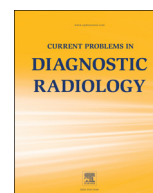




Current Problems in Diagnostic Radiology

journal homepage: www.cpdjournal.com



Three-Dimensional Printing and Medical Imaging: A Review of the Methods and Applications

Alessandro Marro, BSc^{a,*}, Taha Bandukwala, MD^a, Walter Mak, MD^b

^a Department of Medical Imaging, University of Toronto, Toronto, Ontario, Canada

^b Department of Medical Imaging, St. Michael's Hospital, Toronto, Ontario, Canada

The purpose of this article is to review recent innovations on the process and application of 3-dimensional (3D) printed objects from medical imaging data. Data for 3D printed medical models can be obtained from computed tomography, magnetic resonance imaging, and ultrasound using the Data Imaging and Communications in Medicine (DICOM) software. The data images are processed using segmentation and mesh generation tools and converted to a standard tessellation language (STL) file for printing. 3D printing technologies include stereolithography, selective laser sintering, inkjet, and fused-deposition modeling. 3D printed models have been used for preoperative planning of complex surgeries, the creation of custom prosthesis, and in the education and training of physicians. The application of medical imaging and 3D printers has been successful in providing solutions to many complex medical problems. As technology advances, its applications continue to grow in the future.

© 2015 Mosby, Inc. All rights reserved.

Introduction

Also known as additive manufacturing or rapid prototyping, this growing technology is changing the manufacturing industry,¹ and its potential is beginning to be discovered in health care. The process consists of creating 3-dimensional (3D) objects through successive deposition of materials in 2D layers. Pioneered by Charles Hull in 1986,² 3D printers were first adopted by automobile and aerospace industry to create prototypes for testing before proceeding with mass production. Today, 3D printers and their products are an approximately 4-billion dollar market.³ In addition to prototyping, it is used to make a variety of finished products, including jewelry, batteries, and medical implants.⁴ 3D printing offers many advantages over traditional manufacturing, which include the ability to create objects with complex internal structures, improved versatility and customization, and less space requirements.⁵ When combined with medical imaging, 3D printing opens up new opportunities in the advancement of medicine. Clinical applications of this emerging technology are actively being investigated in many fields of medicine. The ability to generate 3D models from patient data allows physicians to create custom prosthetics and implants, visualize complicated pathologies better, and teach trainees like never before.⁶ This article discusses the key features of 3D printed models created from medical imaging data. It focuses on the steps in creating 3D models from Data Imaging and Communications in Medicine (DICOM) images and current applications in medicine.

Process of Creating 3D Objects From DICOM Data

The process of generating 3D objects from imaging data generally follows these steps: (1) acquisition of image data, (2) extraction of the chosen region of interest termed “segmentation,” (3) transformation of the data from volumetric to a 3D triangular mesh, and (4) transfer of the data to a 3D printer for production. A typical sequence of this process can be seen in Fig 1. These steps are each discussed in detail in the following sections.

Image Acquisition

The first step in creating 3D printed models from medical imaging is the acquisition of useable data. Data for generating medical models are typically acquired with computerized tomography (CT) or magnetic resonance imaging,⁷ though other modalities such as ultrasound⁸ can be used. The choice of image data is important, as low-resolution images can result in discrepancy between the generated model and actual anatomy.⁹ Slice thickness requirements depend on the complexity of the anatomy in question. Models used for maxillofacial surgery often use data reconstructed from slice thicknesses of 0.5–1 mm, whereas models of the pelvis and long bones can use slice thicknesses up to 2 mm.¹⁰ The images are initially saved in a DICOM format, but later converted to a format that can be recognized by the printer.

Segmentation and Mesh Generation

Segmentation is an optional step in the creation of 3D printed models, but practically speaking it is almost always employed in medical applications. The goal of postprocessing is to isolate the area of interest within the data set, which is known as

* Reprint requests: Alessandro Marro, BSc, Department of Medical Imaging, University of Toronto, 263 McCaul St, Toronto, Ontario, Canada M5T 1W7.

E-mail addresses: alex.marro@mail.utoronto.ca, alexmarro01@gmail.com (A. Marro).

