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# G-Code Generator from Bone DICOM CT with Cloud

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**Abstract**. A three dimensional (3D) medical image can provide a sense of reality for a doctor. A 3D printer can transform a 3D image into a 3D object, which provides communication between the doctor and his/her patients. One step to make the 3D object is to generate the g-code using a software. However, the existing software for creating the g-code still uses the user interface (a manual process). This study aims to generate g-code from Digital Imaging and Communications in Medicine (DICOM) format in Computerized Tomography (CT) through the cloud. The g-code generator is implemented using Phyton version 3 and runs on a computer using Linux (Ubuntu 18.4) as the operating system. The computer specification is intel core i9-9900K with motherboard Gigabyte Z390 Aorus Elite and graphic card Gigabyte GV-N208TGAMING OC11GC (memory 11GB). The medical image object is a bone that comprises craniofacial bone and thoracic vertebra, taken from multi-slice CT in DICOM format. The g-code file is suitable for a specific 3D printer. The performance criteria are the transferred data and visual shape comparison between the output from InVesalius 3.1 software and 3D printer (manually). The justification of the visual shape match from three radiology doctors for craniofacial bone and a thoracic vertebra is approximately 100% matching.

## 1. Introduction

A three dimensional (3D) medical image can provide a sense of reality for a doctor. A 3D printer can transform a 3D image into a 3D object, which provides communication between the doctor and his/her patients [1]. One step to make the 3D object is to generate the g-code using a software. However, the existing software for creating the g-code, such as Ultimaker Cura, Replicator G, All3DP, Slic3r, FreeCAD, Simplify 3D, still uses the user interface (a manual process) [2].

For some biomedical applications, cloud computing has emerged as an alternative to the traditional computing approaches maintained locally. Desktop computers and high-performance computing systems become the tools for the biomedical digital application. Cloud adoption varies in the industry because of different security levels and other required features [3,4].

This study aims to generate The G-code from Digital Imaging and Communications in Medicine (DICOM) format in Computerized Tomography (CT) through the cloud. With Software as a Service

(SaaS), the cloud providers install, manage, and operate the g-code generator while the CT operator has neither knowledge nor control over the underlying infrastructure. Figure 1 shows the architecture of the g-code generator and the CT operator.

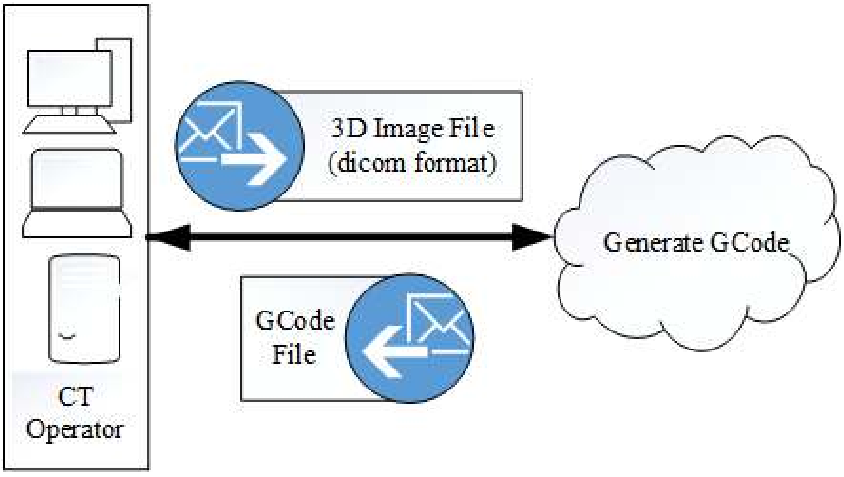


**Figure 1**. The Architecture of the G-Code Generator and CT Operator

## 2. Literature review

With a 3D printer, it is possible to create physical objects using only a digital model. The g-code is an instruction set in which people tell computerized machine tools, how to produce a physical 3D object. G-code instructions provided to a machine controller (i.e., 3D Printer) that tells the motors where and how fast to move [5]. The manipulation and tuning of material properties, with 3D Printer, will eventually allow for the production of patient-specific models that have both anatomical and tissue fidelity [6]. A 3D printer is a powerful tool if combining with medical imaging. It has already had a significant impact on many fields of medicine. It also has successfully created anatomical models. As both medical imaging and 3D printer technology continue to advance, it will discover a new opportunity for the combined use [1]. The biomedical object cases of development 3D printer are the consulting patient with sophisticated skull base cholesteatoma [7], the creation of temporal bone model [8], the creation of brain and skull model [9].

