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Computer Based X-Ray Computed Tomography Training System for Engineering Education

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Abstract

X-ray computed tomography (called CT) scanner is a powerful and widely used medical imaging modality in the hospital. The CT machine is very expensive and it can produce dangerous radiation when a person operates the machine. This makes it difficult for biomedical engineers and radiographer students to learn its working principles. In order to overcome this problem, a computer based CT scanner trainer system has been developed. The system is implemented using National Instrument’s Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW). At the beginning, it was started with the studying of existing CT scan machine. After gathering information, development process continued to develop generator component, x-ray tube subsystem, detector subsystem, imaging subsystem, and finally is reconstruction subsystem. The trainer system that has been developed is able to be used to train students on how to use CT scanner especially to get high quality images with lowest possible radiation. This will help biomedical engineers and radiographer students to have a better understanding of CT scanner in term of its working principle and to prevent radiation hazard during the learning process.

Keywords: Engineering education; computed tomography; biomedical engineers; radiolographer; computer based

1.0 INTRODUCTION

Computed tomography is an x-ray imaging modality used for a variety of clinical applications. CT imaging equipment is used for spine and head imaging, gastrointestinal imaging, vascular imaging (e.g., signs of stroke, detection of blood clots), cancer staging and radiotherapy treatment planning, screening for cancers and heart disease, rapid imaging of trauma and pediatric patients, measuring bone mineral density for diagnosing osteoporosis, imaging of musculoskeletal disorders, detection of signs of infectious disease, and guidance of certain interventional procedures (e.g., biopsies)(Robb & Richard A., 1999).

Nowadays, training system for biomedical engineers or radiographer students is required due to recent technology that may require them to understand on how to manage computed tomography scanner with acquiring a good quality of images without a huge radiation exposure. The radiation dose measured during CT scan is affected by the tube voltage and the tube current (Hye-Kyung Son, Sang Hoon Lee et al, 2006). The results measured by phantoms show that the measured radiation dose is increased as the tube voltage and tube current increased (Hye-Kyung Son, Sang Hoon Lee et al, 2006).

In order to prevent radiation spreading to biomedical engineers or radiographer students, value of current and voltage need to be set appropriately to yield a good quality of images for their study. The problems are they need to know an appropriate value regarding the current and voltage in order to prevent radiation exposure. In addition, the positioning technique is of great importance in radiology in order to obtain an accurate diagnostic information (T. Maruyama & H. Yamamoto, 2007). It is expected that training system will become useful as a teaching material to help the practice of the CT scan uses without a huge x-ray exposure.

The need to reduce CT scan dose to the patients, especially pediatric patients has grown considerably since the introduction of multi-slice CT scanners (D.J. Brenner et al, 2001; A. Paterson et al, 2001; J.R. Haaga, 2001; T.L. Slovis, 2002; L.F. Rogers, 2002) and also to prevent a radiation on biomedical engineers or radiologists. Another big opportunity of having a trainer system for clinical researchers in to investigating the scanning techniques required in order to obtain the image quality, thus a confident diagnosis is obtained for given clinical application. Several researchers have been shown the feasibility of reducing CT doses to the patients while maintaining diagnostic integrity. Manufactures are also doing their shares to improve the dos efficiency (J.G. Ravenel et al, 2001; A.L. Spielmann et al, 2002; S.R. Prasad et al, 2002).

In order to understand the modern advanced CT imaging technology, one should know the basic operation principle of it. But now it is difficult to find a 1st generation CT Scanner for a demonstration. Moreover, X-ray has been proved to be harmful and many people are scared of it. Therefore it will be desirable to have a teaching model, which can demonstrate the operation of a 1st generation CT scanner harmlessly (Chi Hou et al, 2003).

There is evidence suggesting that a general lack of awareness regarding radiation risks among both health care workers and patients (Lee CI et al, 2004). The increase in utilization has led to a parallel increase in concern regarding radiation risks [14]. Almost half (48%) of the total dose of ionizing radiation exposure for individuals in United States (including background radiation) has been attributed to medical tests and procedures (Prokop, 2004; Smith-Bindman et al, 2009; Evan KG et al, 2006). It is estimated that use of CT may be associated with 1.5% to 2% of all cancers in the United States in the future (Brener et al, 2007; Terry, 2007; Larson et al, 2007).

