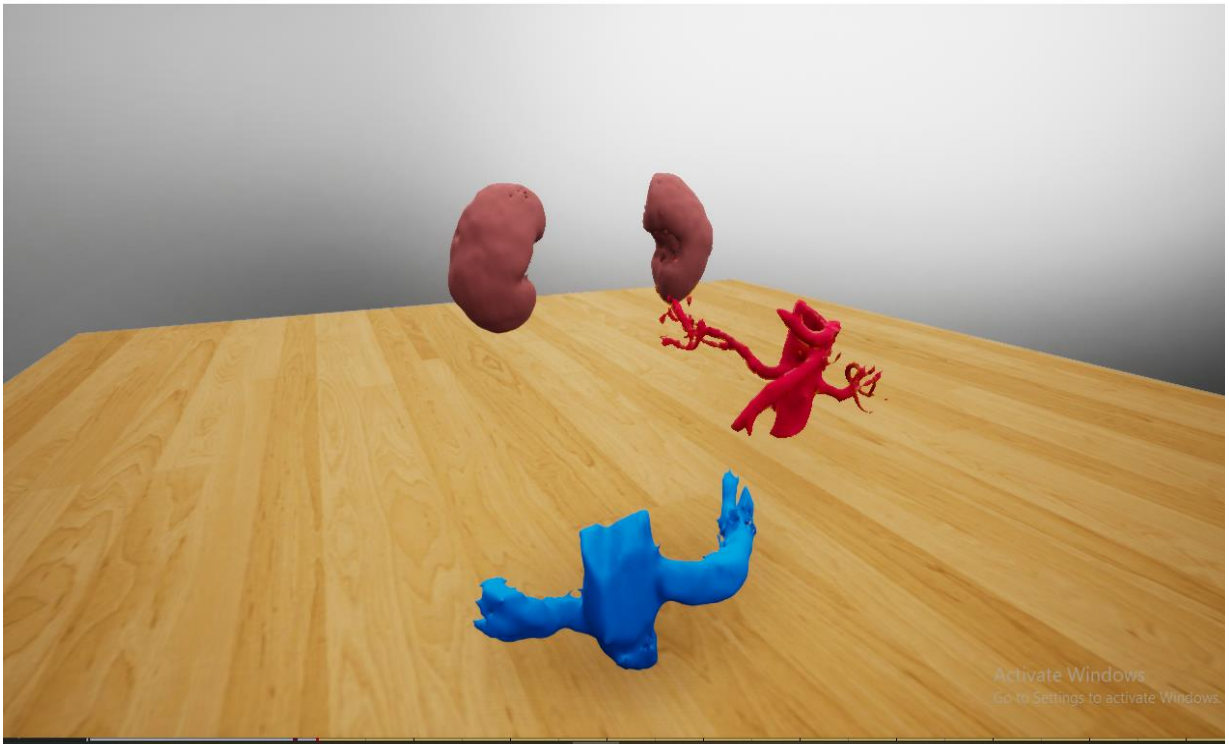

Figure 3.38: The abdominal aorta and Inferior vena cava in desktop interactive VR mode.

