Proceedings of ICXRI 2010
International Conference on X-Rays & Related Techniques in Research & Industry
June 9 – 10, 2010, Aseania Resort Langkawi, Malaysia

ICXRI 2010

Computed Tomography Virtual Lab Software Application in Biomedical Electronic Engineering Programme At University Malaysia Perlis

Zulkarnay Zakaria[1,2], Mohd Hafiz Fazalul Rahiman[1], Saidatul Ardeenawati Awang[2], Nur Farahiyah Mohamad[2], Azaian Azamimi Abdullah[2] and Ruzairi Abdul Rahim[3]

[1] *Tomographic Imaging Research Group,*
School of Mechatronic Engineering,
Universiti Malaysia Perlis,
02600 Jejawi, Perlis, Malaysia.
Tel: 604-9885167, Fax: 604-9886158

[2] *Biomedical Electronic Engineering,*
School of Mechatronic Engineering,
Universiti Malaysia Perlis,
02600 Jejawi, Perlis, Malaysia.
Tel: 604-9885167, Fax: 604-9886158

[3] *Process Tomography Research Group (PROTOM), Control and Instrumentation Engineering Department,*
Faculty of Electrical Engineering, Universiti Teknologi Malaysia,
81310 Skudai, Johor, Malaysia.

E-mail: zulkarnay@unimap.edu.my

Abstract— Computed Tomography (CT) is a medical imaging method and is among the common equipment or machine in a hospital which is vital in imaging certain parts of human body for the purpose of screening and detecting of deceases like cancers, tumors and several others by producing characteristics of the internal structure of the object such as dimensions, shape, internal defects, and density. CT is a powerful nondestructive technique for producing cross sectional image 2D or 3D depends on the technologies applied. Since its introduction in the 1970s, CT has become an important tool in medical imaging to supplement X-rays and medical ultrasonography. In University Malaysia Perlis (UniMAP), Computed Tomography and Applications has been offered as an elective course in Biomedical Electronic Engineering Programme. In this course, the student are introduced to the Computed Tomography Virtual Lab Software which has been developed by Tomographic Imaging Research Group, School of Mechatronic Engineering, UniMAP in 2009 as part of the teaching aids. Through this approached, the course are more attractive and the students are found easier in understanding the concept of basic tomography system, image reconstruction process, limitations and several possible of error sources.

***Keywords*:** computed tomography, virtual software, imaging and elective course

I. INTRODUCTION

The invention of X-ray machine by Roentgen in 1895 has motivated the medical imaging industry in the world. By the year 1974, Siemens Medical Solutions (then known as Siemens Medical Engineering) has introduced first commercially computed tomography systems. While two years before that, Hounsfield and Cormack had invented computed tomography by combining computer technology and x-ray technology [1]. Computed tomography (CT) system is a system which provides cross sectional images of an object non-invasively [2],[5],[6],[9] and [10]. Nowadays the computed tomography have been applied in industrial process through the use of optical technique, electrical capacitance and several others in visualizing the fluid flows, gas and solid hold ups and chemical processes [4]. Even the progress in industrial process tomography is quite aggressive, but the original applications in medical field are not forgettable. In medical applications, CT technology are used for diagnosing purposes such as cancers, tumors, blood clot, brain injuries, scalp fractures and several others. Nowadays CT machine besides Magnetic Resonance Imaging (MRI) has become among vital equipments in hospitals in the world and so to Malaysia. Due this reason, most of the universities whose offer Biomedical Engineering Programme introduces Computed Tomography course in their curriculum structure as part of the exposure to their students to the CT technologies. In Biomedical Electronic Engineering Programme at University Malaysia Perlis (UniMAP), an elective course known as Computed Tomography and Applications has been offered to the final year students to fulfill this objective. With a big numbers of students in the class, it's quite a challenge for the lecturers to deliver the theory on the tomography concepts and several case studies to the students without using real CT scanner machine. Take the responsibility, Tomographic Imaging Research Group in the School of Mechatronic Engineering, UniMAP has invented Computed Tomography Virtual Lab Software which is a standalone software as an initiative to enhance the understanding and create interest of the students during the learning sessions of this course. The simulation software has been develop in such that similar to the actual Computed Tomography Scanning System where the sensor projections have been substituted with the virtual sensor projections. The simulation software eliminates the need of the expensive CT machine to estimate the Computed Tomography Scanned images.

