Development and Reconstruction of Spinal Cord from CT Scan Files and RPT Estimation Analysis

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ABSTRACT: Rapid Prototyping (RP) is an emerging technology, especially in a Three-Dimensional Printing (3DP) application. 3DP is used in many fields such as aeronautical, automotive, architecture, medical, and many others. 3DP can be effectively used in anatomical education for medical students who are pursuing their undergraduate degrees. It can also be used for pre-operative surgical planning by experts before surgery. Some complex organs of the human body which cannot be seen visible even after dissection of the cadaver can be printed using a 3D printer which provides haptic studies on organs and bones to students. These 3D printed parts can be used in pre-operative planning such as analysis and diagnosis formulation of affected organs. Further, it can be used in explaining the operative procedures to patients which helps them to understand and co-operate with the medical procedures. Therefore, this paper aims at 3DP of complex organs and bones for anatomical studies and pre-operative planning procedures. As a first step in the work, some of the human bones were printed and analysed for its quality.

Key words: CT Scan, RPT, 3D Printing, Complex organs.

I. INTRODUCTION

Rapid Prototyping (RP) is a technology that will construct scale models of the prototype from its 3D Computer-Aided Design (CAD) data. Unlike the subtractive process which will remove material to fabricate a part, 3D Printing (3DP) is based on an additive process that adds layer by layer material to the substrate for constructing the whole model. In manufacturing sectors, a lot of time required for fabricating a prototype, patterns, and molds with many complex processes. To reduce the manufacturing time and to avoid the complexity, industries have started using 3DP techniques to produce a complex pattern, molds, and prototypes. In subtractive process, tool movements are planned for material removing from work piece to attain the desired shape compare to subtractive process like milling, turning and machining, AM technology has the most capabilities to get the complex geometries such as anatomical structures. RP provides cost- effective models of the designs that will be used to realize the product before the fabrication of expensive prototypes. Various types of RP techniques include Stereolithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Manufacturing (FDM), Laminated Object Manufacturing (LOM) and Ballistic Particle Manufacturing (BPM). 3D printing is a technique that will print the molten material layer by layer to form an entire 3D structure of a physical part. The 3D model created by CAD software will be converted to. STL format. The STL format was developed by Hull at 3D systems and it is being used as the gold standard for the data transfer between CAD software and the 3D printer. Medical applications of 3D printing include printing of customized implants and prostheses like titanium mandibular prosthesis, skull implant, orthopedic implants, maxillofacial, spinal, hearing aids, Invisalign braces, neuroanatomical models and dental implants. Many researchers have tried to print knee meniscus, heart valve, spinal disk, cartilage tissues, bone, artificial ear, artificial liver and bio-resorbable tracheal splint. For example, 3D printing of a prosthetic socket with respect to the patient's residual limb was done using the rapid prototyping technique. The patient's limb was scanned using the 3D scanner and digital data was processed using TracerCAD software and SolidView Pro and then after rectification, it was printed using Z corporation Z402 3D printer. An anatomical study is very important for the postgraduate specialist to get surgical training. It is the required field of study for students practicing medicine. The knowledge obtained from anatomical study can be effectively used in the examination and diagnosis studies. This knowledge can be further used in explaining the operative procedures clearly to patients. Anatomical errors lead to litigation problems. Anatomical knowledge obtained from anatomical studies will avoid those errors. It provides the students to have haptic studies on 3D anatomy. Various teaching aids have been used for anatomical studies such as dissection by students, prosecution and demonstration, didactic teaching, models, technologies (Computer Aided Learning (CAL),

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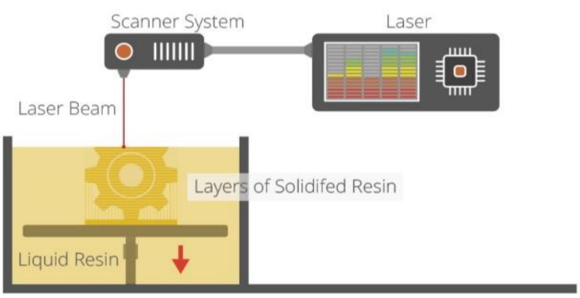
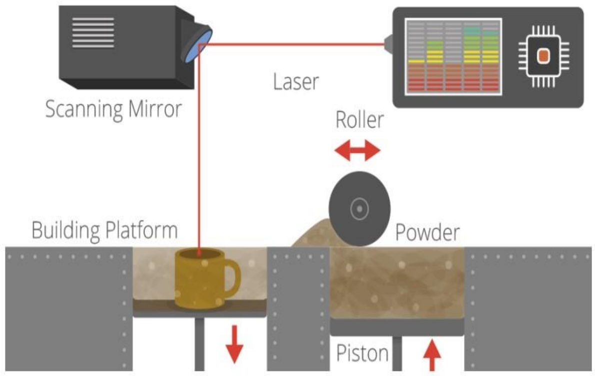
slides and videos), living anatomy and radiological imaging. Among those aids, dissection is the foremost and effective teaching modality for teaching anatomy. Unavailability of dissection facilities may hinder the anatomy education for students. Even though effective methods are there, multi-modal teaching may facilitate the students in a deep understanding of the anatomical features.3D printed parts of bones can aid the teaching process for anatomical studies. Some of the complex organs/bones may not be visible even after the dissection. The students may have difficulty in studying those parts. Hence, those parts can be printed and used for anatomical studies. The hepatic segment is difficult to study for medical students because of its complexity (entwined and branching ducts), hence 3D printed part of the hepatic segment helps students to understand the structure effectively. 3DP of organs/bones provides a haptic study for better understanding. 3DP of human bones/organs is cost-effective since the original cadaver cost is very high. 3D printed parts of the brain and skull can be used for neuro-surgical planning and used to explain procedures to patients before surgery. For epilepsy surgery, the placement of the electrode is a complex procedure. As for the musculoskeletal fields, cardiovascular 3D printing enhances the diagnostic work-up of complex congenital heart diseases, as well as surgical and interventional procedural planning and simulation. 3D printing is also used to fabricate patient specific anatomical phantom to study disease progression and cardiovascular device interaction. If the patient-specific 3D model is obtained, then it can help in surgical planning by professionals. Bone is an important part of the human body and it provides structural support to the body. The bone study helps students to understand the important anatomical features so that they can choose the correct implants with respect to the patient and to pre-plan the operative procedures effectively. 3D printed parts of the human bone can be used for study and planning purposes. Therefore, this paper aims at developing low-cost 3D printed parts of the entire skeleton for anatomical study and patient-specific models for surgical planning and patient communication. 3D printing improves patient engagement in understanding their own diseases and participating in their own decision-making and improves communications with patients and their families.