Basically, the main objective of this study is to develop a training system that can be used by biomedical engineers and radiographer students to learn the basic working principles of x-ray computed tomography system in order to get good quality images with lowest possible radiation hazard. In order to achieve the objective of the project, several scopes had been outlined. The scope of this project is to develop a system that shows the work principles of x-ray computed tomography machine. Last but not least is development of software for training system using National Instrument's Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW). The development process is focused on high voltage generator component, x-ray tube subsystem, detector subsystem, CT imaging subsystem, and reconstruction subsystem.

■2.0 MATERIAL AND METHOD

In this section is discussing about the materials used and methods of development process. Computer based computed tomography training system was developed using LabVIEW. The procedures comprised of various steps such as technology review and system development process.

Development Process

Figure 1 shows the flow chart of the development process. Firstly, we made a review of some CT machine technology over the years. All information such as high voltage generator system, x-ray tube system, displays system and reconstruction process were gathered. After gathering the information, LabVIEW software was used in order to understand the basic codes. Then, development process continued to develop generator component, x-ray tube subsystem, detector subsystem, imaging subsystem, and finally is reconstruction subsystem.

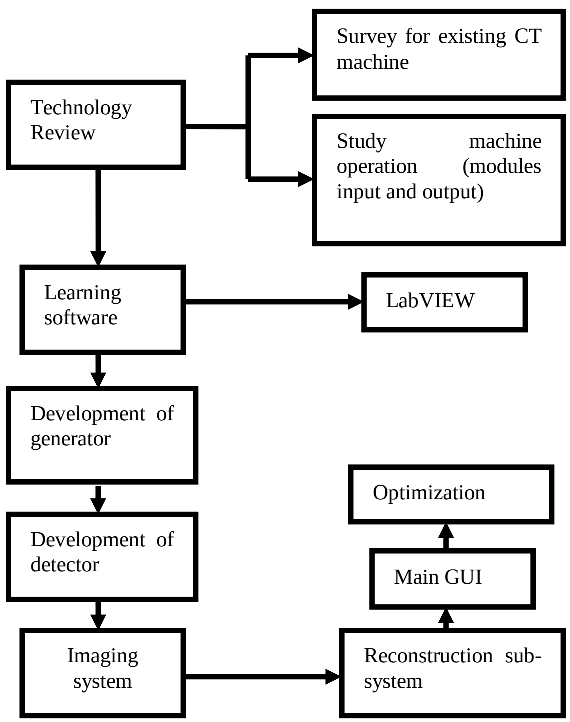

Figure 1 Flow chart of development process

LabVIEW Software

Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) is a product of National Instruments Corp. Its development environment offers fast and intuitive coding with compatible drivers for many laboratory equipment. LabVIEW has in two windows as follows:

1. Block diagram where the code development takes place.
2. Front panel where Graphical User Interface (GUI) is created.

The creation of the GUI is similar to creation of a slide in a PowerPoint presentation; the programmer can select the objects such as controls, devices, plots, or displays from the menu and drop them onto the Front Panel window. The position, size, and appearance can be changed using the mouse keys (Robert, 2006; Rahman, 2000).

In this study, we used LabVIEW version 2011 to develop the GUI. In addition, we also used IMAQ Vision Acquisition Software September 2011 as an additional tool due to the fact that training system requires image processing subsystem. The IMAQ Vision for LabVIEW is intended for engineers and scientists who have knowledge of the LabVIEW programming environment and need to create machine vision and image processing applications using LabVIEW VIs. Moreover, we did not use real-time to acquire the image, but we create a small phantom (circle) in the system in order to be CT scan during the training process.

■3.0 RESULTS AND DISCUSSION

This section shows the results of the study. Graphical User Interface (GUI) was developed and the system is successfully working. It consists of generator component, x-ray subsystem, detector subsystem, imaging subsystem and reconstruction subsystem. All the simulation can be stopped at any time by pressing the 'return', 'stop' or 'exit' button located at each of front panel.

Main GUI

This GUI uses complex codes in LabVIEW. The screen shows an image after reconstruction process in order to display the output to biomedical engineers and radiographer students. Important parameters in real CT scanner can be set in this main GUI such as x-ray tube voltage (kVp), focal length (cm), pixel length (cm) and projection number of scan. These input is affecting the final result of reconstruction process such as image quality in term of contrast, photon emitted, dose value and image pixel row. Figure 2 below shows the main GUI in this study.