II. ULTRASONIC TOMOGRAPHY CONCEPT

This software has applied ultrasonic tomography concept through the implementation of 32 ultrasonic transceivers in a sensor jig as shown in Figure 1. The medium of the measurement is assumed to be liquid while the phantoms used are filled with gas. Since the acoustic impedance difference Z between liquid and gas at interfaces is high, thus the acoustic energy transmitted is almost 100% blocked by the phantom and cannot receive by the receiver. The behaviour of a normal ultrasonic wave front at interfaces in terms of power reflection (P_r) and power transmission (P_T) coefficient are given by the formula:

$$P_r = \left(\frac{p_r}{p_i}\right)^2 = \left[\frac{(Z_2 - Z_1)}{(Z_2 + Z_1)}\right]^2 \quad (1)$$

Where P_r is reflected sound pressures, P_t is transmitted sound pressures, and P_i is incident sound pressures [2].

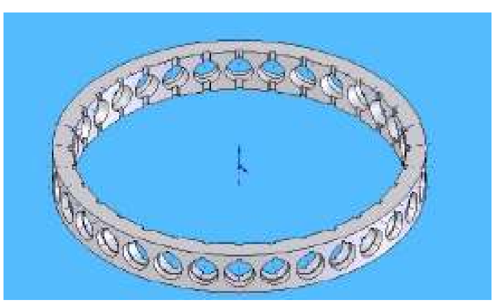

Figure 1: Sensor jig

Data received by the receiver is then processed to produce image of the phantom using image reconstruction algorithm. This software has applied Linear Back Projection (LBP) Algorithm. In LBP technique, in reconstructing the image, each sensitivity matrix is multiplied by its corresponding sensor loss value; this is same as back project each sensor loss value to the image plane individually [3],[5],[7] and [8]. If the scanning of each tomogram slice is fast and a set of axially spaced slice views is obtained, they can be assembled into a whole body image as shown in Fig. 2.

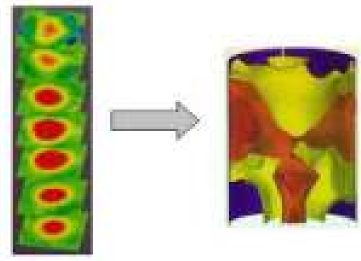

Fig. 2: Image reconstruction concept

LBP algorithm can be best explain by equation (2) below

$$V_{LBP}(x,y) = \sum_{Tx=1}^{16}\sum_{Rx=1}^{16} S_{Tx,Rx} \times \overline{M}_{Tx,Rx}(x,y) \quad (2)$$

Where ;
$V_{LBP}(x,y)$ = voltage distribution obtained using LBP, $S_{Tx,Rx}$ = sensor loss voltage of transmitter and receiver and $\overline{M}_{Tx,Rx}(x,y)$ = Normalized sensitivity maps.