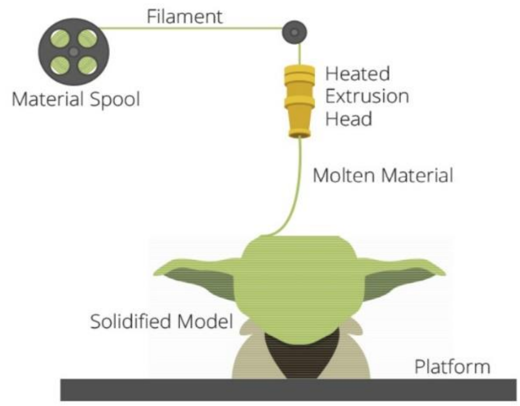
1.1. The process for 3D printing of Bio medical



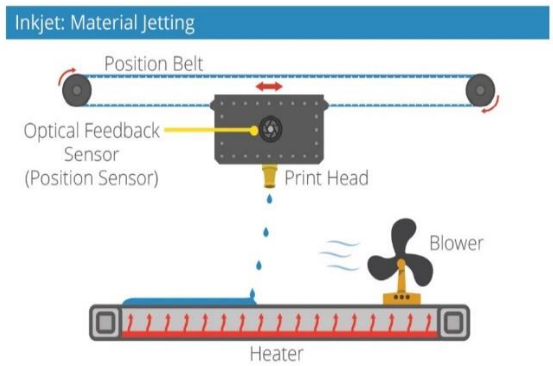
(a) Stereolithography



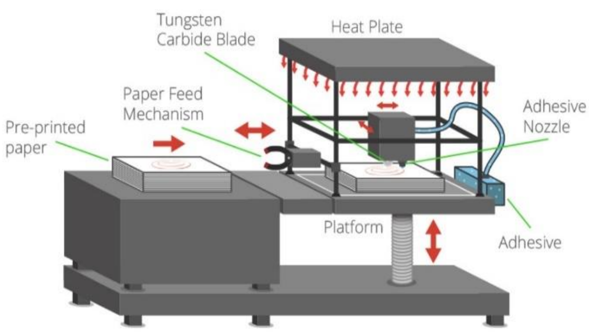
(b) Selective Laser Sintering



(c) Extrusion / FDM / FFF



(d) Material jettin



(e) Selective Deposition Lamination (SDL)

Figure 1: 3-D printer setup

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The above figure are Step-up of the the 3-D printing process which produces the 3-D objects from the different condition based upon the different parameters and the requirement of the objects.

1.2 Biomedical printing materials

In the field of bio fabrication, there is clear distinction between direct printing of a cell-seeded material, termed a “bioink”, and the printing of a cell-free scaffold from a “biomaterial ink”, which can subsequently be seeded with cells or directly implanted . Ink selection is driven by both the final function of the part and the printing technique to be used. Biomaterial inks are generally used to produce a rigid scaffold for the permanent or slow-degrading stabilization of a structure, while bio inks produce a softer scaffold that can be more rapidly replaced by the deposition of a new extracellular matrix (ECM) by the embedded cell population

1.2.1 Bioinks

The Different bioinks added to the different Cell types/Tissue

Bio ink	Cell type/Tissue
Alginate	Chondrocytes/Cartilag
Agarose	HMSCs Chondrocytes
Collagen	Hepatocytes/Liver
Fibrin	hMPCs/Skeletal Muscle HUVECs/Vascular structures
Gelatin	hMSCs/Bone hMSCs/Cartilage
Gellan gum	Chondrocytes/Cartilage Osteoblasts/Bone
Hyaluronic acid	Fibroblasts
PEG	HMSCs Fibroblasts
Tissue-derived ECM	SCAP/Dentin Kidney

Table 1 Commonly used bioinks and their recent tissue engineering applications

1.2.2 Biomaterial Inks

Biomaterial inks often require processing under conditions that are cytotoxic, such as extremes of temperature or the use of solvents; however, they can be loaded with therapeutic molecules that can withstand these processing conditions. Thermoplastics, ceramics, composites and metals have all been additively manufactured for use in biomedical applications.