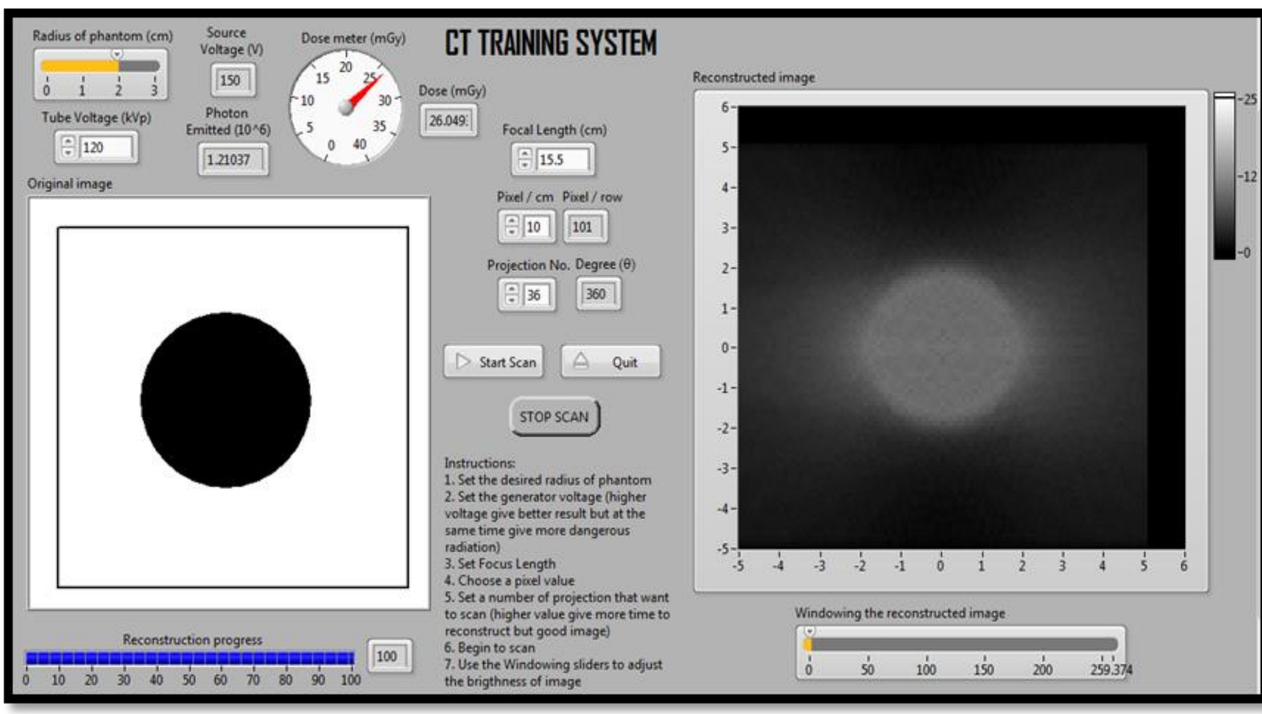

Figure 2 Main GUI of computer based x-ray computed tomography training system

GUI Performance Analysis

In this section is explaining about the performance of the system. This GUI comprised of eight controls; radius of phantom (cm), tube voltage (kVp), focal length (cm), pixel length (cm), projection number, start scan, stop scan and quit button.

I. Changing the tube voltage

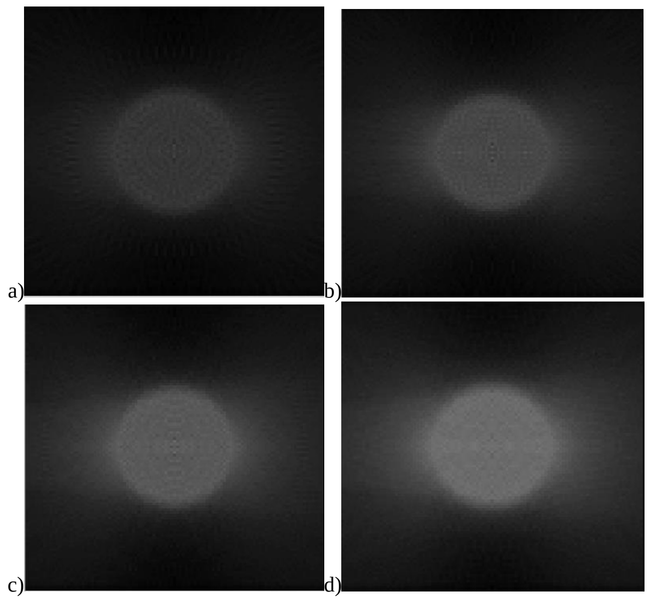

Figure 3 Reconstructed images; (a)60, (b)80, (c)100, (d)120kVp

Figure 3 shows the reconstructed images after scanning process has been done. To differentiate the quality of reconstructed images, we used different value of tube voltage which were 60, 80, 100, and 120 kVp with a constant radius of phantom (2cm), focal length (15.5cm), pixel length (10cm) and projection numbers (36 projections). In this testing, the dose meter and photon emitted value as shown in Table 1.