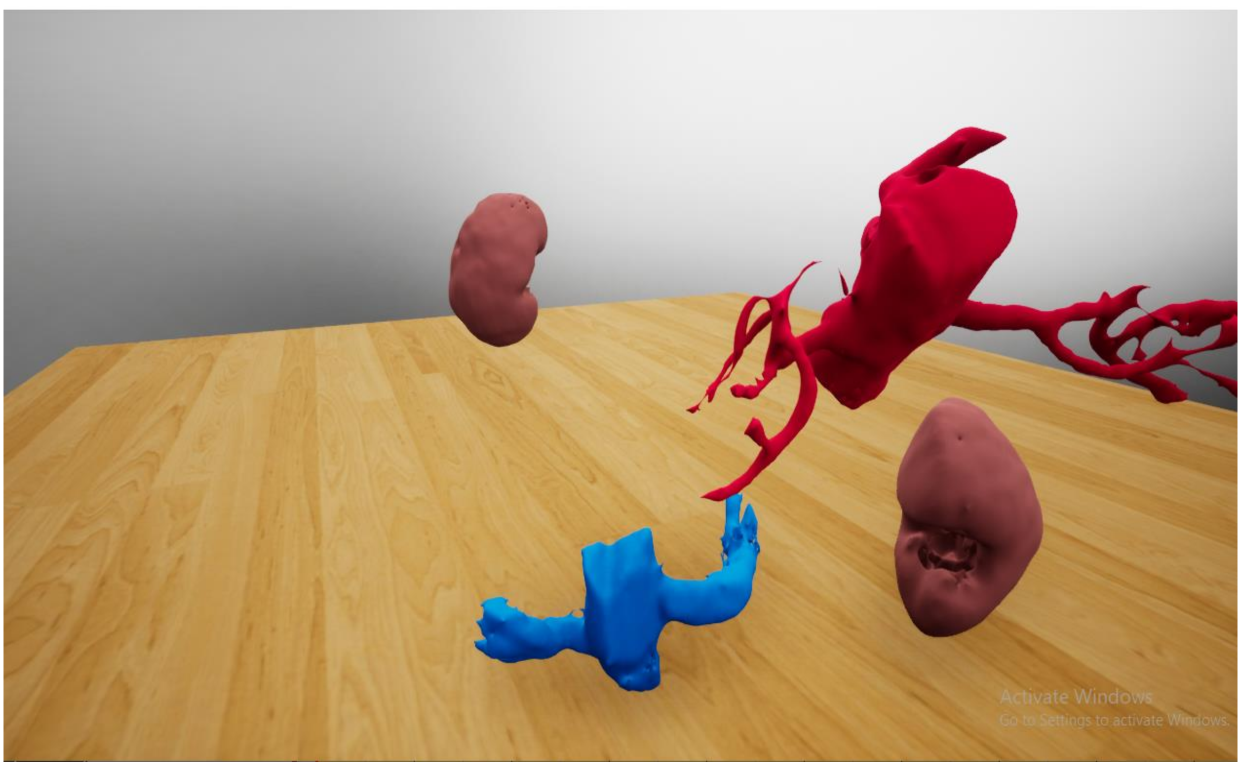

Figure 3.39: Kidney and its associated parts in desktop interactive VR mode.

3.8 System Validation

Likert scale survey instruments were developed and administered to check the effectiveness and benefits of the proposed 3D VR application in human anatomy class. These instruments were designed to check the effectiveness and benefit of 3D VR model in the delivery of practical dissection processes in human anatomy. Data were collected using the developed questionnaires and tilled and analyzed using the mean Likert Scale of the collected data to see the effectiveness and benefits of the VR application using the developed 3D model. Table 1 presents the responses of 38 participants sitting for a dissection class (around 50% of the total student population, about 66% male and the rest 34% female), picked through random sampling among students currently enrolled at St. Paul Millennium Medical College.

Table 1: Do you increase effectiveness by using VR in dissection course?

Items		Respondents					
	n	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Mean Likert Scale
Using Virtual Reality applications help you to do your work more quickly in courses	38	2	3	3	16	14	3.97
Using Virtual Reality applications improves your performance in courses	38	1	2	3	17	15	4.13
Using Virtual Reality applications increases your productivity in courses.	38	2	2	2	18	14	4.05
Using Virtual Reality applications enables the learning process to be effective in your courses.	38	2	4	6	16	13	3.82
Is it easy to use the Virtual 3D model applications	38	2	1	6	16	13	3.97
3D virtual model of kidney helped you to visualize better the relative sizes of different parts	38	2	4	4	18	10	3.79

The total number of respondents, n, is then 38. The responses were given the following weights: Strongly Disagree = 1, Disagree = 2, Neither = 3, Agree = 4 and Strongly Agree = 5. Accordingly the Likert scale is computed and based on the average Likert scale, a conclusion was drawn. Then the average Likert scale was used to determine the effective point that shows the degree of agreeing or disagreeing to a given question. The relationship is given by:

- Strongly Disagree assumes average Likert scale of 1.0 -1.8;
- Disagree assumes average Likert scale of 1.9 -2.6;
- Neither assumes average Likert scale of 2.7 - 3.4;
- Agree assumes average Likert scale of 3.5 - 4.2 and
- Strongly agree assumes average Likert scale of 4.3-5.0.

The average Likert scales computed for the questions under "Do you increase effectiveness by using VR in dissection course?" was between 3.79 and 4.13 indicating that most of the students favor use of VR in their dissection class in terms of grasping the course quickly, increasing performance in the course, and visualizing relative positions of parts of the organ.

Table 2: Is there any benefits using VR application in dissection course?

Items		Respondents					
	n	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Mean Likert Scale
Using Virtual Reality applications is similar to using other computer applications.	38	2	3	3	15	15	4.00
Do you develop deeper understanding of the topic with the use of 3D kidney model dissection	38	1	2	4	17	14	4.08
3D virtual model of kidney helped you to visualize better the relative sizes of different parts	38	4	3	2	15	14	3.84
Use of 3D virtual model enhanced your learning experience and interest in studies	38	2	4	6	13	13	3.82
Is 3D virtual model helping you to differentiate different parts of the organ?	38	4	2	7	16	9	3.63
Do you find the use of Virtual Reality applications beneficial for your courses?	38	3	2	2	16	15	4.00

Table 2 presents the Likert scales computed for the other group of questions under "Is there any benefits using VR application in dissection course?". In this case also, the average Likert scale was computed to be high between 3.63 and 4.08 indicating again that the interviewed students favored use of VR in their dissection classes in terms of its many benefits.