1.2.3 Thetic Hydrogels

Synthetic hydrogels are often not suitable for the direct seeding of cells, but have similar non-Newtonian properties to biopolymeric hydrogels, allowing them to be printed by extrusion. Pluronic is a commonly used synthetic ink that can be thermally crosslinked or functionalized with chemical groups for UV crosslinking. It has been used as support material for structures with overhangs, and also as a sacrificial ink to produce hollow structures. Elastomers are also an attractive material for bioprinting, as their mechanical properties mimic the viscoelasticity of native tissues. Polydimethylsiloxane (PDMS) and silicon have been printed using embedded techniques (freeform reversible embedding (FRE) and printing into microgels, respectively) to produce hollow and bifurcating structures that mimic airways and large vessels. These structures can then be perfused to model flow in large vessels.

1.2.4 Thermoplastics and Resins

Thermoplastics are common materials for 3D printing across many technical industries and are also used by hobbyists. In bioprinting, the key advantage is that they can be processed and undergo multiple thermal cycles for the incorporation of factors, and to form filaments for extrusion, resins for photolithography or polymer melts for electrospinning. We have previously shown that off-the-shelf materials can be used in tissue engineering applications. Thermoplastics such as polycaprolactone (PCL), polyvinyl alcohol (PVA) and polylactic acid (PLA) have been bioprinted for use as both supports for cell-seeded hydrogels that require mechanical reinforcement, and for direct implantation in vivo. They are printed using extrusion from filaments or polymer melts so they can produce structures with high resolution and very good shape fidelity, giving excellent control over porosity, which can in turn influence the mechanical properties of the scaffold. PORO-LAY are a group of PVA–polyurethane–elastomer blends that can be extrusion printed from filament before rinsing with water, to wash out the PVA component, leaving the nano porous elastomer. We have shown the entrapment and subsequent controlled release of doxorubicin (a common anti-cancer drug) or zoledronate (anti-resorptive), over a period of seven days in 3D-printed scaffolds. Using different variations of PORO-LAY with increasing levels of porosity, the total release of doxorubicin was also increased, inducing the largest decrease in metabolic activity in a prostate cancer cell line. Delivery of cancer drugs to specific tissues is often achieved intravenously, but there is little currently done to prevent the venous spreading of excess drug to healthy tissues. A thermoplastic mesh-like filter was printed using continuous liquid interface production (CLIP) before being coated with a polystyrene–sulphonate absorber. Doxorubicin was then injected up-stream of the device, and the levels of doxorubicin in the blood were shown to be significantly lower after blood passed through the coated filter compared with the uncoated control. This offers a solution by which a device can be implanted in large veins leading from diseased tissues to “mop-up” excess chemotherapeutics.

1.3 Different Application

1.3.1 Biomedical application:

a) Mental Implants:

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Metallic implants for orthopedic, dental and craniofacial applications have traditionally been manufactured from stainless steel, cobalt chromium molybdenum and titanium alloys by methods such as casting, forging and machining. Developments in AM technology have now enabled the production of implants designed from reconstructed 3D imaging data to produce patient-specific implants. A key area of recent research has been in adding functionality to these implants. A recent study showed how an antibiotic-eluting cement could be loaded into a central cavity within metallic implants that could not be manufactured by conventional methods. Due to the high resolution achievable by selective laser melting (SLM) of metallic powders, intricate lattices can be produced. This has been investigated to overcome issues surrounding stress shielding in hip implants. Finite element analysis (FEA) was initially used to determine the theoretical mechanical performance, as well as theoretical reductions in bone loss, of porous implants. They were then produced using SLM and FEA was confirmed by mechanical testing.

1.3.2 Healthcare Applications

a) Tissue Engineering
b) Implants
c) Orthopedics

1.3.2 Orthopedics
1.3.3 Drug Delivery
a) Tablets
b) Transdermal Delivery
c) Drug-Releasing Implants

1.4 Litarature Review:

1.4.1 Custom implants

Custom implants Custom implants are used in cranial surgery, dentistry, and maxillofacial surgery. According to 17 out of 28 papers, custom implants reduce OR/treatment time. 25 papers mentioned good accuracy of the custom implants and improved medical outcomes. Radiation exposure was not mentioned in these papers. 14 papers mentioned increased costs, but one described an increase in cost effectiveness. The custom implants were mostly made of titanium (10 of 28), polyether ether ketone (PEEK) (10 of 28), epoxide acrylate hydroxyapatite (2 of 28), hydroxyapatite (2 of 28), polymethyl methacrylate (1 of 28), polypropylene–polyester (1 of 28), and non-specified acrylic-based resin (4 of 28)

1.4.2 Anatomical models

Anatomical models can be used for implant shaping in maxillofacial surgery, a topic that was discussed in nine studies. Five papers mentioned time reduction as advantage. Eight studies concluded that printed models provide good anatomical representations and nine studies mentioned improved surgical outcomes. Two studies mentioned exposure to ionizing radiation and two mentioned increased costs. Anatomical models are also used in selecting patients for cardiovascular surgery; this was discussed in two studies. None of the papers mentioned time reductions, exposure to ionizing radiation, or medical outcome. One paper found the model to be a good representation of the actual pathology but did not mention the associated costs. Another publication mentioned that costs increased as a result of using an anatomical model. Multiple domains use anatomical models for surgical planning. Our research showed anatomical models being used in cardiovascular surgery, vascular neurosurgery, dental surgery, general surgery, maxillofacial surgery, neurosurgery, cranial/orbital surgery, orthopedics, and spinal surgery. Among the 89 studies, 48 (53.93 %) mentioned reduced operation room time. Two (2.24 %) studies mentioned increased operation room time and 37 (41.57 %) did not mention any impact on operation room time. Only 13 of the 48 studies mentioning reduced operation room time and supported this statement with actual numbers or statistics. In 80 (89.89 %) of the publications, the printed part showed good accuracy, although this was only supported numerically in four studies [3, 81, 97]. Exposure to ionizing radiation was not mentioned in 77 (86.51%) of the publications, and eight mentioned decreased exposures. Three publications mentioned increased exposure to ionizing radiation No publication mentioned decreased medical outcomes with the use of anatomical models, while 73 publications mentioned improved medical outcomes. On the cost side, 52 publications did not mention costs, four mentioned decreased costs, and 32 mentioned increased costs. Two-thirds of the studies reporting increased costs supported this claim with numbers or statistics.

