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Full paper

Edge Detection Algorithm For Enhancement of Linear Back Projection Tomographic Images

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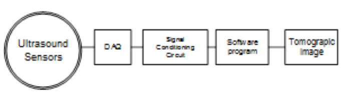
Graphical abstract



Abstract

Process tomography (PT) is a leading technique for multiphase flow measurement and flow monitoring systems in various fields. PT has the advantage of interpreting acquired measurement data and transforming it into visual tomographic images. The most common method of image reconstruction uses the linear back projection algorithm which often results in blurry images. This paper proposes an enhancement of the reconstructed images using an edge detection image processing technique to convolve with the original image. This filtering technique calculates approximation changes of the horizontal and vertical image derivatives, thus further enhancing image accuracy. Several ultrasonic tomography images were put into a simulation test to validate it. Hence, the image results are being assessed for its performance.

Keywords: Process tomography; ultrasonic tomography; image reconstruction; edge detection; convolution; multiphase flow measurement

■1.0 INTRODUCTION

Process tomography (PT) has forged a successful path as a well-known and important technique for multiphase flow measurements in real-time process monitoring systems. The efficiency of such a system is closely related to the accuracy of the measurements and the image quality.

A PT system concept can be built by mounting several sensors on a pipe's circumference invasively or non-invasively. The basic block diagram of ultrasonic tomography (UT) is illustrated as below in Figure 1.

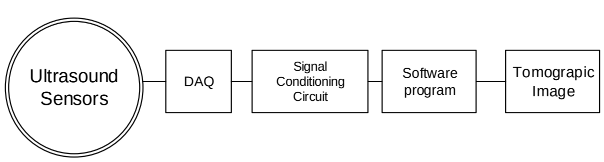


Figure 1 Ultrasonic tomography basic block diagram

1.1 Ultrasonic Tomography

UT has been employed non-invasively in this research. An ultrasonic transducer propagates acoustic waves within the range of 315–330 kHz through an acrylic pipe with a wall thickness of 5 mm before the transmitting signal wave penetrates through the liquid-gas medium inside the pipe. The basic principle of UT and its hardware setup is further discussed in [1–3].

The UT system has the advantage of imaging two-phase flow composition in the form of a tomographic image. To transform the acquired data into these images, the linear back projection (LBP) image reconstruction technique was applied. It is advantageous in that it requires little computation processing, thus LBP is computationally straightforward and easy to implement [4]. For this reason, LBP has been preferred by many previous researchers [3, 5–7] in their research fields.

Although LBP is simple and fast in performance, its accuracy is lower than that of iterative reconstruction methods such as that of Landweber and others. This is due to the smearing effect of each normalized measurement along its sensing zone which causes blurring in the reconstructed image [8]. Therefore, an image filtering technique, such as the edge detection method, could contribute to reducing the blurred effect, thus further enhancing the image quality.

■2.0 EDGE DETECTION

Edge detection (ED) methods are based on the information of each image's pixel edge by evaluating the adjacent pixel value. This method detects varying grey-level changes in the adjacent pixels. ED is a fundamental step in image analysis and image processing in the areas of feature detection of operators such as the Sobel operator.

2.1 Sobel Edge Detection Method

Sobel edge detection (SED) is one of the ED methods. It is a grey weighted algorithm of adjacent point pixels of Omni direction, which detects edges according to the phenomenon that it can reach extreme values in the edge points. SED is formed by two convolution kernels or mask operators as in the matrix Equations (1) and (2) as follows:

$$M_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (1)$$

$$M_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (2)$$

where M_x and M_y are the kernel masks in the horizontal (x) and vertical (y) directions of each convolved image pixel point which is represented as $f(x,y)$ by the size of the 3x3 matrix [9].