Chapter 4

Discussion

The aim of anatomical dissection in human anatomy is to educate medical students practical aspects of human anatomy. For this research work, standard CT-DICOM datasets obtained from the Osirx imaging library were used to develop the virtual 3D model of the human kidney by using 3D slicer. The 3D slicer is a software platform used for the visualization of DICOM dataset; to reconstruct the 3D model of the ROI by importing the DICOM dataset which is obtained from the Osirix imaging library. The data includes axial, sagittal as well as coronal scans. This is followed by generation of the 3D mask which is used for the reconstruction of the region of interest (ROI) given the entire abdominal CT-DICOM dataset. Then, using the 3D slicer software, one can visualize the 3D model of the human kidney with the associated parts of the kidney.

The reconstructed 3D model of the human kidney with its associated parts is saved using segmentation module by exporting the 3D model in the file format called STL (Standard Tessellation Language) to the destination folder. The reconstructed model has a vast amount of meshes (triangular faces). Due to this vast amount of faces, the model is not supported by the Google Sketch up. In order to reduce the number of triangular faces of the model, the researcher uses another platform called Transmutr. The model is imported into this software which is used for adjusting the units, scale, axis, simplification of the model geometry as well as setting the required rendering materials. Then, the 3D object is transmutted without affecting the overall shape of the original object. Then, the transmutted file is used by Google Sketch Up and SimLab Composer software for further work.

The dissection process is done by Google Sketch Up by importing the model from the transmuter. Naturally, the imported 3D model is tilted backwards from the top side which makes it very difficult to visualize the internal structure using the software. To this end, the model setup should be adjusted using rotating tools from the top towards the front side for visualizing the internal structure during the dissection process. We use the section plane as cutting tool from back to the front side at a thickness of 15 mm and set the scene sequence for 20 seconds to visualize the internal structure. Based on this timing and spacing, the kidney dissection is carried on sequentially by the cutting section plane. The dissected part of the model is labeled and rendered using adobe premium pro video animation software.

The first task of the SimLab Composer is importing the model from the destination folder to the SimLab Composer workspace and then set the start position by loading the human model into the scene. As mentioned previously, the human model is the representative of the camera in the VR experience. Following this, rendering takes place on the model without affecting the overall shapes of the original object. Then by setting the animation timeline for each part of the 3D model, the animation timeline sequence is attached to the specific parts of the object with the timeline sequence. Using a VR viewer option and by selecting the Desktop VR mode, the entire work is exported for an interactive VR viewing animation in the VR experience.

Chapter 5

Conclusion and Future Works

5.1 Conclusion

This study introduced a 3D model of the human kidney for use in dissection applications in the dissecting room while exercising with the human anatomy. As part of the VR, a virtual 3D human kidney model has been developed using standard CT DICOM data set. The DICOM dataset was imported into 3D slicer which is an open source software platform used for developing 3D model of the human kidney, abdominal aorta with its renal artery as well as inferior vena cava with its renal vein from the imported DICOM dataset. The final output of the 3D slicer is exported to the destination folder in STL file format. Slicer uses vast amount of meshes (triangular faces) to develop 3D model and the STL file saving standard format has the capacity to hold these vast amount of meshes of the model. The model is then imported to Transmutr. Transmutr is a software which has the capacity to significantly reduce the number of faces. It is also used for adjusting units, scale and axes of the developed 3D model without affecting the overall shape of the original object as well as preparing render ready 3D model of the developed object. Therefore, Transmutr is used for retaining the model hierarchy. The transmutted object is imported to software called Google Sketch Up, which is used for dissection of the developed 3D model of the human kidney using section plane of the software. In the current study, five section planes were used to dissect the 3D object to visualize the internal structures of the kidney. Accordingly, five different scenes were developed to create animation sequences for the dissection of each section plane. Finally, by combining the different scenes, a video of the dissection sequence is developed. The transmutted 3D model of the object is imported into the SimLab Composer. Here, the first action is rendering the object followed by setting of the animation time line. Next action was attaching the animation sequencing to the specific action of the object and finally exporting the 3D object to VR viewing menu of the software aiming for interactive visualization of the object.

The developed VR tool should lessen the need for use for expensive cadavers while exercising dissections. It could at list supplement use of expensive cadavers, particularly in low resource settings where such resources may not be found amply. Such tools are believed to deliver a more proper understanding of anatomy as compared to the traditional ways of teaching that includes formal lectures with 2D slideshow presentations and cadaver. While anatomical learning is best done in a setting where desired structures can be observed from all angles. Dissection in particular provides an efficient method for learning anatomical details, familiarizing the learner with variations in human physiology and appreciating structures of the body.. In order to gain such exposures, students will need alternative supplementary materials to reinforce their anatomical knowledge through self-directed study in a 3D setting, other than cadavers. The proposed interactive multimedia learning VR tool is believed to have answers to such gaps.

5.2 Future Works

The proposed VR tool was developed using latest versions of 3D slicer, Transmutter, Google Sketch Up and SimLab Composer softwares. If one has a high performance computing facility with high speed and better graphic card capabilities, it would be possible in principle to develop a VR system which allows a more detailed 3D visualization of human organs. Though the focus of the current study was on kidneys, the tool could be developed to accommodate other organs of interest as well.

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