# Medical imaging and processing software
by Andy Christensen

Without high-quality medical image data, output by additive manufacturing can be less than ideal. In this field, the old adage of "garbage in, garbage out" applies. Computed tomography (CT) scan imaging is the method of choice for replicating bone structures. Another technique that is used for imaging in the dental field is cone-beam computed tomography (CBCT). Another popular imaging technique for medical modeling is magnetic resonance imaging (MR or MRI). Although this technique is less useful for bone imaging, it can be quite useful for soft tissue structures and cartilage.

Computed tomography: CT uses many x-ray projections through a subject to computationally reconstruct a cross-sectional image. In the traditional implementation, an x-ray source—producing a narrow collimated beam—is directed so that the beam passes through the subject and onto an opposing detector. The x-ray source and detector pair rotate about the subject so that thin x-ray beams pass through the subject in a single plane, and thus are attenuated, and then are measured by the detector system. CT is considered the imaging modality of choice for bone imaging and production of medical models of hard tissue structures like bone.
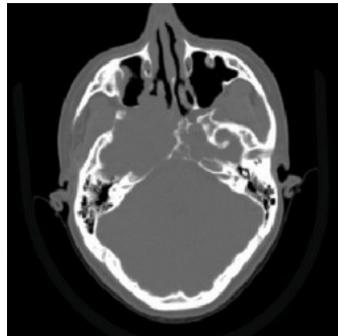
CT scan image depicting a cross section through the head, courtesy of Medical Modeling, Inc.

Cone-beam computed tomography: CBCT operates on the same principle as traditional CT. However, instead of a single, thin x-ray beam making one revolution per image slice, a larger, diverging x-ray beam (a cone beam) is paired with a larger 2D detector. In this way, CBCT makes it possible to acquire a single image dataset from one revolution of the source–detector pair. This has many benefits in terms of logistics, ease of scanning, and reduced radiation exposure. However, the contrast resolution is poorer than with traditional CT, making segmentation somewhat difficult. Nevertheless, CBCT is becoming more common in clinical use, particularly in dental specialties, as well as with ear, nose, and throat specialists. It is also being used for patient alignment tasks in radiation therapy and surgery.

Magnetic resonance imaging: MRI is based on the principle of nuclear magnetic resonance and employs strong magnetic fields and radio waves. Hydrogen protons in water molecules become aligned in the strong primary magnetic field. Radio waves at a specific frequency, which can be calculated from the strength of the magnetic field, are introduced to perturb protons from their alignment within the magnetic field. When the

radio waves are removed, protons return to their alignment within the magnetic field at different rates, depending on the surrounding molecules (i.e., tissue type), and emit an echo signal that can be measured. The echo signal is used to determine relaxation times (the time required for hydrogen nuclei to return to their alignment in the magnetic field). Local relaxation times are used to reconstruct cross-sectional images.
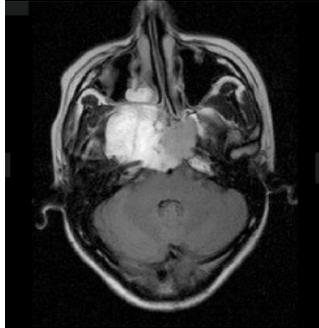

MRI image (showing the same cross-sectional area of anatomy as the previous CT scan image) with enhanced resolution of the tumor in the center of the image, shown as more "white," courtesy of Medical Modeling, Inc.

Most medical-imaging technologies used for medical modeling produce data in serial section format in the form of 2D images. These images represent a finite thickness of data taken at increments along the object being scanned. Think of these stacked 2D images together forming a 2.5D, or pseudo-3D, volume. For example, a CT scan can be taken using a slice thickness of 1 mm (0.040 inch) and repeated every 1 mm (0.040 inch). In this case, an object that is 20 mm (0.80 inch) in length would have 20 slices. Within these 20 slices, data would be available for the entire object being scanned, but image-processing tools are needed to "extract" the areas of interest, such as bone structure or a tumor.

To efficiently and accurately handle the previously discussed medical image data, specialized software is needed to interpret different formats and enable image processing. The export of this medical image data to a suitable additive process format is also crucial to the accuracy of the process. Several software products provide tools for exporting to the STL format, and a few offer a direct slice interface to machines from 3D Systems, Stratasys Ltd., and others.

The most common format found today for medical imaging is the open-source standard Digital Imaging and Communications in Medicine (DICOM) 3.0. This industry format is to medical radiology what the JPG format is to general photography. Primary tasks within the field of medical image processing for AM include 1) import of native medical images, 2) thresholding images, 3) slice/volume editing, 4) region growing, and 5) STL file generation. The chart below shows some of the major steps involved when producing an anatomical model of bone structure.
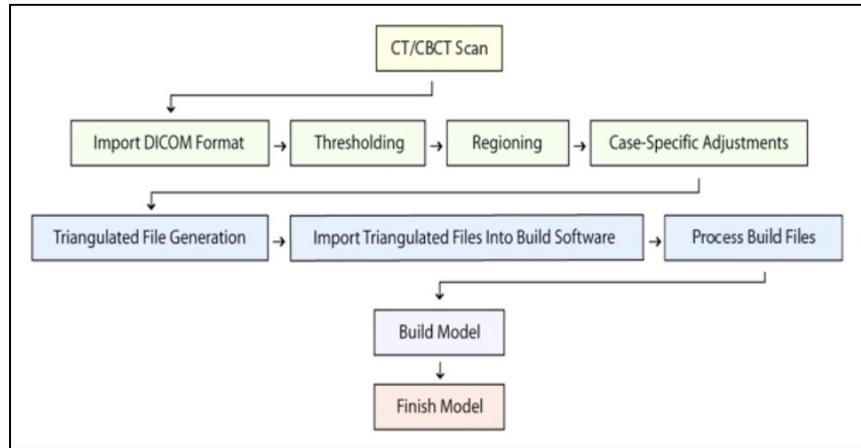
Overview of the process of using medical-imaging data to produce a physical model of bone structure, courtesy of Medical Modeling, Inc.

The following table illustrates the most widely used software products for medical image processing and integrated prosthetic design.

Product Manufacturer Website	Description
Mimics Materialise materialise.com	Imports from various medical-imaging modalities, processes the images, and exports to STL and native additive-manufacturing formats
3Matic Materialise materialise.com	Allows for digital design by manipulation of STL files; useful in design and manufacture of complex prosthetic devices
RapidForm 3D Systems rapidform.com	Imports DICOM image data, processes the images, and exports to various formats
Amira Visage Imaging amiravis.com	Imports from various medical-imaging modalities, processes the images, and exports to STL format
Osirix Open Source osirix-viewer.com	Imports from various medical-imaging modalities, processes the images, and exports to STL format; allows for image fusion between different scan types
Geomagic Studio 3D Systems geomagic.com	Imports CBCT images and provides tools for the design of dental-related prosthetics

Medical image-processing software products, courtesy of Medical Modeling, Inc.