ISSN 2730-2601
RICE Journal of Creative Entrepreneurship and Management, Vol.3, No.1, pp. 37-44, January-April 2022

doi: 10.14456/rjcm.2022.4
Received 14.12.21/ Revised 24.03.22/ Accepted 5.04.22

Medical Image Data Conversion to Design Anatomical 3D Models for Creative Medical Applications

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Abstract

This academic paper reports a practical guide to creating an anatomical 3D design using medical image data conversion techniques and examines the creative purposes of using anatomical 3D models in the medical field. Anatomical 3D models are regularly used in clinical training, diagnoses, and surgical planning for physicians. The creation of anatomical 3D models has required accuracy of size, scale, and proportion of anatomical data. Hence, the technology in medical imaging, such as CT scan and MRI, is used to capture precise anatomical data from patients. However, the anatomical images dataset from CT Scan and MRI are only two-dimensional and require further processing to convert the file to a 3D model. Two different medical image file formats are generally used in healthcare, namely PACS and DICOM. This paper has demonstrated the features of the DICOM file format that contained better references data, such as slicing thickness, spacing between slices, and converting image resolution to a 3D Model. The methods to convert DICOM to STL file format also require specific techniques to handle the automatically generated function from open-source programs with lower image quality. The author described the improvement techniques by using Materialize Mimics software to adjust parameters and selected tissue surfaces before conversion to Stereolithography (STL) file. With the STL file format, physicians can edit and design the 3D models to achieve objectives and use anatomical 3D models for other creative purposes.

Keywords: *Medical image data, 3D Design, anatomical model, 3D printing, Computer-Aided Design, Rapid-Prototyping, CT Scan, PACS, DICOM, STL*

1. Introduction

Anatomical 3D models are three-dimensional materials created as replicas of organs that represent structures of particular systems, either partly or entirely of human or animal anatomical features that are easy to view and convenient for learning of medical personnel. There are many purposes of medical 3D models, depending on the underlying objectives of their uses; for example, using medical models as learning media that can represent anatomy. This model could be enlarged, as the organs can be too small and cannot be observed by the naked eye. Alternatively, it can design to reduce the size to represent specific anatomical parts with more significant components (Edelmers, Kazoka & Pilmane, 2021).

Traditionally, 2D measurements were used to assess medical images. Unfortunately, it is difficult to know which slice should be measured, and since organs are irregularly shaped, there is no point in taking a 2-dimensional measurement. Likewise, 3D imaging has allowed for more multifaceted volume measurement and monitored anatomical position more accurately. Hence with elevations and precise positioning, the physicians can access vital data to help identify the patients' diagnosis easier. The physical interaction with anatomical 3D models endorsed learning anatomy, and differentiated structures interact spatially in the body in the clinic. This method can reduce the risks of surgical interventions by training with 3D surgical simulation models, which requires accuracy of size, scale, and proportion of anatomical data. The accuracy of anatomy can be generated from medical image data. The CT scan and MRI are widely used to image biological features, ranging from whole-body imaging to particular areas of interest and tracking and generating accurate scale and proportion (Bucking et al., 2017).

Recent advanced technology in software segmentation has made it increasingly easy to convert the surface of structures of interest from medical imaging data to three-dimensional (3D) forms and create anatomical models using a personal computer with prior anatomical knowledge by computer software, i.e., Materialize Mimics (Bucking et al., 2017).

The study presents an improved method for reconstructing the shape of 3D objects from 2D DICOM datasets generated from Materialize Mimics software. The focus is on DICOM data processing based on digital image processing techniques to get a 3D point cloud, reconstruct the 3D object based on triangulation of 3D point clouds, and build an application for rendering and visualizing the 3D medical image objects. The proposed method is expected to serve best in creating a 3D object from DICOM images.