1.4.3 Molds for prosthetics

3D-printing techniques can be used to produce molds for making prosthetics, as discussed in three studies. We encountered this approach in cranial surgery, maxillofacial surgery, and ear surgery. In all the studies, the printed parts were accurate and improved the medical outcome. Both cranial studies were discussed in a single paper. One of these studies mentioned reduced OR time as an advantage. The study using 3D-printed molds for ear prosthetics stated that their use reduced costs and was cost-effective. None of these studies mentioned exposure to ionizing radiation.

1.4.4 Surgical guides

Surgical guides are the most popular medical application of 3D printing, with mentions in 137 of the 270 papers (50.74 %). Apart from orthopedics (guides for knee arthroplasties), 3D-printed surgical guides were also used in neurosurgery, dental surgery, spinal surgery, and maxillofacial surgery. 28 of the 53 studies that mentioned reduced operation room time also supported this claim with numbers or statistics. Increased procedural time was seen in seven papers, of which five supported this with numbers or statistics. 88

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studies reported that the guides had good accuracy, while 23 reported average accuracy, and ten mentioned insufficient accuracy. Interestingly, six out of the ten papers reporting insufficient accuracy backed this up with numbers or statistics. Radiation exposure was not mentioned in 123 (89.13 %) studies. Less radiation was mentioned in nine studies, including by six of the 11 spinal surgery studies. Surgical guides improved clinical outcomes in 86 (62.31 %) cases, gave similar results in 31 cases, and had a negative impact on clinical outcome in seven studies, all of which were knee orthopedics. The cost associated with the guides was only mentioned in 42 studies, of which 39 stated it to be more expensive and two stated it to be equally expensive. 19 of the 39 studies which indicated that the new technology was more expensive supported this finding with numbers or statistics. Ten studies stated that the guides were cost-effective, while six stated that they were not cost effective. None of these studies backed these claims with numbers.

II. METHODOLOGY

Bone models used in this study were obtained from the MRI scan data of the patients under observation. These MRI scans were used to build an .STL file for 3D printing. The framework of 3D printing of scanned parts are showed in figure 2

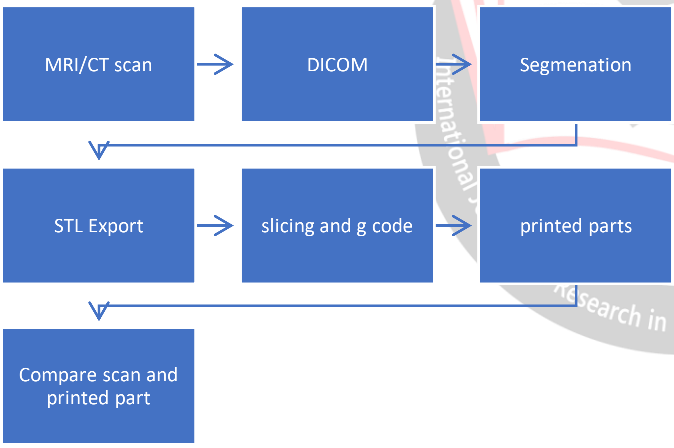

Fig. 2 Framework of 3dprinting of scanned parts

The DICOM (Digital imaging and Communication in Medicine) file which has the CT-Scan of the full skeleton system was obtained. But only few bones were the region of interest. needed was few bone parts. Using the crop volume tool, the exact volume which has to be processed was extracted. After defining the working volume, the model editor of the program was used to create a label map of the model. There are few tools used for processing such as a threshold effect tool that allows selecting a range of gray colors. This is very useful with the bones since they have a distinctive contrast between white and gray surroundings.

Other parts such as ligament parts, blood vessels or nerves has white tone. Other tools are for erasing undesirable parts or paint others that should have been painted. By using these tools, the model was improved by filling holes that may appear or remove parts that are not from the model.

