A Platform for Processing the Electrical Capacitance Tomography Images

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Abstract: Electrical capacitance tomography is a process tomography technology based on medical CT technology. In recent years, ECT technology has been widely used in industry because of its non-invasive, safety and low-cost advantages. It is of great theoretical significance and practical value to further study the visualization technology of pipeline fluid by ECT technology. However, due to the limitation of the number of sensors' inductive electrodes, the capacitance data collected are not complete, and the traditional reconstruction algorithm cannot completely restore the distribution of fluid dielectric constant, which makes the spatial resolution of ECT reconstruction image low, even produces noise and artifacts. Therefore, the better reconstruction algorithm further processing of ECT reconstructed images are needed. In this paper, the better reconstruction algorithm and the post-processing methods of ECT reconstructed images are studied in detail. In this paper, a better reconstruction algorithm and ECT reconstruction post-processing method are studied in detail, a better reconstruction algorithm is designed, and a more perfect and convenient post-processing platform for processing the Electrical Capacitance tomography images is established.

1. Introduction

1.1 Research Background and Significance

In the process of capacitance tomography, due to the limitation of the number of inductive electrodes of the capacitance sensor, complete capacitance data cannot be collected, which will lead to the fact that the image reconstruction algorithm cannot completely restore the distribution of fluid dielectric constant, and make the spatial resolution of ECT reconstructed image relatively low, and even producing noise and artifacts. Therefore, in order to obtain image reconstruction features more efficiently, and then obtain higher quality imaging effects for us to have a more accurate grasp of fluid flow state, ECT reconstruction images need to be further processed [1].

We improved the ECT reconstruction algorithm, and then enhanced, de-noised and fused reconstructed images to smooth artifacts and separate the different phases of the fluid. By this method, the fluid state inside the multiphase flow can be visualized more accurately and the complex and changeable flow patterns that cannot be correctly reflected by conventional measuring instruments can be better monitored.

1.2 The Main Research Contents

The author introduces the software processing platform from four aspects respectively.

I functional requirements of the platform

II the overall display of the platform, the work display of the platform and the display of the divided areas of modules

III detailed function description of each module in the platform

IV main innovation points and features of the platform

2. The Main Research Contents of the Platform

2.1 The Functional Requirements:

The functional requirements of the platform are as follows:
1. Optimization of capacitance tomography algorithm
2. Phase separation holdup measurement
3. Analysis and measurement of image details
4. Post-processing the reconstructed image

2.2 Platform Display

2.2.1 The Overall Display of the Platform

The overall display of the platform is shown in figure 1.

Figure 1:the overall display of the platform

2.2.2 The Divided Areas of Platform Modules

The divided areas of platform modules are shown in figure 2.

2.3 Module Function Introduction:

2.3.1 Module 1: Capacitance Tomography Image Reconstruction Module

ECT can be divided into two parts: forward problem solving and inverse problem solving. The forward problem is to solve the electromagnetic field problem, that is, to solve the sensitivity distribution. However, the image reconstruction of capacitance tomography is to solve the inverse problem, that is, to obtain the medium distribution of the measured field through the distribution of capacitance measured values.

Figure 2: the module division area of platform

In ECT image reconstruction, the algorithms of inverse problem can be generally divided into three categories: the first is the direct algorithm, the second is the iterative algorithm, and the third is the new algorithm.

According to the research on various image reconstruction algorithms and the consideration of the reconstruction algorithm requirements, we discretized the cross-section image into 913 small grids (grid diagram is shown in figure 3), simulated the fluid state of the section, and finally designed the optimal image reconstruction algorithm (comparison of algorithms is shown in figure 4).Now users can accurately simulate ECT reconstructed images of fluid.

2.3.2 Module 2: Image Post-Processing Operation Module

This module mainly includes the function of optimizing and post-processing the reconstructed image to facilitate the user to analyze and process the reconstructed image. And each processing method also provides a variety of processing algorithms for users to choose according to their different needs for their own use.

The main functions of this module are:

1. Image size change

The image size transformation algorithm can be selected by the user. The nearest neighbor interpolation algorithm, bilinear interpolation algorithm and bicubic interpolation algorithm can be realized by the built-in parameters nearest, bilinear and bicubic in imresize function. Among them, the image size transformation multiple can be manually input to the edit box by the user and transferred to the size transformation function through the handle function for image processing.

2. Image rotation

Object rotation includes three basic rotation operations: horizontal rotation, vertical rotation and diagonal rotation.

3. Image threshold segmentation

For image threshold segmentation, users can choose to use Otsu algorithm, iterative segmentation algorithm based on minimum error threshold method, histogram threshold segmentation algorithm, general watershed segmentation algorithm, gradient quadratic watershed segmentation algorithm and gradient mask cubic watershed segmentation algorithm.

