

## EMINENT PIXEL RECONSTRUCTION ALGORITHM FOR ULTRASONIC TOMOGRAPHY

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**Abstract.** Image reconstruction software and its image reconstruction algorithm are an important step towards constructing a tomography system. In this paper, description on the introduction of an image reconstruction algorithm for two-phase ultrasonic tomography system is presented. The algorithm, termed as the Eminent Pixel Reconstruction (EPR) algorithm is derived based on the basic Linear Back Projection (LBP) algorithm. This new image reconstruction algorithm successfully highlights high intensity pixels from the surrounding pixels in the cross-section image. The EPR algorithm are then combined with the useful Median Filter which helps eliminate the unrepresentative pixels resulting in reduced noise on the final reconstructed image. The algorithm is also deemed as a preferable choice other than the LBP algorithm since like the LBP, EPR is also a straightforward imaging method with higher success of reconstructing the component distribution and provides more accurate statistical estimation capability on the two-phase distribution.

**Keywords:** Image reconstruction algorithm; eminent pixel reconstruction; ultrasonic transmission tomography; two-phase flow; median filter; component distribution

**Abstrak.** Perisian rekonstruksi imej dan algoritma rekonstruksi imejnya merupakan antara kaedah penting dalam pembangunan sebuah sistem tomografi. Kertas kerja ini akan membentangkan sebuah algoritma rekonstruksi imej untuk sistem ultrasonik tomografi dua-fasa. Algoritma tersebut, dikenali sebagai algoritma Rekonstruksi Piksel Utama (RPU) dirumus berdasarkan algoritma Unjuran Balik Linear (UBL). Algoritma rekonstruksi imej yang baru ini berjaya menyerlahkan piksel berintensiti tinggi daripada piksel-piksels sekeliling di dalam imej keratan rentas yang terhasil. Algoritma RPU kemudian digabungkan pula dengan Penapis Median yang membantu menghilangkan piksel-piksels yang tidak representatif dan membantu meningkatkan mutu rekonstruksi imej. Algoritma ini adalah pilihan yang sesuai berbanding dengan algoritma UBL memandangkan seperti UBL, RPU juga merupakan teknik pengimajian

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yang mudah tetapi mempunyai kejayaan yang lebih tinggi dalam merekonstruksi distribusi komponen dan mampu memberikan estimasi statistik distribusi komponen dua-fasa yang lebih tepat.

*Kata kunci:* Algoritma rekonstruksi imej; rekonstruksi piksel utama; tomografi transmisi ultrasonik, aliran dua-fasa; penapis median; distribusi komponen

## 1.0 INTRODUCTION

One of the available tomographic imaging algorithms [1] includes the Linear Back Projection (LBP) algorithm. This algorithm is implemented as this method is the most basic algorithm. Granted that the image quality is well enough for human interpretation which is why it is chosen as the basis for image reconstruction on several researches. The back projection algorithm is also the first analytic method to perform image reconstruction from projection signals in medical X-ray tomography [2].

Most of the work in process tomography is focused on the use of Linear Back Projection (LBP) algorithm [3, 4, 5]. The algorithm has the most advantage of demanding low computation processing. The LBP is computationally straightforward to implement and is a popular method for image reconstruction. The modeled sensitivity matrices are used to represent the image plane for each view.

To reconstruct the image, each sensitivity matrix is multiplied by its corresponding sensor reading [6]. This is the same as back projecting each sensor reading to image plane individually. The process of obtaining concentration profile using LBP can be expressed mathematically as follow:

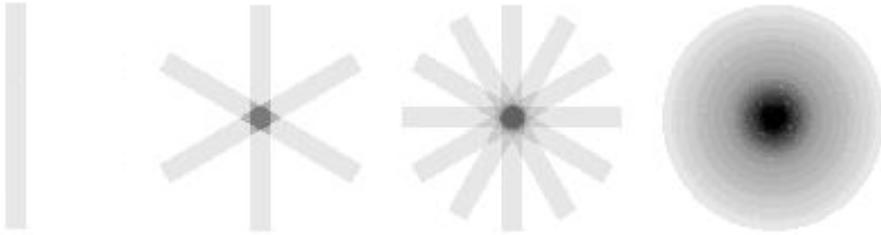
$$V_{LBP}(x, y) = \sum_{Tx=0}^{16} \sum_{Rx=0}^{16} S_{Tx,Rx} \times \bar{M}_{Tx,Rx}(x, y) \quad (1)$$

where,

$V_{LBP}(x, y)$  = voltage distribution obtained using LBP algorithm (concentration profile in unit volt) in  $n \times n$  matrix where  $n$  equals to dimension of sensitivity matrix.