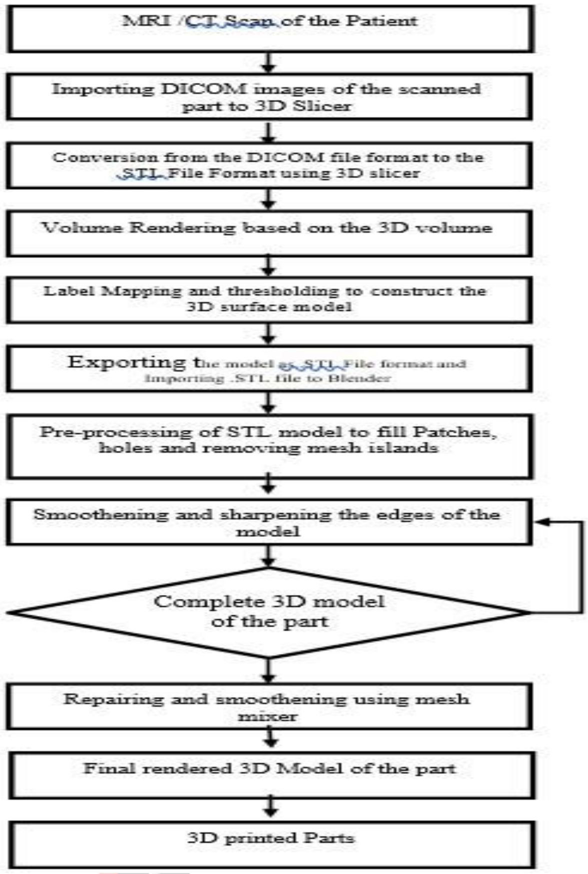

Fig. 3 Flow chart for present methodology

The DICOM format files were converted to .stl files using 3D slicer program as shown in Figure 3. After the generation of surface model from the 3D slicer, the surface model still still has some patches/holes which were processed using various CAD tool to generate the complete CAD model without any patches/holes. All models can be exported then as. STL files. Various additive manufacturing techniques had been used in fabricating educational medical models. Most of these techniques used the Fused Deposition Modeling (FDM) based method for developing these models. The methodology usedin the present study is shown in Figure 4.

In the present study, FDM was used to fabricate human anatomical models. PolyLactic Acid (PLA) based filament was used for the present work with conditions for 3D printing given in Table 3.1.

Table 2 Parameters used in FDM printer

S. No	Parameter	Value
1	Filament Diameter	1.75 mm
2	Extruder temperature	205 C

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3	Bed temperature	60 C
4	Nozzle Diameter	0.4 mm
5	Print speed	60 mm/s
6	Infill density	20%
7	Material used	PLA

III. CREATION OF PRINTABLE MEDICAL CAD MODEL RESULT & DISCUSSION

3.1 BIOMEDICAL IMAGES FOR FINITE ELEMENT MESH DEVELOPMENT

3.1.1 X-RAY IMAGING

X-ray imaging is one of the oldest transmission-based techniques which uses ionizing radiation to take 2D images of exposed tissues by sending X-ray's beams through ROIs. These X-ray beams are absorbed in different amounts depending on the density of the material through which it is passing. These densities are expressed using the Hounsfield (HU) scale values, named after Sir Godfrey Newbold Hounsfield (Aug. 1919eAug. 2004), as shown in Fig. 9.1. The values are measured based on a scale where radio density of water at standard pressure and temperature is defined as zero HU, while radio density of air on the same scale is defined with 1000 HU. The formula for calculating HU value based on this scale is shown in Eq. (9.1)

$$HU = 1000 \times \frac{\mu - \mu_{water}}{\mu_{water} - \mu_{air}},$$

where m ¼ original linear attenuation coefficient of substance, water ¼ linear attenuation coefficient of water, and mair ¼ linear attenuation of air. In a typical transmission-based imaging technique, the emitted X-rays pass through ROIs, which affect the level of energy reaching to the detector, depending upon the type of tissue or organs encountered along the path. Tissues having low Hounsfield scale values darken the film such as lungs and fat, while tissues having higher Hounsfield scale values lighten the film and provide white spots such as hard bones. Therefore, the denser the tissue, the brighter the image will be as the detector

will return weak signals. Similar tissues can provide different X-ray images depending on the hardness or penetrating ability of X-rays, which is adjusted by selecting the voltage for the emitter. But longer emissions of these X-rays can be harmful as they ionize the biological tissues. The most common clinical uses of X-rays are detecting fractured bones, dental cavities, swallowed objects, and breast mammography. Conventional X-ray techniques provide flattened 2D images which cannot be used to generate 3D segmented regions of tissues.

3.1.2 COMPUTED TOMOGRAPHY IMAGING

CT, or computer axial tomography (CAT), uses multiple X-ray projections taken from different angles to produce detailed cross-sectional images of ROIs. Similar to X-ray imaging, when these beams pass through different dense tissues, it gets FIGURE 9.1 Hounsfield number for different human tissues. 9.2 Biomedical Images for Finite Element Mesh Development 391 weaker after absorption and the final intensity is measured by the detectors providing different contrast imaging of tissues. Since the same cross section is scanned at different angles, it can be used to reconstruct a 3D image of the tissues. By adding more than one detector, the processes can be faster and more accurate. CT imaging is commonly used to diagnose presence of tumors, colon cancer, bone injuries, and internal bleeding.

3.1.3 MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging (MRI) generates cross-sectional images of the tissues by using a strong magnetic field to magnetize protons within the tissue. The basic principle of MRI imaging is to align the nuclei of atoms which have a spin and exhibit magnetic moment. Magnetic field intensity lies between 0.1 and 3.0 T, a standard unit of magnetic flux density named after Nikola Tesla (Jul. 1856eJan. 1943). The image contrasts are achieved by using different pulse sequences and by changing the imaging parameters relative to longitudinal relaxation time (T1) and transverse relaxation time (T2). The signal intensities on the T1- and T2- weighted images correspond to specific tissue characteristics. Irrespective of the difference between T1- and T2-weighted images, proton density weighing is also used to get contrast between soft tissue images. The major difference between MRI and other transmission-based techniques, such as CT and X-ray, is that MRI is based on signals sent by the tissue while the others use an external source such as X-rays to get the contrasts. With CT, detailed anatomical details can be achieved, while with the MRI tissues having different biological functions can be distinguished more clearly. MRI imaging is generally used to evaluate abnormal tissues, spinal injuries, brain abnormalities, tendon or ligaments tears, etc.