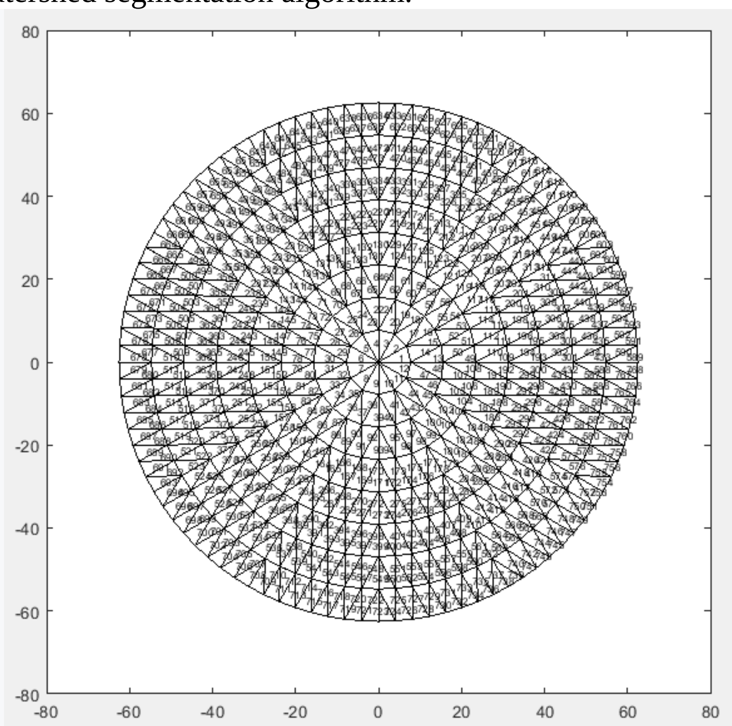

Figure 3: grid diagram

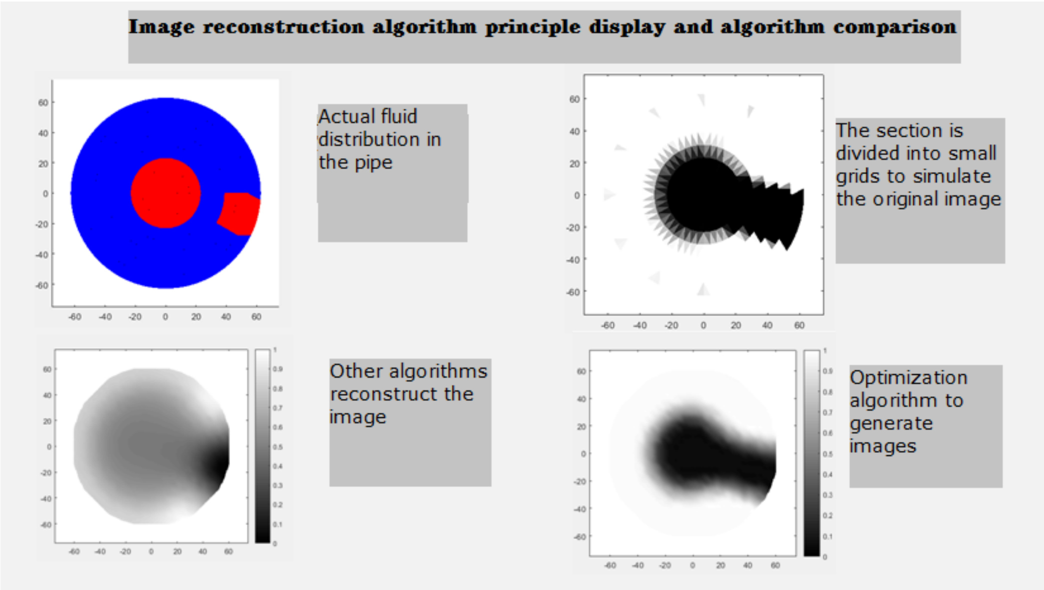

Figure 4:Algorithm comparison diagram

4. Image sharpening

For image sharpening, users can choose to use Soble operator filter method and butterworth high-pass filter method.

5. Image smoothness

For image smoothing, users can choose to use grayscale transformation method, median filter method, low-pass filter method and Deconvwnr function restoration method.

6. Image edge extraction

Edge extraction of the image is realized by the edge function in Matlab, which allows users to freely select built-in operators such as sobel, Roberts, prewitt, log, canny, etc., and then modify them by adjusting the parameters. The boundary between phase and phase is given after edge extraction, which greatly improves the visual effect of reconstructed image.

7. Image denoising

Image denoising is realized by medfilt2 median filter function and filter2 mean filter function.

8. Image histogram equalization

Histogram equalization is realized by histeq function.

9. Image enhancement

Image enhancement is achieved by Matlab built-in imadjust linear transform function.

2.3.3 Module 3: Phase Holdup Measurement Display Module

The application of electrical capacitance tomography in the study of two-phase flow is mainly aimed at monitoring the distribution, velocity and flow rate of each phase fluid when two-phase mixing is carried out in closed pipelines, oil-water flow systems and other industrial sites. In order to better determine the flow state of the closed pipeline, we need to reconstruct the ECT image in real time and calculate the holdup of each phase.