2. The Different Medical Functions of PACS and DICOM format

Generally, a diagnosis of medical image data is a cooperative process where radiologists and medical doctors are involved. A radiology technician carries out all tasks that involve the localization and initial arrangement of the 2D images. The preparation includes affixing images on the lightbox so that a diagnostic process is supported optimally. This process is based on a series of actions performed to arrange images for optimal softcopy viewing, so-called ‘hanging protocols.’ The term initially referred to the arrangement of physical films on a lightbox. In either application, the goal of a hanging protocol is to present specific types of diagnosis regularly and reduce the number of manual image ordering adjusted and performed by the radiologist. A standard method for a hanging protocol for CT scans and X-ray images is lateral and frontal images scan. Even though CT scans often comprise the complete body, the clinician often only requires a small sub-volume of a scan (Berkowitz, Wei & Halabi, 2018).

PACS (Picture Archiving and Communication System) is a medical imaging technique commonly used in healthcare organizations to store and digitally transmit electronic images and clinically-relevant reports securely. PACS eliminates requirements to file manually, retrieve, store, film, report, and send information. Medical documentation and images can be securely recorded in distance databases and safely accessed from anywhere using PACS software, workstations, and mobile devices. PACS systems can archive medical image files received from scanning and photographing hardware, e.g., CT Scan, MRI. However, they are limited in functions and metadata. That is why physicians tend to use DICOM, which can be used as a communicative platform that includes information stored within PACS systems (Berkowitz, Wei & Halabi, 2018).

DICOM (Digital Imaging and Communications in Medicine) is an international standard platform for communicating, managing, and transmitting medical images and related data. It contains the interoperability of systems used to produce, store, share, display, send, query, process, retrieve and print medical images, and manage related workflows. DICOM and PACS are related applications but different technologies. DICOM acts as a file format and the international communication standard. Otherwise, PACS transfers medical images data. With advanced imaging technologies and the increasing use of computing in clinical work. DICOM is used widely to store, exchange and transmit medical images. They were especially enabling to integrate with medical imaging devices from multiple manufacturers. Patient data and related images can be exchanged and stored in a standard format instead of interpreting multiple image formats between different imaging devices. Hence, physicians have easier access to images and reports with the DICOM standard, allowing more comprehensive diagnoses. Images in the DICOM format have metadata or references for each slice, including the thickness, spacing between slices, and image resolution. Currently, the reconstruction of 3D images is performed by stacking DICOM images according to their metadata (Kamio, Suzuki, Asaumi & Kawai, 2020).

Consequently, the reconstruction success depends on the accuracy of the DICOM images and their metadata. Images in the DICOM format can be converted to their 3D form by proposing and selecting tissues from various 2D segmentation. The current reconstruction method of 3D images from DICOM files requires a technique for the reconstructed scanned images to have the same metadata: slice thickness, spacing between slices, and image resolution. Standard slice thickness of DICOM file requirements depends on the complexity of the anatomy. Models used for dental and surgery often use data reconstructed from slice thicknesses of 0.5-1 mm, whereas models of long bones and the pelvis can use slice thicknesses up to 2 mm (Marro, Bandukwala & Mak, 2016).

3. The Methods to Convert DICOM to STL File Format

The general 3D file format conversion is Stereolithography (STL) file format, the most commonly used Computer-Aided Design (CAD) format for 3D Models, especially 3D Printing. The STL file captured geometry as a triangular mesh but contained no color or texture information within the file. There are two different ways of STL data storage, namely, binary encoding and ASCII encoding, which contained exact information, but the binary format is more compact and produces a smaller file capacity (Hwang, Jung & Cho, 2018).

Numerous open-source and proprietary software programs are available for converting a patient's DICOM data set to Stereolithography (STL) file format. Commonly used open-source programs included OsiriX and MeshLab (Marro, Bandukwala & Mak, 2016). However, the automatic open-source DICOM conversion to the STL file is generally inaccurate. The STL file may contain scraps and unnecessary surfaces, making it difficult to edit and erase in the CAD software. Proprietary-software programs, such as Materialize Mimics has built-in presets for bone and soft tissues by selecting different density layers by applying density parameters in the program. The software can also edit the 3D mask and make changes by removing unwanted pieces and cropping the unwanted areas. Once the mask is edited, the software will calculate the 3D object from the mask. The 3D object can further be exported into 3Matic for additional changes, or exported as an STL file format.