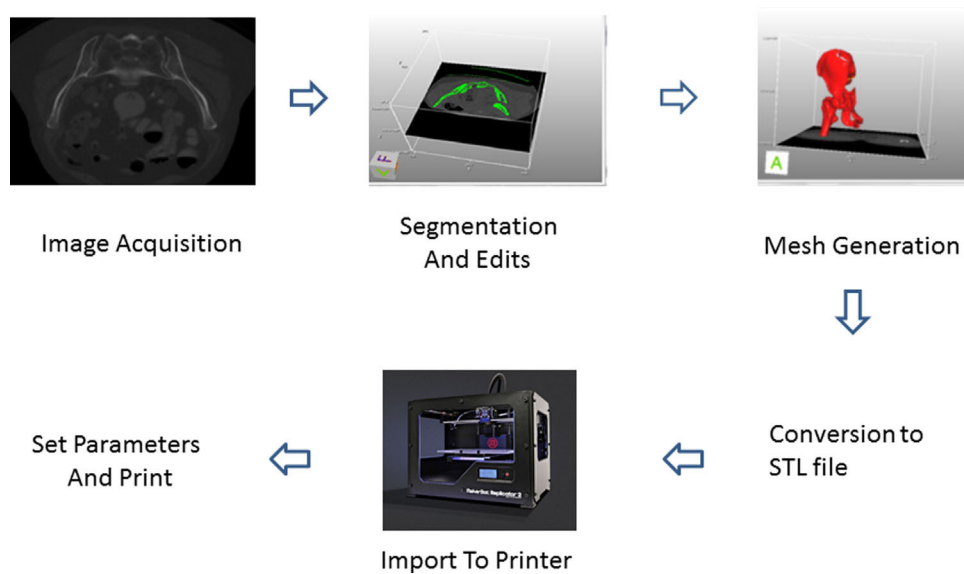


Fig. 1. Generalized procedure to create 3D models from DICOM data. (Color version of figure is available online.)

segmentation, and to extract a surface from the segmented data, known as generating a surface mesh. There are numerous open-source and proprietary-software programs available for use with DICOM data sets.¹¹ Commonly used open-source programs include OsiriX¹² and MeshLab.¹³ These programs contain a variety of manual and automatic tools for manipulating DICOM data into files ready for printing. Some commonly used tools are discussed here.

A threshold tool allows one to set a range of values from the data to be retained, while ignoring data that fall outside the range.¹¹ This is a very useful tool for retaining or removing areas of interest corresponding to density values of tissue types (Fig 2). Another tool for segmenting is seed-based region growing (Fig 3). With this tool the operator selects areas from the image by using a starting point or seed, and chooses voxel density parameters.¹⁴ The program then adds additional voxels to the seed that meet the defined density criteria. Additional voxels are then added to subsequent adjacent voxels that meet the criteria.

Once the segmentation is complete, a surface is extracted from the volumetric data by converting the data from voxels into a mesh composed of a series of triangular facets. This can be accomplished

using automated surface rendering tools contained within programs discussed earlier. The transformation from a voxel to a polygonal model results in a smoother surface, but is an approximation of the original image.⁹ Additional changes can be made manually or automated algorithms may be used to smooth out artifacts.¹⁵

The process of segmentation and mesh generation can result in significant inaccuracies between the original DICOM data and final 3D generated model.¹⁶ It is important to compare the region of interest from the processed data with the original unprocessed DICOM data at every step to ensure that it remains a true anatomical representation.

Finally the data are saved in a file format recognized by the 3D printer software. The most commonly used format is standard tessellation language (STL) file format.

3D Printing and Postprocessing

Recent advances in 3D printing technology have produced new processes that make it possible to use a variety of materials,

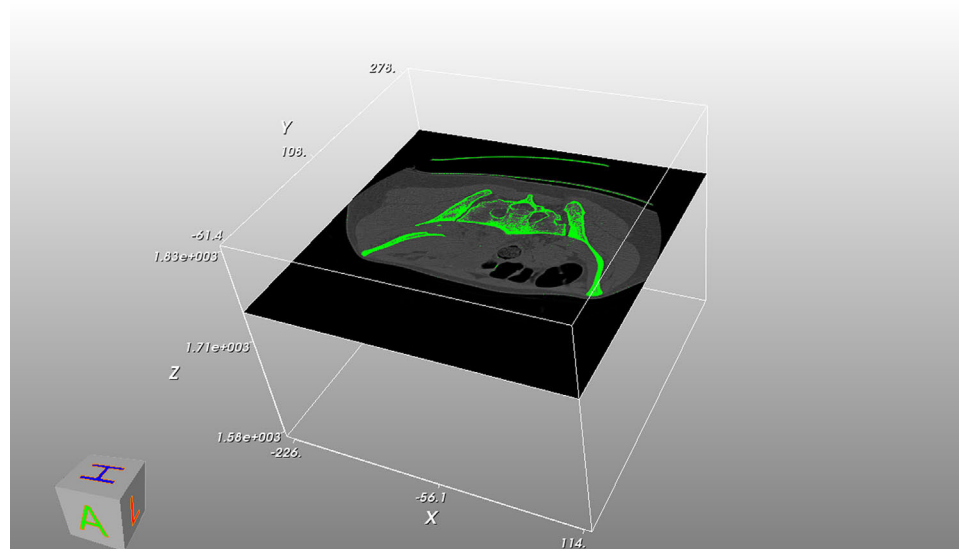


Fig. 2. Threshold tool used to isolate bone from remaining tissues. (Color version of figure is available online.)

Download English Version:

<https://daneshyari.com/en/article/4223443>

Download Persian Version:

<https://daneshyari.com/article/4223443>

[Daneshyari.com](https://daneshyari.com)