Table 1 Results of reconstructed images

Images	Tube voltage (kVp)	Dose value (mGy)	Photon emitted (10^6)
a	60	13.02	0.6052
b	80	17.37	0.8069
c	100	21.71	1.0086
d	120	26.05	1.2104

Referring to the Figure 3, higher tube voltage value increased the brightness of the reconstructed image (Robb & Richard, 1999). But at the same time, unfortunately, x-ray radiation hazard is increased (Hye-Kyung Son et al, 2006) as shown in Table 1.

II. Changing the projection number

A good reconstruction result can be achieved with smaller angular resolution of the object projection image (Evan KG & Lafleur HG, 2006). By setting higher projection number, angular resolution will be decreased. The simple equation for angular resolution is shown as follows:

angular resolution = 360° / projection number

For example, if projection number is 36, the angular resolution is 10°. That means the x-ray tube will scan 36 times with 10° of angular resolution. By using this system, constant value for radius of phantom (2cm), tube voltage (100kVp), focal length (15.5cm) and pixel length (10cm) were set to reconstruct the image for 36, 48, 60 and 72 of projections. Reconstructed results are shown in Figure 4.

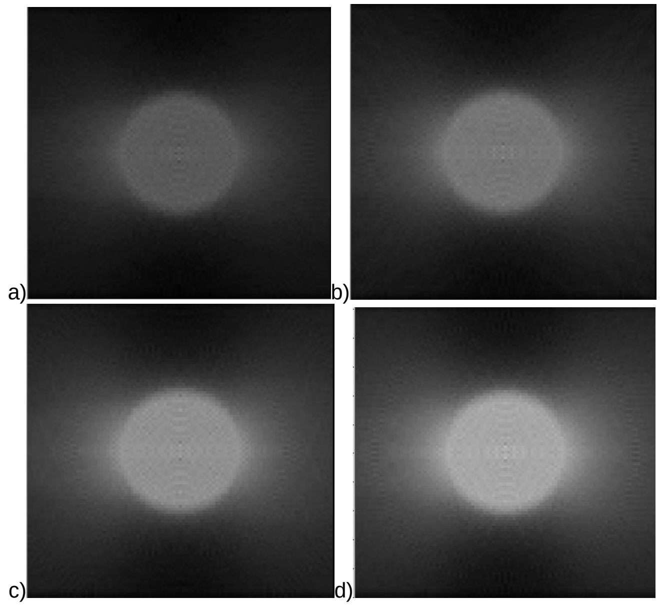

Figure 4 Reconstructed images; (a)36, (b)48, (c)60, (d)72 projections number

As shown in Figure 4, projection number is also play an important role in producing good quality images (Evan KG & Lafleur HG, 2006). With high value in projection number, reconstructed image is better and brighter. Results shows that image in Figure 4 (d) is brighter than image in Figure 4(a), 4(b) and 4(c). Unfortunately, by using 72 projection number, time to reconstruct the image is an issue. The time taken is much higher than using less number of projection.

Another method to obtain good quality of images is by setting value for tube voltage, focal length, projection number as well as pixel length (Evan KG & Lafleur HG, 2006).. Unfortunately, in real CT machine, it will give more radiation exposure to the patient if the radiographer uses high kVp. Moreover, the reconstruction process is also time consuming. Nevertheless, by using this system as a training module, biomedical engineers and radiographer students will more understand better the concept of x-ray CT machine without radiation exposure during the learning process.

■4.0 CONCLUSION

A system has been developed for biomedical engineers and radiographer students to learn basic principles of CT machine. A computer based x-ray computed tomography training system was developed using LabVIEW which provide real world relevant training at low cost as well as prevent radiation exposure. The system developed has graphical user interface that easy to use, understand and can be installed at any computer in the laboratory.

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