$S_{Tx,Rx}$  = signal loss amplitude of receiver  $Rx$  th for projection  $Tx$  th in unit of volt.

$M_{Tx,Rx}(x, y)$  = the normalized sensitivity matrices for the view of  $Tx Rx$ .



**Figure 1** Back projecting an image

The obvious disadvantage of using Linear Back Projection (LBP) is the smearing effect introduced by the algorithm. The effect increases measurement deviation from the actual value albeit the algorithm's discernible popular characteristics such as low computational usage, straight-forward and simple integration into any tomography system and delivers well enough tomogram images for end-user interpretation [7]. Post processing of LBP-based images is recommended for further improving the quality of the images. Thus in this paper we discussed the proposed technique for further improving the Linear Back Projection algorithm resulting in more apparent tomogram images, clearly distinguishing the liquid and gas distributions.

## 2.0 EMINENT PIXEL RECONSTRUCTION ALGORITHM

Eminent Pixel Reconstruction (EPR) algorithm is based on the previous development by Sallehuddin [8]. This algorithm determines the condition of the concentration profile and improves the reconstruction mechanism by passing the high intensity pixels post reconstruction.

The algorithm masks the reconstruction process with binary values. If the pixel value equals or less than the concentration threshold pre-set, the final pixel value is set to zero. Using the signal loss measurement approach, the pixels with high intensity values also term as the eminent pixels are better highlighted by adopting EPR algorithm into the system. As a result, the smearing effect caused by the linear back projection technique is greatly reduced.

Mathematical model for EPR are shown as below:

$$B(x, y) = \prod_{Rx}^{16} \prod_{Tx}^{16} Z_{Rx,Tx} \begin{cases} Z_{Rx,Tx} = 1 & S_{Rx,Tx} > P_{Th} \\ Z_{Rx,Tx} = 0 & S_{Rx,Tx} \leq P_{Th} \end{cases} \quad (2)$$

$$V_{EPR}(x, y) = B(x, y) \times V_{LBP}(x, y) \quad (3)$$

where,

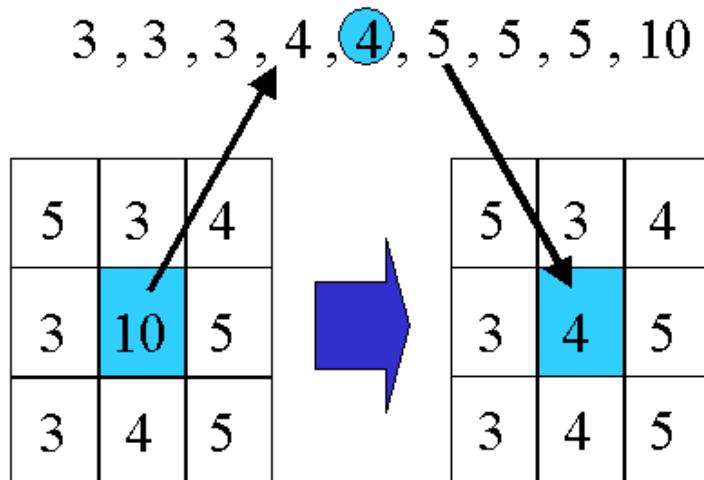
$B(x, y)$  = EPR 'marking' matrix, where 1 represent eminent pixels.

$V_{LBP}(x, y)$  = Reconstructed concentration profile using LBP algorithm.

$V_{EPR}(x, y)$  = Improved concentration profile using EPR algorithm.

### 3.0 EMINENT PIXEL RECONSTRUCTION ALGORITHM WITH MEDIAN FILTERING

In image processing, it is often desirable to be able to perform some kind of noise reduction on an image. Thus it is also vital for a tomography system to have the ability to pre-process the reconstructed tomogram so that the final image produced is able to reduce some noise. Such noise reduction is a typical pre-processing step to improve the results of later processing and in this case for better spatial analysis on the component distribution.