III. SOFTWARE FEATURES

The Computed Tomography Virtual Lab software is capable of performing the forward modeling based on the pre-defined image reconstruction algorithms and sensor array arrangements. Conventionally, to design and develop the tomography system, the mathematical modeling of the sensor projections are needed in order to determine the suitable image reconstruction algorithm. To follow such requirement, it has to go along the process which waste lots of time. Some interesting features of this software are:

i) User friendly software
ii) Multiple phantoms available for simulation
iii) Easily link the output data with MATLAB
iv) Phantom Size Estimation
v) Simplify modelling for Image Reconstruction Algorithm development

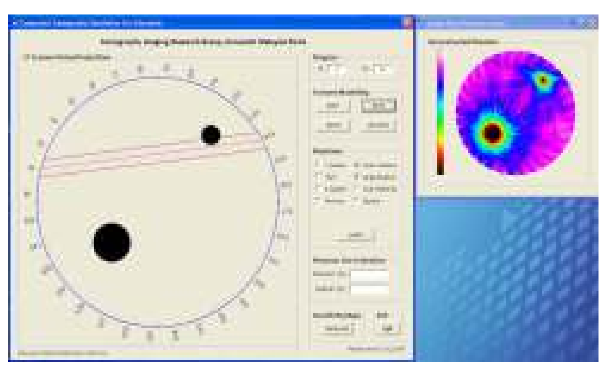

Figure 3: User friendly GUI of Computed Tomography Virtual Lab Software

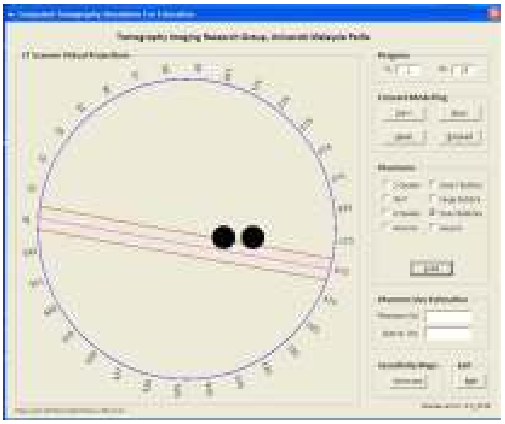

Figure 4: Multiple phantom selection

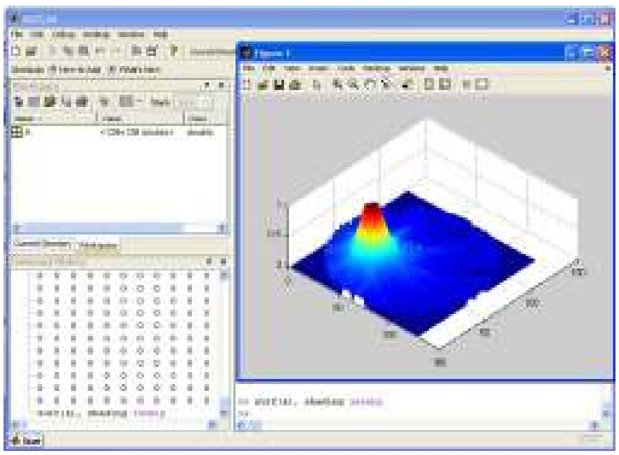

Figure 5: Linking with MATLAB

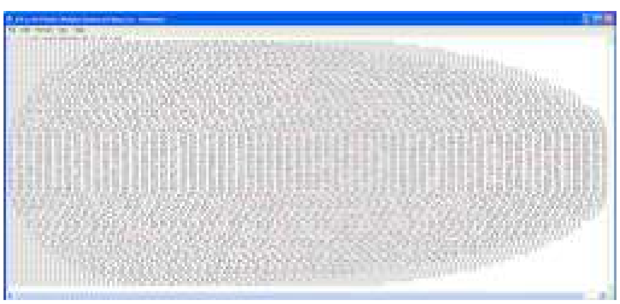

Figure 6: Data matrix

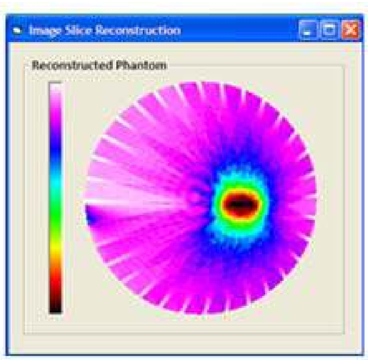

Figure 7: Reconstructed Image

All the mentioned features above as in Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7 have made this software very helpful as a learning aid for the course either during lecture, tutorial or lab sessions. Several case studies or analysis based on phantom size, location and data matrix also available for the students.