3.1.4 POSITRON EMISSION TOMOGRAPHY

Positron emission tomography (PET) is a nuclear imaging technique which uses a dye-like substance having radioactive tracers to identify cellular level changes in the tissue. Computer analysis of tracer concentration in the tissue along with a CT scan helps in generating a 3D image. PET is primarily used in clinical oncology for medical imaging of tumors, and in the diagnosis of neurological diseases, e.g., Alzheimer's and multiple sclerosis, as it is able to collect diagnostic information which cannot be acquired by other methods. This imaging modality is sparingly used in FE model development as it is quite expensive.

2.1.5 ULTRASOUND IMAGING

The principle behind ultrasound imaging is to record the

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reflection of sound waves penetrating through different tissues and reflecting back from boundaries of structures having different densities and velocities of sound-wave propagation. The velocities of ultrasound waves vary in different substances as shown in Fig. 9.2. The contrast images of different tissues are generated based on these sound-wave propagations. Depending on the reflection-echo quality, ultrasound images may be noisy and have spatial deformities. There are different methods to get these contrast 2D images such as B (brightness)-mode, M (motion)-mode, or D (Doppler)-mode. Ultrasound imaging is mainly used in fetal scans during pregnancy, and to evaluate symptoms of pain, swelling, or infections. The contact between the transducer and the adjoining surface is very crucial and refined by using gel-like substances or water-filled plastic bags. Although large numbers of medical modalities are available, the task of segmenting the detailed geometry of all human organs, such as bones, soft tissues, muscles, and veins, through medical images provided by different modalities is not straightforward. One single imaging technique cannot be used to acquire all 3D geometry information due to the limitations associated with each technique. The similar attenuation of the signal is not provided by soft tissues, which will show up as several overlapping grey spectrums of fat, skin, muscles, etc. The CT, or Hounsfield, number described as the density are assigned to a voxel in a CT scan on an arbitrary scale on which water has density 0, air 1000, and compact bone þ1000 (Fig. 9.1). Most of the soft tissues have a CT number closer to water; therefore, the boundaries of adjacent soft tissues cannot be easily separated in CT scan. MRI technique can provide excellent soft tissue contrast as it uses a magnetic field which aligns orientations of protons (nuclei of hydrogen atoms) and is abundant in water and fat. Therefore, in general, 3D geometry of bones is segmented through CT scan images, while the soft tissues, such as heart, lungs, and abdominal organs, are segmented with the help of MRI images where the distinction between the such as PET, single-photon emission computed tomography (SPECT), contrast CT, or contrast MRI can also be used to distinguish the boundaries of adjacent soft tissues more clearly, if required.

3.2 Digital Imaging and Communications in Medicine (DICOM)

DICOM is a worldwide information technology standard established in 1993. The standard covers file format and transfer protocol, permitting exchange of data regardless of hardware origin. Devices that make up a DICOM system are:

a) Hardware modules, such as CT and MRI scanners

b) Picture Archiving and Communication Systems (PACS)

c) Reporting and post processing workstations

d) Printing services

3.2.1 DICOM Process

5 A CT scan is performed

6 The scanner console generates a set of images from the unprocessed data.

7 The CT console forwards the study to a PACS

8 Data is reformatted; this creates images from the original study.

9 These images are returned to the archive and merged with the rest of the study

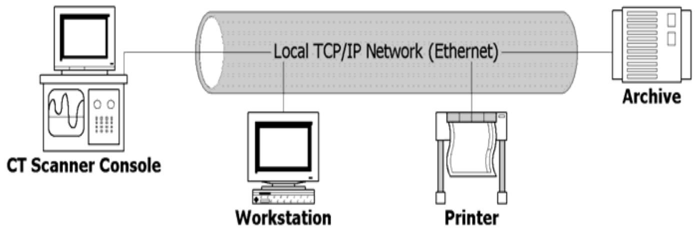

Figure 4 A standard DICOM Network.

3.3 Slicer Software:

Slicer interfaces between scanner data (CT, MRI, Technical scanner) and Rapid Prototyping, STL file format, CAD and Finite Element analysis. The Mimics software is an image-processing package with 3D visualization functions that interfaces with all common scanner formats.

Additional modules provide the interface towards Rapid Prototyping using STL or direct layer formats with support. Alternatively, an interface to CAD (design of custom-made prosthesis and new product lines based on image data) or to Finite Element meshes is available.

Slicer is an interactive tool for the visualization and segmentation of CT images as well as MRI images and 3D rendering of objects. Therefore, in the medical field Mimics can be used for diagnostic, operation planning or rehearsal purposes. A very flexible interface to rapid prototyping systems is included for building distinctive segmentation objects.

The software enables the user to control and correct the segmentation of CT-scans and MRI- scans. For instance, image artifacts coming from metal implants can easily be removed. The object(s) to be visualized and/or produced can be defined exactly by medical staff. No technical knowledge is needed for creating on screen 3D visualizations of medical objects (a cranium, pelvis, etc.)

Separate software is available to define and calculate the necessary data to build the medical object(s) created within Mimics on all rapid prototyping systems.

The interface created to process the images provides several segmentation and visualization tools.