In the medical imaging domain, cloud computing is still in its infancy. The potential driving forces of the increasing use of cloud computing in medical imaging, among others, are raw data management, image processing, and sharing demands, which require high-capacity data storage and computing. Medical image processing can benefit from having access to cloud computing. Research in different areas of medical image processing over the past decade has led to continuous algorithmic improvements [3]. The cloud applications in the medical image processing are medical image processing as a service for regional healthcare [10], healthcare management service [11,12], cardiovascular imaging [13], molecular diagnostic[4], automated fractured bone [14].

## 3. Methods and data

Figure 2 shows the flowchart of the general process to generate g-code. The first time, the CT operator is required to register first by providing a username, password, operator CT name, cellphone number, and email address. The login process requires the operator to input the username and password. The data from the registration process are saved into the database. The unique entity of the database is the username.

At step 1, the process starts with user registration and/or login-entry data. The DICOM 3D image must be uploaded in a zip file format. Step 2 extracts the zip file. Step 3 reconstructs DICOM file. Step 4 will generate the STL file, and the following step 5 generates the g-code. The last step (step 6) sends the g-code file to the CT operator by email. The reconstruction 3D image use improved marching cube algorithm [15]. The threshold for object bone 3D image is 200 with single-slice CT [16], and 210 with multislice CT [17]. The detail process of generating the g-code shown in Figure 3. After reading the STL file, the first step starts by resizing the 3D image to cover the work area of the 3D Printer. Step 2 is the slicing process. The last step is to generate a g-code line for every slice.

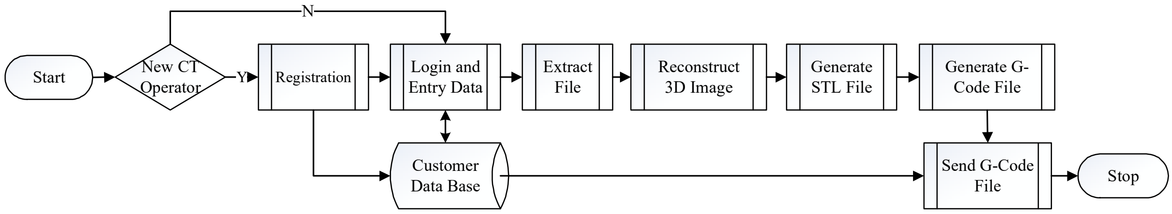


**Figure 2.** Flowchart of general generate g-code process

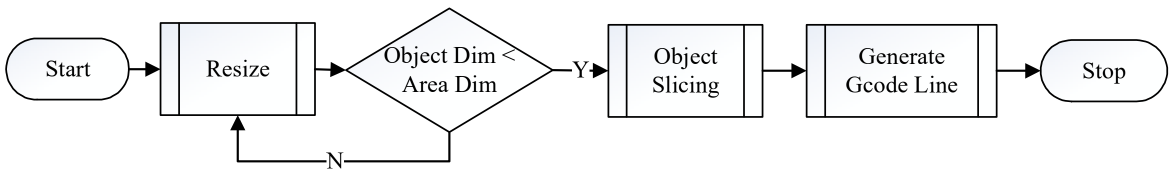


**Figure 3.** Flowchart of detail generate g-code process

This flowchart is implemented using Phyton version 3 and Linux operating system (Ubuntu 18.4). The computer specification is intel core i9-9900K with motherboard Gigabyte Z390 Aorus Elite and graphic card Gigabyte GV-N208TGAMING OC-11GC (memory 11GB).