**Figure 2** Median filtering technique

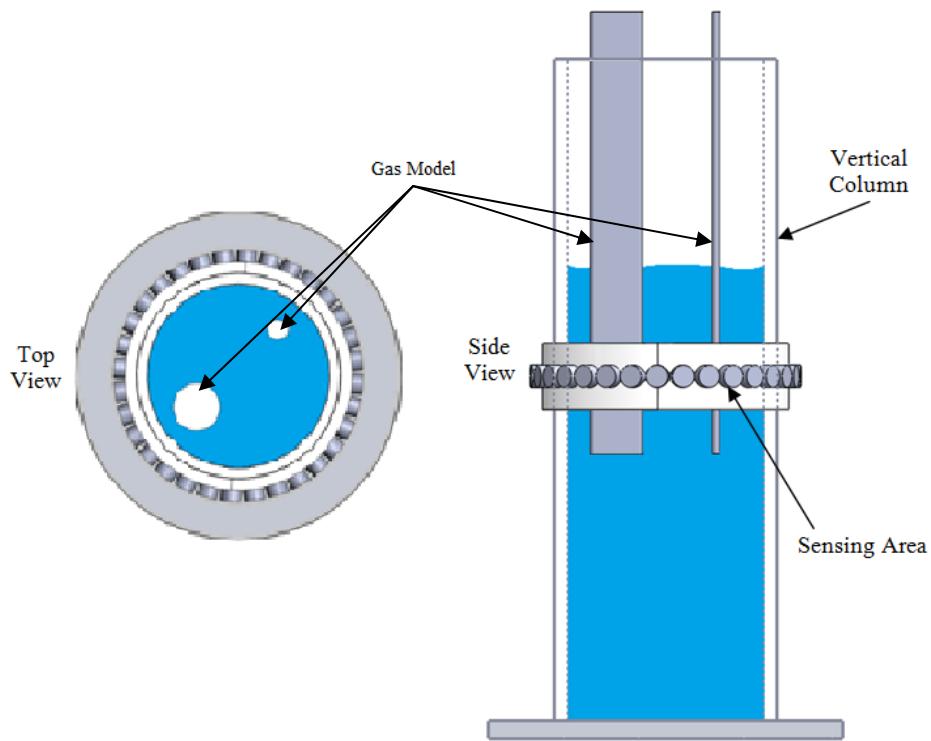
For that purpose, Median Filter (Figure 2) has been chosen for filtering noise during pre-processing. Median filtering is a nonlinear digital filtering technique, which is also often used for noise removal. The main reason Median filter is used is because of its familiarity in image processing to reduce "salt and pepper" noise, which in a tomography system if prevented will result in better image interpretation. Additionally, a tomographic image with applied median filtering technique helps reducing the amount of intensity variation between one pixel and the next.

Median filtering is performed by numerically sorting the entries inside an  $m$  by  $n$  window. Each output pixel after median filtering contains the median value in the  $m$  by  $n$  neighbourhood around the corresponding pixel in the input image [9]. The idea of median filtering is simply to replace each pixel value in an image with the median value of its neighbours, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings [10]. Median filtering is usually thought of as a convolution filter. Like other convolutions, it is based around a kernel or a window, which represents the shape and size of the neighbourhood to be sampled when calculating the median value.

## 4.0 EXPERIMENTAL DESIGN

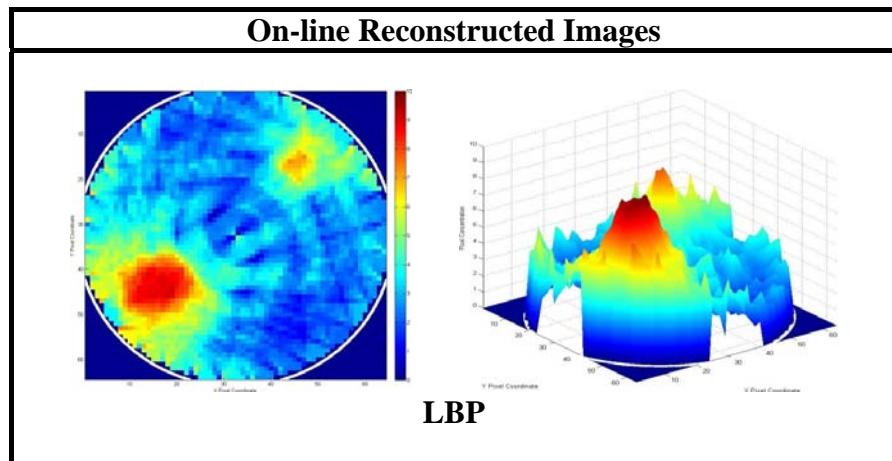
To evaluate the image reconstruction algorithm's capabilities, an experimental model was built as illustrated in Figure 3. The experiment model consists of the experimental pipe (vertical column) which is filled with liquid (water) and test tubes (gas).