The formula for calculating the content is formula 1:

$$V_A = \frac{1}{N} \sum_{i=0,j=0}^{i=n,j=n} p(i,j) \tag{1}$$

In this formula, N is the number of pixels representing the section of the pipe, n is the image side length, p(i,j) is the gray value of pixel points in row i and column j. After threshold segmentation, the gray value of the background is 0. After calculation, VA is the desired holdup.

The four-bubble drip model with a holdup of 88.25% was used to simulate and reconstruct the image reconstruction algorithm of Landweber, and ECT images were processed. Otsu algorithm and the iterative algorithm based on the minimum error threshold were used to calculate the holdup after threshold segmentation, and compared with the model, we obtained the following set of results, as shown in table 1:

The content and error are shown in table 1.

Table 1. holdup and error of the four-bubble drip model with holdup of 88.25%

Threshold segmentation method	Phase holdup	error
Otsu algorithm	89.63%	1.56%
Iterative algorithm based on minimum error threshold method	89.13%	1.00%

According to the analysis of the obtained holdup and error, the segmentation results of the two algorithms are more in line with expectations, but the error is relatively large. This is because the artifact processing of the reconstructed image is not in place and the media distribution of the original model cannot be restored.In the actual post-processing of ECT reconstructed image, Otsu algorithm and the iterative threshold selection algorithm based on the minimum error threshold method have their own advantages and disadvantages, which are suitable for different flow patterns, and further identification and analysis of the image are needed for the specific selection.

2.3.4 Module 4: Image Detail Processing and Parameter Measurement Module

To study some of the more fuzzy or concentrated areas of the fluid, such as bubbles and impurities, we can zoom in on such detailed areas and further observe the shape of the fluid inside the pipe.

At the same time, the platform also has some measuring tools, which can measure the diameter and length of some objects locally in the image.

2.3.5 Module 5: Image Processing Method Comparison Module

For the post-processing function of reconstructed image, we usually provide a variety of processing methods for users to use. In order to let users, choose the most suitable processing method, we design an image processing method comparison module to facilitate users to choose the processing method they need.

2.4 Main Innovation Points and Features of the Platform

Specialty: the image reconstruction of liquid in industrial pipeline by the capacitance tomography simulation module in module 1 and the solution of image phase saturation in module 3 are both important parts of the capacitance tomography technology, because of this, this platform has strong practicability in ECT of industrial pipeline.

Industriality: as the background of the project is industrial pipeline, we focus on the application of the platform in industry for the research of various algorithms and experiments. The phase holdup study in module 3 and the detailed study in module 4 on bubbles or liquid impurities in industrial pipelines are based on the industrial background.

Friendly interface: compare the image processing method of module 5 with the image processing function of module 2, which gives users more comfortable experience.

3. Conclusion

In recent years, the rapid development of electrical capacitance tomography technology, with its non-invasive, low-cost, imaging speed, high security advantages, in the future industry, especially in the field of multi-phase flow, will play an important role. The principle is to reconstruct the distribution of fluid dielectric constant by measuring the capacitance distribution in the pipeline. In this paper, based on the current ECT system reconstruction image is not directly applied to data analysis and flow pattern identification, the reconstructed image is post-processed and human-computer interaction interface is designed. The main works are as follows:

1.Firstly, the research status of multiphase flow and capacitance tomography at home and abroad is reviewed, and the development trend is forecasted.

2.Then according to the existing ECT image reconstruction algorithm, a better image reconstruction algorithm is designed. Different image processing methods, such as histogram equalization, image denoising, threshold segmentation and edge extraction, were used for simulation experiments to compare the processing effects of various specific algorithms on ECT reconstructed images. Calculate the holdup of the simulation image and compare it with the original model, calculate the error, verify the application of Otsu algorithm and minimum threshold segmentation in ECT reconstruction image threshold segmentation.

3. At last, MATLAB was used to design human-computer interaction interface to realize simple and efficient one-click processing of ECT simulation images.

Acknowledgments

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References

[1] Ma min, zhang caixia, lu chengchao, wang huaxiang. ECT image processing based on wavelet transform [J]. Journal of central south university (natural science edition),2016,47(06):1947-1952.

[2] Dong feng, deng xiang, xu lijun, xu lingan. Overview of process tomography technology [J]. Instrument user,2001(01):6-11.

[3] Zhao yulei, guo baolong, yan yunyi. Research progress and analysis of capacitance tomography [J]. Chinese journal of instrumentation,2012,33(08):1909-1920.

[4] Ma ping, zhou xiaoning, tian pei. Development and application of process tomography [J]. Chemical automation and instrumentation,2009,36(01):1-5.

[5] Yu jinping. Research on image reconstruction and fusion methods of capacitance tomography [D]. Harbin university of science and technology,2016.

[6] Ma min, zhang caixia, lu chengchao, wang huaxiang. ECT image processing based on wavelet transform [J]. Journal of central south university (natural science edition),2016,47(06):1947-1952.