

Graphical User Interface for Electrical Resistance Tomography System on Static Gas Bubble in a Vertical Metallic Column

Suzanna Ridzuan Aw^{1*}, Wan Azman Wan Abdullah¹, Ruzairi Abd Rahim², Yasmin Abdul Wahab³, Mohd Hafiz Fazalul Rahiman⁴, Zulkarnay Zakaria⁴, Elmy Johana Mohamed⁵, Siti Zarina Muji⁵, Jaysuman Puspanathan² and Leow Pei Ling²

¹Faculty of Engineering Technology, University College TATI, 24000, Kemaman, Terengganu, Malaysia

²School of Electrical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

³Faculty of Electrical & Electronics Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia

⁴Centre of Excellence for Advanced Sensor Technology, School of Mechatronic Engineering, Universiti Malaysia Perlis, Arau 01000, Malaysia

⁵Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia

*Corresponding author: suzanna_aw@uctati.edu.my, Tel: 609-8601453

Abstract: This paper presents the software development for the ERT system used to monitor the static two phase (liquid/gas) flow for the application of a metallic bubble column wall. The software is developed using Graphical User Interface (GUI) application program in MATLAB. The software contains numerous functions to enable users to obtain the necessary information from the research. The animated projection of a single pair projection of the sensitivity distribution for a conducting boundary strategy, along with its weight balance map and normalised sensitivity map, can be viewed from the sensitivity distribution dropdown list. The images for the metal column with several phantoms using COMSOL simulation and experimental data can be viewed by clicking the construct image button in the GUI. The value for the assessment of the quality of each image is also displayed concurrently for each phantom selected.

Keywords: Electrical Resistance Tomography, GUI, MATLAB user interface

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1. INTRODUCTION

Knowing the process flow conditions can help in managing the downstream processes. It would be highly beneficial to measure the flow of each phase in the pipe; ideally the mass, volume, and degree of mixing within the pipe.

By adapting ERT, early monitoring of the existence of gas can be facilitated, resulting in an ability to monitor or assess the effect of process changes on process quality and efficiency. It may also be used to compensate the process instrumentation affected by entrained gas, mainly in relation to flow measurement, density measurement, and watercut measurement. Changes in process operations, due to air or gas leaks caused by the pump/valve packaging or flange/pipe problems, can be detected if tomography is applied. Monitoring the process flows will increase throughput, enhance measurement accuracy, and optimise chemical additive usage.

The ERT system has been used in numerous applications in process tomography. There are numerous examples of ERT being employed to qualitatively image

the material distribution of multiphase processes within electrically insulated (non-conducting) walls. Among them are the research by Low et al. [1] which demonstrated the great potential of ERT in measuring active volume in a mixing column for multiphase flow, Sardeshpande et al. [2], [3] published papers on the use of ERT in visualising the gas liquid flows in a stirred tank reactor and Hashemi et. al [4] investigated bubble behaviour in an aerated mixing vessel of a viscous corn syrup solution. Babaei et al. [5] used ERT to analyse gas phase behaviour in an activated sludge bubble column. Bubble size and conductivity of the boundary of bubbles in a flotation froth were estimated by Nissinen et al. [6].

However, relatively few empirical research studies have investigated ERT systems for a conducting wall application [7]. The aim for this research part is to develop a software using MATLAB GUI so that it can benefit other researchers in the same field.

2. ERT MEASUREMENT STRATEGY FOR CONDUCTING VESSELS

A measurement strategy is necessary, especially in ERT, to define an experiment that involves a metal or conducting vessel. In ERT, quantitative data which describe the state of the conductivity distribution inside the vessel are obtained. It is important to have some good data collection strategies. This is because largely misleading images can be rebuilt if a full set of independent measurements are not collected. For all intents and purposes, selecting a strategy that has a good ability to distinguish and high sensitivity to conductivity changes in the process is necessary. There are four main strategies in ERT: the adjacent strategy, conducting boundary strategy, opposite strategy, and diagonal strategy [8].

The first application of ERT only considered electrode arrangements operating within vessels that have insulating walls and applied the adjacent measurement strategy, which is the most common. It involves injecting current between an adjacent pair of electrodes and measuring voltage from successive pairs of neighbouring electrodes. The injection pair is switched through the next electrode pair until all independent combinations of measurements have been completed. However, most of the process vessels in industry have conducting walls and therefore provide an additional current sink during the measurement process. This causes both reduced sensitivity in the bulk of the material and increased difficulty in obtaining stable measurements referenced to the injected currents [9].