After improvements of the data in Materialize Mimics software, the exported STL file is still required for editing in proprietary 3D CAD software again to enclose the surfaces of the 3D model. For this method, the researcher has recommended using Zbrush Software. Pixologic ZBrush is an advanced 3D sculpting program that uses digital sculpting tools that mimic traditional sculpting techniques. The method of sculpting in ZBrush is similar to shaping with a form of clay. The sculpting tools from ZBrush allow a wide range of creative freedom. Not only able to create more organic and detailed models, the program can often arrive at the finished product faster than other 3D programs like Maya or 3ds Max. By using Zbrush, designers can enclose the surface of the 3D model in detail and edit the mesh of the anatomical model easier. However, a limitation of Zbrush is the software interface that does not show measurement guidance in the program, making it very difficult to edit the 3D model according to the given dimension. As mentioned earlier, if the design is required to edit the 3D model to the exact size. The STL files are further needed to adjust in other CAD programs, such as Rhinoceros 3D that has measurement guidance or ruler tabs.

4. The Further Creative Purposes of Using STL Anatomical 3D Models

Stereolithography is a solid freeform technique (SFF) that was developed by 3D Systems in 1986. Whereas many other formats were developed since then, the STL file format has remained one of the most versatile solid freeform techniques. This technique has the highest fabrication accuracy, and an increasing number of materials that can be processed are becoming available. Solid freeform fabrication techniques have initially been developed to create prototypes for purposes of designing products. (Khatri, Frey, Raouf-Fahmy, Scharla & Hanemann, 2020) Traditional anatomical model prototyping methods involve handcrafted mold making and casting techniques. On the contrary, the ability to create an object within hours from a Computer-Aided Design by Rapid Prototyping (RP) significantly speeds up the production of 3D models. Rapid Prototyping using SFF techniques is a common practice in the industrial design, automotive industry, jewelry making, and designing end-user devices and appliances (Melchels, Feijen & Grijpma, 2010).

In the field of medicine, the Rapid Prototype has been introduced when compared to its long-standing use in various engineering applications, and so numerous researchers have reported the influence of anatomical 3D models and rapid prototype technology in various areas of the medical field: (1) Surgical Planning**,** (2) Customized Prosthesis Design, (3) Medical Education and Training, (4) Virtual Reality (VR) and Augmented Reality (AR) in Health Care, and (5) Bioprinting. The details are given below.

(1) Surgical Planning

The rapid prototype medical models have been developed to use in surgical planning, as these models provide the visual aid that can be used by physicians to plan for surgery, and by surgical teams to study the anatomical structure of patients before the surgery. These models can help decrease surgery time and risk during surgery, predict problems during operation and facilitate diagnostic quality. The rapid prototype medical models enable physicians to rehearse complex procedures and better understand the complex anatomy. Hence, these models are beneficial in surgeries, especially where there are anatomical abnormalities and deformities (Sharma, Dhiman & Negi, 2014).

(2) Customized Prosthesis Design

The rapid prototype medical models are able to fabricate customized prostheses and fixtures due to the inherent strength of this technology, and to fabricate complex geometry within a very short time. The combination of medical imaging technologies makes it possible to manufacture customized prostheses and fixtures that precisely fit a patient at a reasonable cost. Such combination allows the physicians to create accurate implants for their patients rather than the use of standard-sized prostheses that do not completely fit with patients (Sharma, Dhiman & Negi, 2014).