In the partial derivatives of x and y, the direction can be represented in Equations (3) and (4) [10, 11].

$$G_x = S_1 - S_2 \quad (3)$$

$$G_y = S_3 - S_4 \quad (4)$$

where:

$$S_1 = \{f(x+1, y-1) + 2f(x+1, y) + f(x+1, y+1)\}$$
$$S_2 = \{f(x-1, y-1) + 2f(x-1, y) + f(x-1, y+1)\}$$
$$S_3 = \{f(x-1, y+1) + 2f(x, y+1) + f(x+1, y+1)\}$$
$$S_4 = \{f(x-1, y-1) + 2f(x, y-1) + f(x+1, y-1)\}$$

The Sobel operator is the magnitude of the gradient computed by Equation (5).

$$G_{(x,y)} = |G_x| + |G_y| \quad (5)$$

The advantage of this method is that it is insensitive to noise compared to other types of operator, thus it has certain smoothing effects on noise [10]. Therefore, the blurry image caused by the smearing effect of the LBP could be reduced for image reconstruction processes. Figure 2 shows the Sobel filtering process.

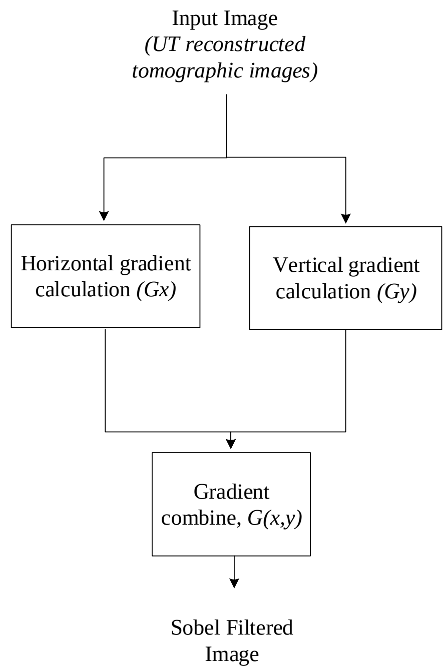


Figure 2 Sobel filtering process diagram

■3.0 RESULT AND ANALYSIS

The proposed SED algorithm was tested by employing it on simulated UT input images using Matlab software. The simulation analysed images are presented in Figure 3.

Three test profiles for the centre bubble profile, single bubble profile and two bubbles profile were generated as the reference images for image analysis and comparison purposes. The simulated input image of these test profiles was reconstructed using the LBP method as in Figure 3. The smearing effect of each projection beam, which causes the image to be blurred, is obvious in the LBP reconstructed images. After applying the Sobel filter, the result shows that the filtered input images are smoother and the smearing effect is further reduced.

Somehow, the quality of the filtered images has to be evaluated and analysed to validate their accuracy and performance.