Before applying ERT to an electrically-conducting vessel, an electrical path passing through the vessel wall must be considered. The adjacent strategy is unsuitable for application to the conducting vessel because much of the electrical current from the injection electrode would travel to ground through the material of the wall, rather than through the multiphase mixture, greatly reducing sensitivity. This is known as the grounding effect of the vessel. One possible method of accounting for the conducting vessel wall is to use the wall itself as the ground electrode. The conducting boundary strategy, as discussed previously, was proposed and developed by Wang [10] for conducting vessel walls to overcome the grounding effect. The grounding effect for both adjacent and conducting strategies is illustrated in Figure 1.

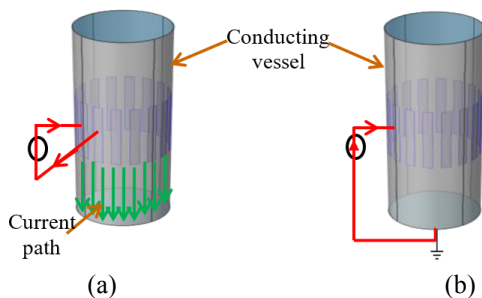


Figure 1. Grounding effect
a) Adjacent strategy,
b) Conducting boundary strategy

The conducting boundary strategy considers each electrode acting sequentially as a current source, whilst the whole of the metallic vessel behaves as a grounded current sink. In this strategy, all voltage measurements are referenced to the same earth potential as the conducting boundary.

3. METHODOLOGY

The output potential reading obtained in COMSOL for homogeneous and non-homogeneous systems were recorded to form the sensor loss data. The same procedure was applied to the experimental part. The data were then transferred into MATLAB workspace for further processing. For each phantom under investigation, the sensor loss data were loaded before performing the LBP algorithm for image reconstruction. Subsequently, the LBP routine in Figure 2 was applied towards the selected phantom. For the routine, the output potential at receiver 1 was recorded first when transmitter 1 transmitted the current source. All possible independent measurements for that particular phantom were then taken to obtain the sensor loss. Once the sixteen scans were completed, the tomogram was reconstructed by performing the LBP algorithm as in [11].

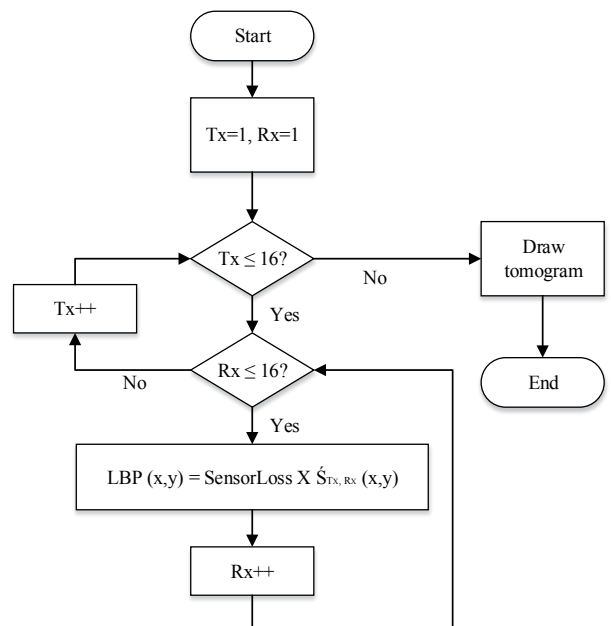


Figure 2. LBP routine

After the image reconstruction part were done, the software for the current study was developed using the Graphical User Interface (GUI) application program in MATLAB. The software contains numerous functions to enable users to obtain the necessary information from the research. The GUI that is created is depicted in Figure 3. The animated projection of a single pair projection of the sensitivity distribution for a conducting boundary strategy, along with its weight balance map and normalised sensitivity map, can be viewed from the sensitivity distribution dropdown list. The images for the metal column with several phantoms using COMSOL simulation and experimental data can be viewed by clicking the

construct image button in the GUI. The value for the assessment of the quality of each image is then displayed for each phantom selected.