(3) Medical Education and Training

The anatomical 3D models can clearly demonstrate human anatomy's external and internal structures in colors. Thus, these models can be used as teaching aids in research, medical education, and museums for educational and display purposes. Moreover, medical practitioners can use these models to better understand the problems or surgical procedures without causing discomfort to the patients (Sharma, Dhiman & Negi, 2014).

(4) Virtual Reality (VR) and Augmented Reality (AR) in Health Care

Healthcare services are improving their customer experiences by effectively engaging them in Virtual Reality (VR) and Augmented Reality (AR) technologies in health care activities. Health care specialists can evaluate their ability to facilitate realistic simulations of complex procedures in support of surgical planning, training, medical education, and communication in order to plan the sequence of procedures for their patients. For this reason, patients are able to understand the diagnosis better and get actively engaged in their treatment.

(5) Bioprinting

Bioprinting technology allows the precise placement of cells, biomaterials, and biomolecules in spatially predefined locations within confined three-dimensional structures. This technology emerged as a powerful tool for building tissue and organ structures in tissue engineering. This technique is required in combination with medical imaging, such as MRI and CT Scan and conversion to STL file format, all of which have developed into a broadly applicable technique for biomedical engineering purposes Melchels, Feijen & Grijpma, 2010).

5. The Future of Anatomical 3D Models: Artificial Intelligence (AI), Machine Learning (MI), Cloud Computing and Beyond

With the advancements in computing power, connectivity, and better-integrated sensors, Artificial Intelligence (AI) and Machine learning (ML) complement the work of physicians to enable the development of new treatment paradigms by improving and learning to recognize patterns of disease features. All of these are the potential to improve clinical outcomes and enable patients to be treated promptly (Alexander, McGill, Tarasova, Ferreira, & Zurkiya, 2019).

Artificial Intelligence (AI) and Machine learning (ML) technology are automation technologies that can convert anatomical 3D models to 3D models faster. These technologies can be integrated in use for recognizing patterns that can be applied to medical images with the algorithm system computing the image features that are believed to be important in making the prediction or diagnosis of interest.

With remarkably enhanced computing power, communication and cloud storages in medicine have received good attention from all users concerned. Cloud Computing refers to accessing computing resources through the Internet with the capacity to act on the data with computational algorithms and software packages. This technology provides flexible and scalable computing resources from remote locations. The other potentials of the increasing use of cloud computing in medical imaging are raw data management and image processing and sharing, which require high-capacity data storage and medical image processing benefiting from access to cloud computing. This technology enables physicians to manage the needed medical data in distance (Kagadis et al., 2013).

6. Conclusion

As stated in the purposes of this paper, the author would like to show a practical guide to creating an anatomical 3D design using medical image data conversion techniques and examines the creative purposes of using anatomical 3D models in the medical field. The features of the DICOM file format were explained that they contained better references data, such as slicing thickness, spacing between slices, and converting image resolution to a 3D Model. The methods to convert DICOM to STL file format were shown to handle the automatically generated function from open-source programs with lower image quality. The author described the improvement techniques by using Materialize Mimics software to adjust parameters and selected tissue surfaces before conversion to Stereolithography (STL) file. Physicians can use the STL file format to edit and design the 3D models to suit their purposes.

This paper also reports that in recent years advances in computing technology, 3D printing, and Artificial Intelligence (AI) technologies have revolutionized the medical world. The three-dimensional anatomical models produced by medical image processing have been used primarily in medical education. Medical practitioners can also familiarize themselves with the anatomy before performing a procedure, especially in surgical cases. Several models can be replicated in large quantities for students to be used during practical classes and allow specialists to review normal and abnormal anatomical structures. Likewise, the 3D models can also describe diagnosis and conditions to patients, not particularly for medical practitioners. Physicians also can educate health care consumers on better care about their health using the three-dimension model.

It should be noted that the conversion of patients' medical imaging to anatomical 3D models has recently gained popularity in healthcare and medicine. They can already provide high-quality assistance to doctors and medical specialists in treatment which has been proven to facilitate, decrease time consumption and improve the quality of surgical procedures by planning and optimizing surgical approaches.