Use slicer to:

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- Easily and quickly create accurate 3D models from imaging data.
- Accurately measure in 2D and 3D
- Export 3D models in STL format for additive manufacturing
- Export 3D models to 3-matic to optimize the mesh for FEA or CFD
- And much more…

Main Features:

Import DICOM, JPEG, TIFF, BMP, or Raw image data

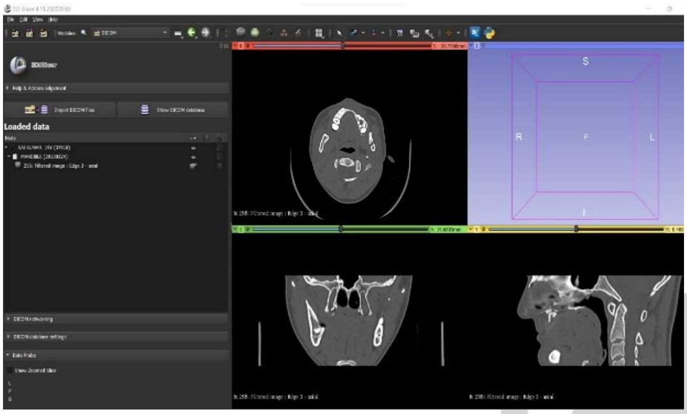


Figure5: X ray view of DICOM file

3.4 Segmentation of required bone part

Segmentation of images (also known as contouring or annotation) is a procedure to delineateregions in the image, typically corresponding to anatomical structures, lesions, and various other object space. It is a very common procedure in medical image computing, as it is required for visualization of certain structures, quantification (measuring volume, surface, shape properties), 3D printing, and masking (restricting processing or analysis to a specific region), etc. Segmentation may be performed manually, for example by iterating through all the slices of an image and drawing a contour at the boundary; but often semi-automatic or fully automatic methods are used. Segment Editor module offers a wide range of segmentation methods. Result of a segmentation is stored in segmentation node in 3D Slicer. A segmentation node consists of multiple segments. A segment specifies region for a single structure. Each segment has a number of properties, such as name, preferred display colour, content description (capable of storing standard DICOM coded entries), and custom properties. Segments may overlap each other in space. A region can be represented in different ways, for example as a binary label map (value of each voxel specifies if that voxel is inside or outside the region) or a closed surface (surface mesh defines the boundary of the region). There is no one single representation that works well for everything: each representation has its own advantages and disadvantages and used accordingly.

Fig 6 image segmentation

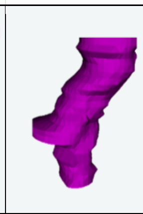
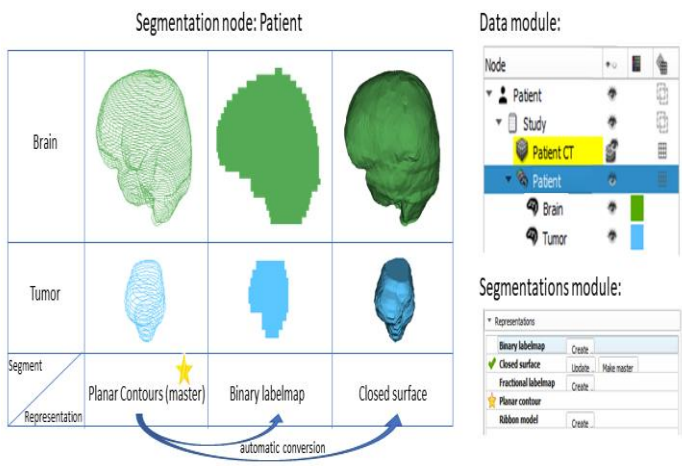
Binary labelmap	Closed surface	Fractional labelmap	Planar contours, ribbons
			
easy 2D viewing and editing, always valid (even if transformed or edited)	easy 3D visualization	quite easy 2D viewing and editing, always valid, quite accurate	accurate 2D viewing and editing
inaccurate (finite resolution) requires lots of memory if overlap is allowed	difficult to edit, can be invalid (e.g., self-intersecting), especially after non-linear transformation	requires lots of memory	ambiguous in 3D, poor quality 3D visualization

Table 7 Different representations of regions

Each segment stored in multiple representations. One representation is designated as the master representations (marked with a “gold star” on the user interface). The master representation is the only editable representation, it is the only one that is stored when saving to file, and all other representations are computed from it automatically.



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Binary labelmap representation is probably the most commonly used representation because this representation is the easiest to edit. Most software that use this representation, store all segments in a single 3D array, therefore each voxel can belong to a single segment: segments cannot overlap. In 3D Slicer, overlapping between segments is allowed. To store overlapping segments in binary labelmaps, segments are organized into layers. Each layer is stored internally as a separate 3D volume, and one volume may be shared between many non-overlapping segments to conserve memory.