In developing the software, a MATLAB user interface, UI using GUIDE, was chosen over programmable UI. The GUIDE environment consists of push buttons, pull-down menus, list boxes, and plots. Users can creatively design the environment to suit their needs. To create the ERT software for this research, a blank window was opened using the “guide” command in MATLAB. After a blank GUI appeared, the required components were positioned within the graphical layout editor as displayed in Figure 4. The components in the GUIDE can be manipulated programmatically according to user requirements by right clicking the mouse within the window to open the MATLAB editor.

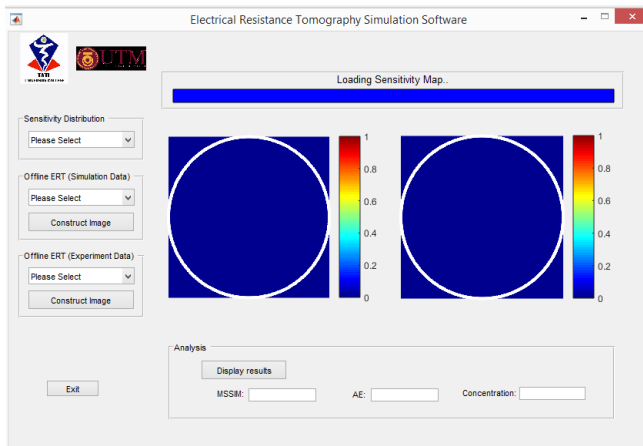


Figure 3. GUI application program

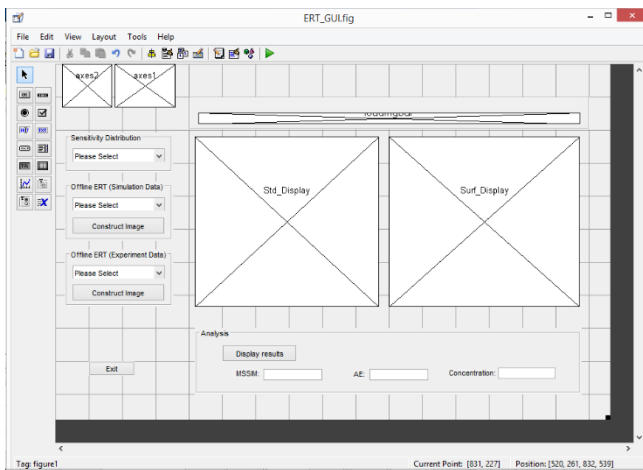


Figure 4. Software development using GUIDE

4. RESULTS AND DISCUSSION

The GUI was first initialised in the MATLAB editor linked by the saved GUIDE. The related variables were then loaded into the software. These include the sensitivity maps, weight balanced maps, and the normalised sensitivity maps. When users select the single pair projection from the sensitivity distribution droplist, the software will show the animated projection for every

single projection electrode pair developed for the conducting boundary strategy. This is shown in Figure 5. The weight balance map can also be viewed from the sensitivity distribution selection droplist, as shown in Figure 6. The animated projection for normalised sensitivity maps in 2D and 3D plot will be displayed in the software, as shown in Figure 7.