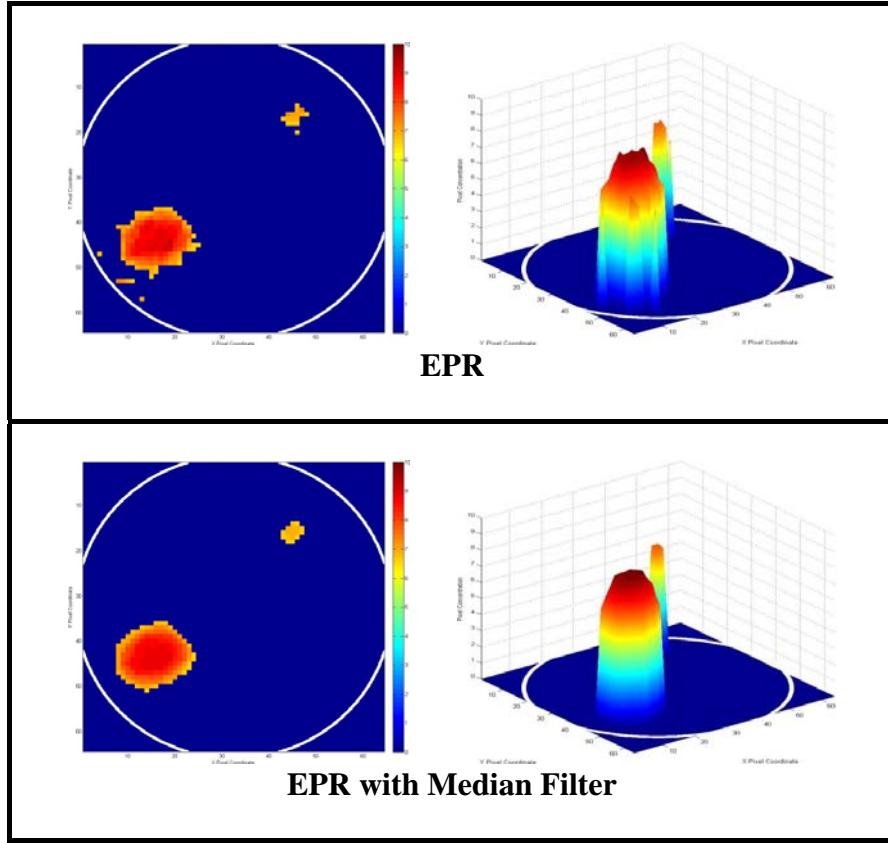
The setup in use simulates a typical measurement of the distribution pattern for the liquid-gas flow inside the vertical column. This evaluation of reconstruction algorithm for on-line measurement data is necessary in order to make general conclusion about the algorithm's performances.



**Figure 3** Experimental design - dual phantoms

## 5.0 RESULTS





**Figure 4** On-line measurement - dual phantoms

The results presented shows that the Linear Back Projection algorithm smears out and introduces false images elsewhere. As seen in Figure 4 the reconstructed images clearly contain qualitative information about the component information but it is hard to obtain the correct measurement on the distribution percentages due to the smearing effect introduced using LBP algorithm.

The EPR reconstruction images of the two objects shows that the area of high component concentration is able to be distinguished from the background image and the shape and the position of the reconstructed images is approximate with the experimental model. The advantage of median filtering technique is also better demonstrated in Figure 4 labeled *EPR with Median Filter*, where it greatly helps in reducing the amount of intensity variation between pixels and improved the quality of the reconstructed image.

## 6.0 CONCLUSION

A new image reconstruction algorithm termed the Eminent Pixel Reconstruction has been developed. It is derived to highlight high intensity pixels from the surrounding pixels. The EPR algorithm are then combined with the useful Median Filter which helps eliminate the unrepresentative pixels resulting in reduced noise on the final reconstructed image as have been shown as a comparison in previous images.

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