IV. ADVANTAGES

Since the software is standalone, the Computed Tomography and Aplications course lab sessions are run in a computer lab with all desktop computers installed with the software. All the students have to do the lab simulations, analysis and exercises in each session individually as shown in Figure 8. This will force the students to work independently while having more opportunity to understand the course during the lab sessions.

Figure 8: Lab session of Computed Tomography & Applications course

V. CONCLUSION

For a university with no university's hospital like UniMAP, in teaching the theoretical course like Computed Tomography and Applications, it is worth of focusing on this software rather than spending large amount of budget for buying a real CT scanner machine. It is a bonus if have one. The drawback are not only the price is high, to operate the machine also need a well trained staff which is involve another extra amount of money and time. Other than that, large space is compulsory for locating the machine in the lab. Last but not least is on the maintenance side.

REFERENCES

[1] A Brief History of Computed Tomography, www.medical.siemens.com

[2] Zulkarnay Zakaria, Mohd Hafiz Fazalul Rahiman, Ruzairi Abdul Rahim (2010), "Simulation Of The Two-Phase Liquid – Gas Flow Through Ultrasonic Transceivers Application in Ultrasonic Tomography", IFSA Sensors & Transduces Journal (ISSN 1726-5479), Vol.112, Issue 1, January 2010, pp.24-38

[3] R Abdul Rahim, M H Fazalul Rahiman, K S Chan, S.W. Nawawi (2007). "Non-invasive Imaging of Liquid/Gas Flow using Ultrasonic Transmission-Mode Tomography". Elsevier Sciences Journal Sensors and Actuators A: Physical, Vol 135, Issue 2, pp: 337-345.

[4] R Abdul Rahim L C Leong, , K S Chan, M.H Rahiman and J F Pang (2008). "Real Time Mass Flow rate measurement using multiple fan beam optical tomography". The Instrumentation, Systems and Automation Society (ISA) Transactions journal, USA, Vol 47, Issue 1, pp: 3-14.

[5] K.S. Chan, "Real-Time Image Reconstruction for Fan Beam Optical Tomography System," M.Eng. Thesis, Universiti Teknologi Malaysia, 2002.

[6] Yang, M., Hermann, I. S., Hoyle, B.S., Beck, M. S., Lenn, C., (1999). "Real Time Ultrasound Process Tomography for Two-Phase Flow Imaging Using a Reduced Number of Transducers." IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 46.

[7] Fazalul Rahiman, M.H., Abdul Rahim, R., Fazalul Rahiman, M.H., and Tajuddin, M. (2006). Ultrasonic Transmission-Mode Tomography Imaging for Liquid/Gas Two-Phase Flow, *IEEE Sensors Journal*. 6: 1706-1715.

[8] R Abdul Rahim, M H Fazalul Rahiman, K S Chan, S.W. Nawawi (2007). "Non-invasive Imaging of Liquid/Gas Flow using Ultrasonic Transmission-Mode Tomography". Elsevier Sciences Journal Sensors and Actuators A: Physical, Vol 135, Issue 2, pp: 337-345.

[9] B.S. Hoyle, and L.A, Xu, "Ultrasonic Sensors," in R.A. Williams and M.S. Beck, Process Tomography: Principles, Techniques and Applications, Oxford: Butterworth-Heinemann, pp. 119-149, 1995.

[10] W. Warsito, M. Ohkawa, N. Kawata, and S. Uchida, "Cross-Sectional Distributions of Gas and Solid Holdups in Slurry Bubble Column Investigated by Ultrasonic Computed Tomography," Journal Chemical Engineering Science, vol. 54, pp. 4711-4728, 1999.