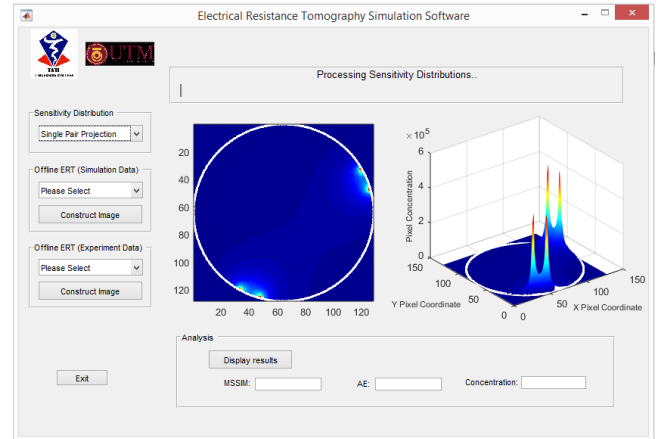


Figure 5. 2D and 3D plot of sensitivity maps for the conducting strategy

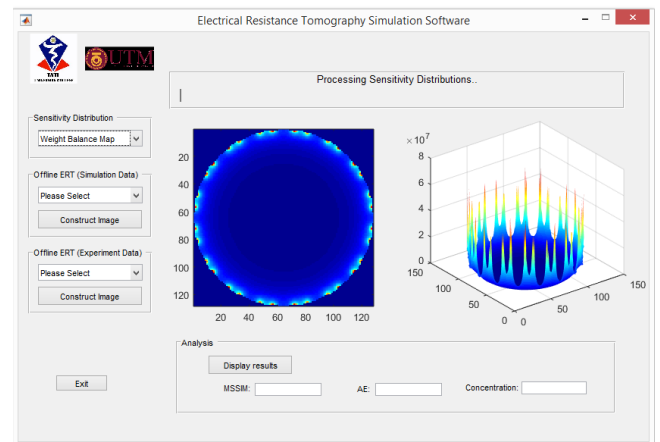


Figure 6. Weight balance map for the conducting boundary strategy

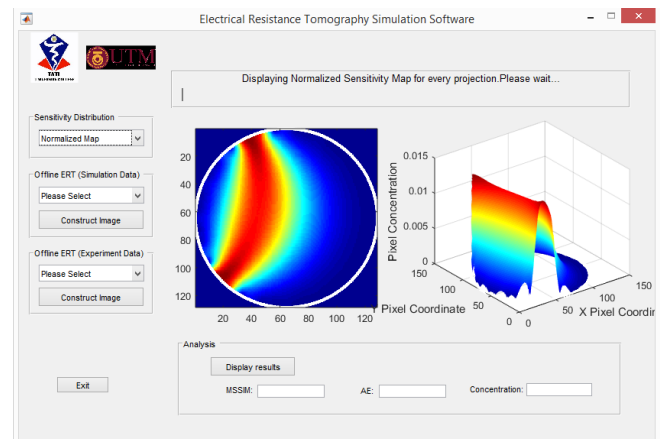


Figure 7. 2D and 3D plots for normalised sensitivity map

The software also provides the LBP reconstructed images for every single phantom created in the COMSOL simulation and via experiment. The user simply needs to

select the phantom from the selection droplist and click *Construct Image*. The values for the MSSIM, the AE, and gas concentration will be displayed for every image generated. Figure 8 illustrates what happens when four 10 mm diameter bubble phantoms in a column are selected. The right-hand side shows the image displayed when the *Construct Image* button was clicked.

For the simulation data, the output potential readings obtained in COMSOL for homogeneous and non-homogeneous systems were recorded to form the sensor loss data. The same procedure was applied in the experiments. The data were then transferred into MATLAB workspace for further processing. For each selected phantom, the sensor loss data were loaded before performing the LBP algorithm for image reconstruction. Subsequently, the LBP routine in Figure 1 was applied to the selected phantom.

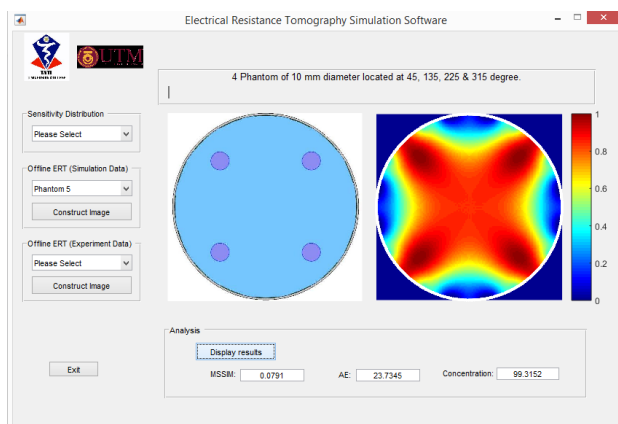


Figure 8. LBP reconstructed image for selected gas phantom

5. CONCLUSION

For the software development, a MATLAB user interface was applied and explained thoroughly in this paper. A MATLAB user interface, UI using GUIDE, was chosen to create the software. The software developed successfully viewed the animated projection for every single projection electrode pair developed for the conducting boundary strategy, the weight balance map, the animated projection for normalised sensitivity maps in 2D and 3D plot the LBP reconstructed images for every single phantom created in the COMSOL simulations and experiments. The values for the image quality assessment were also displayed for every image generated.

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