The experimental data were craniofacial bone DICOM and thoracic vertebra DICOM that are both from DICOM library. Table 2 shows the experiment data. The slice thickness of the experimental data is 1mm

**Table 1.** The Data of Experiment

| Category | Slice Quantity | Format Size |
|---|---|---|
| Craniofacial Bone | 181 | 512 x 512 |
| Thoracic Vertebra | 142 | 512 x 512 |

The validation process of this software is communication data and the visual shape comparison of the 3D image from InVesalius software and 3D image product printed manually using the 3D printer. We consult the visual comparison with three radiology doctors. The observation of craniofacial bone focuses on frontal, nasal, maxilla, mandible, parental, temporal, sphenoid, zygomatic, and mastoid. The thoracic vertebra focuses on spinous, costal surface, vertebral foramen, vertebral body, lamina, and pedicle.

The g-code file can be run on a specific 3D printer. The specification of the 3D printer is:

(a) The printer setting: X-axis (width) 110 mm, Y-axis (depth) 120 mm, Z-axis (height) 170 mm

(b) Material: PLA, with printing temperature 200 °C and diameter 1.75 mm

**4. Results**
Figure 4 shows the screenshot of the registration for the new CT operator. The login process shows with a screenshot in Figure 5. After the login process, the screenshot of the upload 3D image process in zip file format shows in Figure 6. The end of the process is to send a g-code file via email, depicted in figure 7.

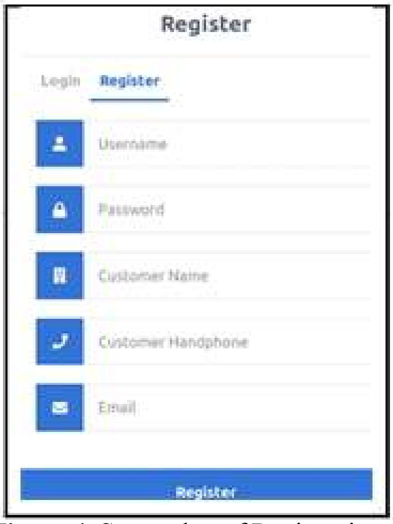


**Figure 4**. Screenshot of Registration


**Figure 5.** Screenshot of Login


**Figured 6.** Screenshot of Upload 3D Image Zip File


**Figure 7.** Screenshot of Email Message

The output 3D image from InVesalius software and 3D Printer for craniofacial bone and thoracic vertebra are shown in figure 8 and 9. The justification of visual shape from the three radiology doctors perfectly match (100% match) between the output 3D image from InVesalius software and the output 3D object from 3D printer. Transfer data for the 3D image with zip file (upload data) and g-code file (by email) are

100% success (no corrupt file), but the size of transferred data is limited to the maximum of 25 MB. If transfers data more than 25 MB, it must be used OneDrive (cloud).

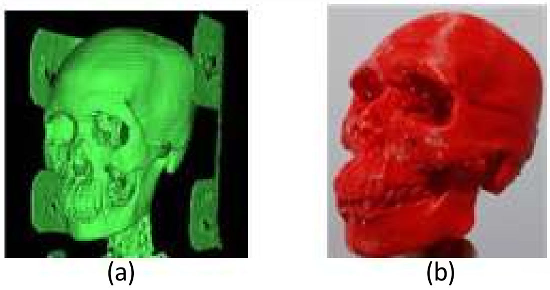


**Figure 8.** The output Craniofacial Bone from (a) InVesalius Software and (b) 3D Printer

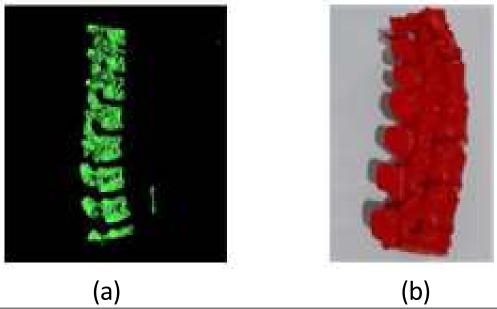


**Figure 9.** The output Thoracic Vertebra from (a) InVesalius Software and (b) 3D Printer

## 5. Conclusion

The g-code generator software with cloud platform runs 100% successfully. The justification of the visual shape match from Invesalius software and 3D printer manually from three radiology doctors is 100% match. The g-code file is for suitable of a specific 3D printer. In line with the development of industry 4.0, future research will focus on developing a connection with a 3D printer. The connection uses the wireless platform.

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