Computer Simulation of Contrast Agent Injection in Coronary Angiography

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Abstract

Coronary angiography is a relatively safe invasive procedure for coronary anatomy and pathology. In this paper, a simulation of contrast injection in coronary angiography is presented with focuses on visualization of coronary arteries and animation of contrast agent flow after contrast agent injection. This simulation is designed and implemented in Python programming environment. This simplified coronary angiography graphic simulator can be used for training medical students to analyze correctly and effectively images from coronary angiography.

Keywords: Coronary angiography, simulation, medical education, contrast agent injection.

Introduction

Coronary Angiography (CA) is a procedure that shows the insides of coronary arteries using contrast agent and special x rays. The coronary arteries supply oxygenated arterial blood to the heart. Any blockage of coronary arteries may cause serious health problems. CA is performed to find out whether there is a blockage in a coronary artery. Cardiac catherization is used to get the contrast agent into the coronary arteries. The contrast agent is used to visualize blood paths in the coronary arteries. CA is one of the most common invasive procedures in medicine and a relatively safe procedure.

CA simulators have become increasingly popular in medical training with cautions. There are researches on the use of CA simulators in medical training. Jensen et al. (2014) concluded that the use of simulators did not improve learning of CA. Several years later, Jensen et al. showed the better performance of trainees who were trained with simulators than the trainees who were not (Jensen et al., 2016). There were significant advancements of technology that can be adopted in CA simulators such as graphic processors and sensors. Those advancements improved computing speed and graphics, which resulted in more efficient simulators. Four commercial simulators were introduced and compared: CathLabVR, Angiomentor, Simsuite and Procedicus VIST (Green et al. 2014).

The purpose of CA simulators is to train trainees so that they become competent in the performance of CA. In order to meet the purpose, the simulators should produce ideally the same tactile feedback and be compatible with the same devices that are used in the real CA. Since the purpose of CA is to find out whether there is any blockage in coronary arteries, if any blockage is found, the blockage should be located through X-ray images from CA. CA simulators have to train trainees to locate anomaly of coronary arteries quickly and precisely so that patients may get right interventions in time.

CA Graphic Simulator

Most CA simulators are composed of four components: Display, Controller, Interface and Computer. But this study focuses on the display and computer components. It reconstructs 3D coronary arteries and simulates contrast agent injection. It is a simplified version of simulation of blood flow after contrast agent injection.

Compared with other commercial CA simulators, this simulator is very simple with less fidelity. However, due to the high cost of those well-known CA simulators that were mentioned previously, trainees have limited accessibility to

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the simulators in the market. This simulator, developed with free resources and equipped with many potential features that will be discussed later, would be readily accessible to trainees in coronary angiography.

In order to reconstruct coronary arteries graphically, Blender (v2.76) was used. Blender is a free and open-source 3D computer graphics software. It is used for 3D modeling, animations, visual effects, and interactive 3D applications. Scripting language Python was chosen since it is compatible with Blender. With Python console in Blender, repetitive tasks can be done through a script written with Python programming language. The repetitive tasks include getting the vertices coordinates for the creation of arteries. Through scripts, the objects can be controlled in animation.
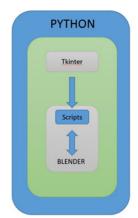

Fig. 1. *Schematic Diagram of the graphic simulator. Tkinter GUI selects which script to run and the chosen script is executed for modification of the objects or animation.*

A human heart anatomy file in a stl format was downloaded from the site, thingiverse.com. The site provides digital design files. The file is licensed under the GNU General Public License under which end users are free to run, study, share and modify the file.
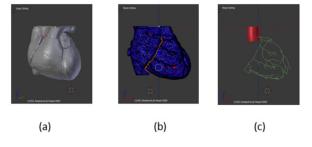

Fig. 2. *3D model of a heart: (a) downloaded 3d heart model (b) selected vertices for the right coronary artery (c) meshed curves of coronary arteries*
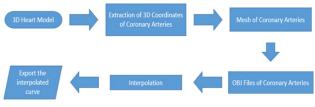

Fig. 3. *Flow Chart of 3D modeling*

After the file was imported to Blender, each coronary artery was identified. Each artery was connected according to the coronary artery tree. The centerlines of the coronary arteries were delineated manually in the middle of the coronary arteries on the surface of the heart. For this, several scripts were written in Python programming language in order to automate the manual process such as getting 3D coordinates of each vertex, saving them as an obj file, drawing curves and converting curves into meshes. Since the arteries have different lengths, the curves contain different number of vertices. Each curve was interpolated with Matlab. The interpolation makes easier to control the simulation and smooth curves without any sudden variation.
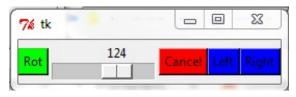

Fig.4. *Tkinter GUI Controller*

Python scripts were created to simulate contrast agent injection to either left coronary artery or right coronary artery. The controller has four buttons and one slider. The blue buttons choose which artery it injects contrast agent into, right coronary arteries or left coronary arteries. The simulated graphics can be rotated with either the green button or the slider.
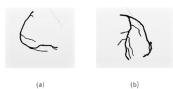

Fig. 5. *Coronary Arteries after contrast agent injection: (a) Right Coronary Arteries, (b) Left Coronary Arteries*
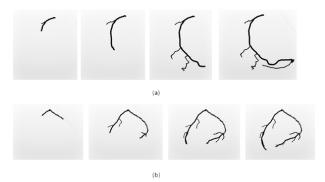

Fig. 6. *Simulated X-Ray Images of contrast agent injection. (a) Right Coronary Artery (b) Left Coronary Artery*

Discussion

The simulation was made with normal coronary arteries which have no blockage or narrow blood path. However, the significance of this simulator is its extensibility. Written in Python programming language and animated with Blender, it can provide a variety of coronary angiography simulations. For example, each simulation can be run with parameters for the location of blockage and the severity of blockage. With those parameters entered by an operator, abnormal coronary arteries may be created with a narrow diameter in a specified coronary artery. In this way, abnormal coronary arteries can be created also with other pathological characteristics. The database of coronary arteries may be built easily and used for training to find the blockage and other anomaly due to the blockage. A training program can be developed so that trainees can pinpoint arteries to address and come up with treatments.

For accurate diagnosis, cardiologists need to have multiple specific angiographic views such as caudal, cranial and straight view for left coronary artery and right coronary artery. The more buttons or selections can be added to Tkinter controller to show different angiographic views of coronary arteries.

Contrast agent injection action can be simulated with a syringe. Real contrast may be replaced with solution. This would give a better tactile feedback than the injection of air that triggers the simulation of contrast agent injection in the simulator like Mentice VISTTM system. For this feature, an interface between PC and a sensor is required.

This simulator can be evaluated through tests in which trainees trained with this simulator read real X-ray images. Tests should be designed to measure how well the trainees read real X-ray images.

Conclusion

In this paper, a simple CA Graphic simulator was presented with its high extensibility.It simulates contrast injection during CA in a Python programming environment. It has many potential uses in medical training of analyzing images from coronary angiography. Expanded with the database of coronary arteries from patients and other suggestions that were made in the section of discussion, it can prepare trainees better for real CA.

Referances

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