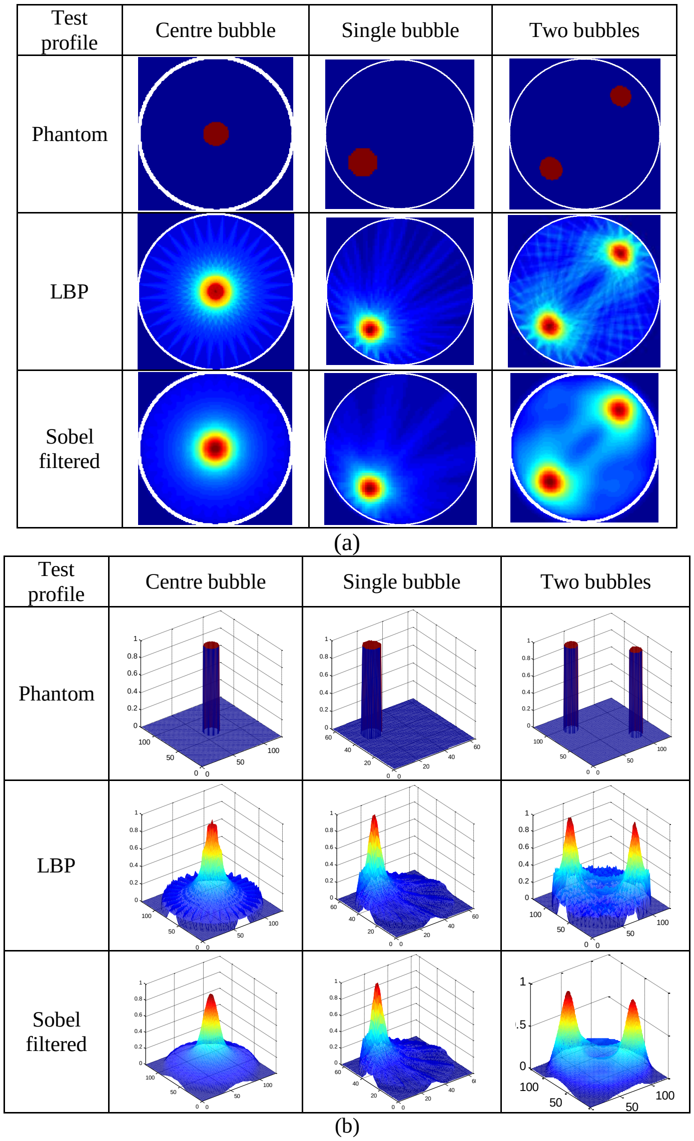


Figure 3: Simulated test profile images for: (a) 2D tomographic results (b) 3D tomographic results

3.1 Image Quality Assessment

To verify the performance of the output image, the linearity between the reconstructed image and the reference phantom image has to be measured. This can be done by assessing the correlation coefficient (r) method, as in Equation (6), of the output image.

$$r = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mn} - \bar{A})^2)(\sum_m \sum_n (B_{mn} - \bar{B})^2)}} \quad (6)$$

where A is the reference phantom image, $\bar{A}$ is the mean of the reference phantom image, B is the filtered output image and $\bar{B}$ is the mean of the filtered output image. Table 1 below shows the evaluation result while Figure 4 compares the evaluated results of both the LBP and Sobel filtered images.

Table 1 Correlation coefficient result for LBP input image and Sobel filtered output image

Test Profile	LBP	Sobel Filter
Centre bubble	0.6652	0.7120
Single bubble	0. 5977	0. 6320
Two bubbles	0.6195	0.6659

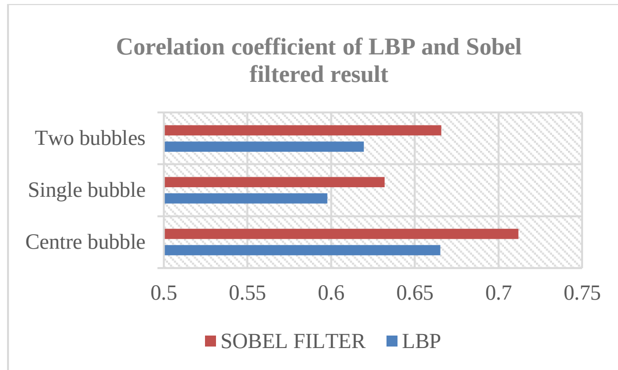


Figure 4 Correlation coefficient comparison for LBP and Sobel filtered results

The evaluated results from Table 1 and Figure 4 show that the post filtering output image has better results, which means it is highly correlated to the reference image compared to the LBP reconstructed input image. Consequently, the SED method has been proven to be effective and has successfully enhanced the image quality.

4.0 CONCLUSIONS

This paper presented SED, a method using the ED technique for tomographic image enhancement. This method has proven to be successful in improving the quality of the input image. To validate the output image results, both the input images were reconstructed using LBP and then the filtered output images were assessed using the correlation coefficient method. Moreover, the smearing effects arising from the LBP reconstructed image were reduced after the SED filtering took place, thus further smoothing these images for better visualization.

Acknowledgement

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