In order to create effective anatomical 3D models, physicians and medical specialists still need experiment techniques to generate the form, for recently, there have been no prompted devices that can automatically generate medical imaging data to anatomical 3D models. The making of 3D processes is time-consuming and requires delicate design processes. Engineers and scientists are now developing the concept of generating medical imaging data to anatomical 3D models using cutting-edge technologies.

As in the near future, the uses of Virtual Reality (VR) and Augmented Reality (AR) are increasing along with Artificial Intelligence (AI) and Machine learning (ML). These technologies will be able to integrate and possibly can deliver effective anatomical 3D models in a short time. These will enable physicians and medical specialists to use patient's 3D model along with the software interfaces, or even collecting pathology data from patients and diagnosis by cloud computing. The technologies are now in progress in adoption and adaptation in health care, and many medical entrepreneurs are currently investing in digital health care solutions for the future and beyond.

7. The Author

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8. References

Alexander, A., McGill, M., Tarasova, A., Ferreira, C. & Zurkiya, D. (2019). Scanning the future of medical imaging. *J Am Coll Radiol, 2019, 16*(4 Pt A), 501-507. doi:10.1016/j.jacr.2018.09.050

Berkowitz, S. J., Wei, J. L. & Halabi, S. (2018). Migrating to the modern PACS: Challenges and opportunities. *Radiographics, 2018, 38*(6), 1761-1772. doi:10.1148/rg.2018180161

Bucking, T. M., Hill, E. R., Robertson, J. L., Maneas, E., Plumb, A. A. & Nikitichev, D. I. (2017). From medical imaging data to 3D printed anatomical models. *PLoS One, 2017, 12*(5), e0178540. doi:10.1371/journal.pone.0178540

Edelmers, E., Kazoka, D. & Pilmane, M. (2021). Creation of anatomically correct and optimized for 3D Printing Human Bones Models. *Applied System Innovation, 2021, 4*(3). doi:10.3390/asi4030067

Hwang, J. J., Jung, Y. H. & Cho, B. H. (2018). The need for DICOM encapsulation of 3D scanning STL data. *Imaging Sci Dent, 2018, 48*(4), 301-302. doi:10.5624/isd.2018.48.4.301

Kagadis, G. C., Kloukinas, C., Moore, K., Philbin, J., Papadimitroulas, P., Alexakos, C. & Hendee, W. R. (2013). Cloud computing in medical imaging. *Med Phys, 2013, 40*(7), 070901. doi:10.1118/1.4811272

Kamio, T., Suzuki, M., Asaumi, R. & Kawai, T. (2020). DICOM segmentation and STL creation for 3D printing: A process and software package comparison for osseous anatomy. *3D Print Med, 2020, 6*(1), 17. doi:10.1186/s41205-020-00069-2

Khatri, B., Frey, M., Raouf-Fahmy, A., Scharla, M. V. & Hanemann, T. (2020). Development of a multi-material stereolithography 3D printing device. *Micromachines (Basel), 2020, 11*(5). doi:10.3390/mi11050532

Sharma, K., R., Dhiman, S. & Negi, S. (2014). Basics and applications of rapid prototyping medical models. *Rapid Prototyping Journal, 2014, 20*(3), 256-267. doi:10.1108/rpj-07-2012-0065

Marro, A., Bandukwala, T. & Mak, W. (2016). Three-dimensional printing and medical imaging: A review of the methods and applications. *Curr Probl Diagn Radiol, 2016, 45*(1), 2-9. doi:10.1067/j.cpradiol.2015.07.009

Melchels, F. P., Feijen, J. & Grijpma, D. W. (2010). A review on stereolithography and its applications in biomedical engineering. *Biomaterials, 2010, 31*(24), 6121-6130. doi:10.1016/j.biomaterials.2010.04.050