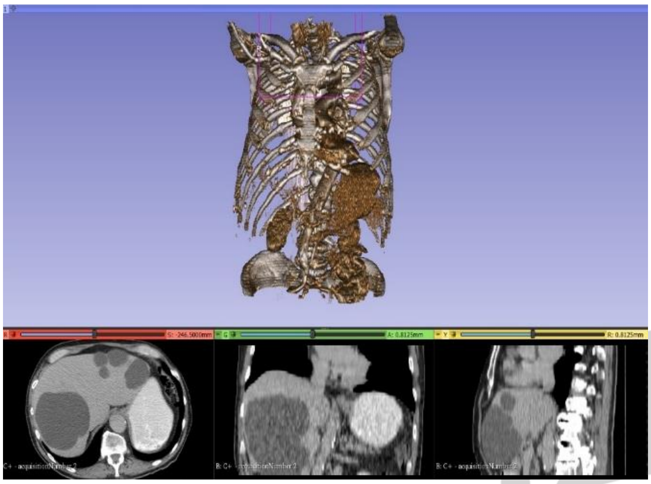

Fig 5.12 CT AAA volume view

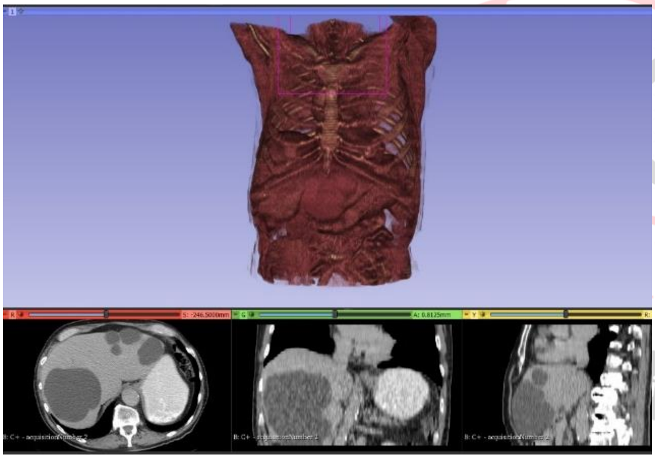

Fig 5.13 CT bone volume view

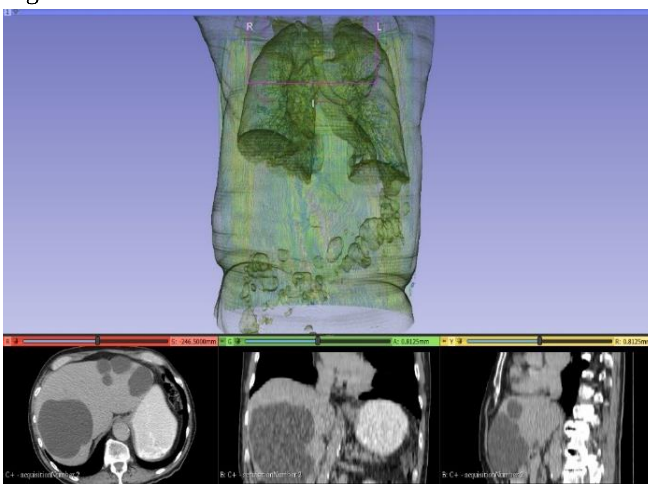

Fig 5.14 CT lung volume view

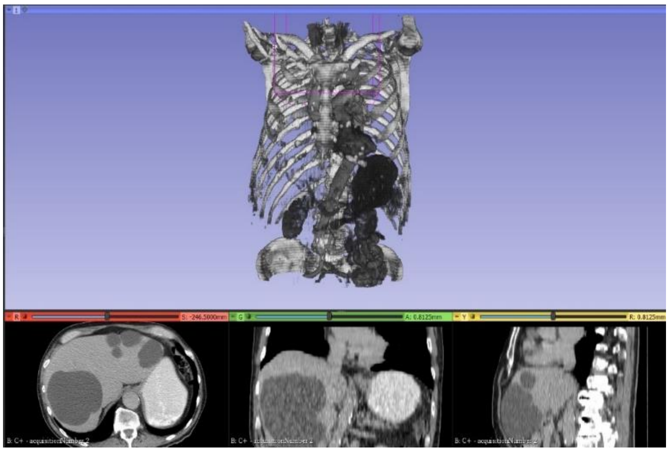

Fig 5.15 CT coronary arteries volume view

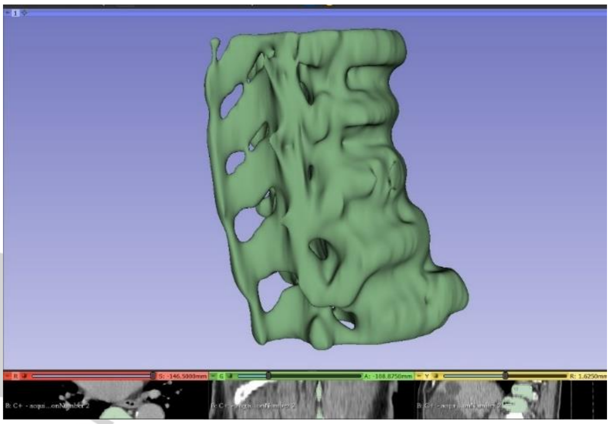

Fig 5.21 Part segmentation by using scissor operation

IV. Conclusion and Future Scope

1. CT/MRI scan data of the patients was obtained from the hospital. The DICOM format of the scan data was converted to .stl file using 3D Slicer software. Prior to 3D printing, pre-processing of CAD model was done for removing extra mesh islands and to reconstruct the patches/holes in the bone model using Blender and Meshmixer software.

2. The time taken to build the implants/models on the FDM 3D printer was less than the time taken to build the same implants with other methods.

3. After slicing the spinal cord model in Ultimaker CURA in different orientations. In first orientation gives better printing time and minimum material consumption. If we still want to reduce the printing time, we can modify the printing process parameters to reduce the printing time.

4. Future work from this research is to broaden this examination to include new materials that are biocompatible, to use other AM technologies, to redefine measurement procedure, to address other related AM research problems and to find new material that meet the current recommendation of the FDA and can be used on existing and emerging 3D printing machines.

5. Further research is to explore materials and 3D printer

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that can be used for 3D printing delicate organs like the kidney, liver, etc. so that 3D printed organ can be produced for patients who requires organ transplant due to liver and knee failure

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