

# Fast Image Reconstruction Research Based on $H_\infty$ Filtering for Electrical Resistance Tomography<sup>\*</sup>

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## Abstract

In order to improve the image reconstructed quality affected by soft filed feature and the speed of dynamic on-line data processing in Electrical Resistance Tomography, we propose a fast image reconstruction algorithm based on  $H_\infty$  filtering theory. Mainly, on the  $H_\infty$  filtering principle, a dynamic system is formulated firstly, whose inputs have unknown disturbances including noise errors and model errors, and the outputs have the estimation errors. Then, making the  $H_\infty$  norm of this dynamic system as a cost function, a fast  $H_\infty$  filtering algorithm is proposed whose criterion is to guarantee that the worst-cast effect of disturbance on estimation error is smaller than a given boundary. Experimental work was carried out for three typical flow distributions. Results showed that  $H_\infty$  filter method improves the resolution of the reconstructed images and gains the strong robustness and anti-interference performance in unknown interference noise conditions. In addition, it dramatically reduces the computational time compared with the traditional Gauss-Newton iterative and Kalman filter methods. Therefore, the method is suitable for on-line multiphase flow measurement.

*Keywords:* Electrical Resistance Tomography;  $H_\infty$  Filtering; Image Reconstruction

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## 1 Introduction

In recent years, certain attempts have been made to adapt computerized tomography techniques to the needs of multiphase flow measurement. Electrical Resistance Tomography (ERT) have great potential for two-phase flow measurement, biomedical engineering, geophysical prospecting, etc [1-4]. The image reconstruction processing is inverse problem which will directly affect the medium distribution results. As a non-linear problem, ERT generally adopts some strategies to get a result. The existing image reconstruction algorithms have Truncated Singular Value Decomposition (TSVD), TV regularization algorithm and Newton-Ralph algorithm, etc [5-9],

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their purposes are to calculate the minimization residual errors through least squares estimate. Reconstruction algorithms can also be seen as a state estimation. The Kalman filter is an effective state estimation method. The attractiveness of the Kalman filter lies in the fact that it is the one estimator that results in the smallest possible standard deviation of the estimation error. That is, the Kalman filter is the minimum variance estimator if the noise is Gaussian [10]. But when the external disturbance signal is strong in ERT measurement system, the system model about external noise disturbance have certain uncertainty. Generally, the particle filter algorithm has a very good robustness. But numerous sampling particles are used to accurate approximation of the posterior distribution, the computational complexity is usually higher. Therefore, to solve the problems of high computational complexity and long computational time, we apply a high speed image reconstruction algorithm to gain optimal estimation for image reconstruction system. The method is based on optimal  $H_\infty$  control theory whose criterion is to guarantee that the worst-cast effect of disturbance on estimation error is smaller than a given boundary.

## 2 CT Model for ERT

ERT system is composed of hardware parts which include the sensor array, analog switches, data acquisition system, and the computer to generate images. In ERT, the current patterns are injected into the unknown object through electrodes and the corresponding voltages on the surface of the object are measured. This procedure is repeated for all the electrode pairs. Then, each dataset is interpreted by image reconstruction algorithms to compute a cross-sectional image reconstruction. The composition of ERT system is shown in Fig. 1.

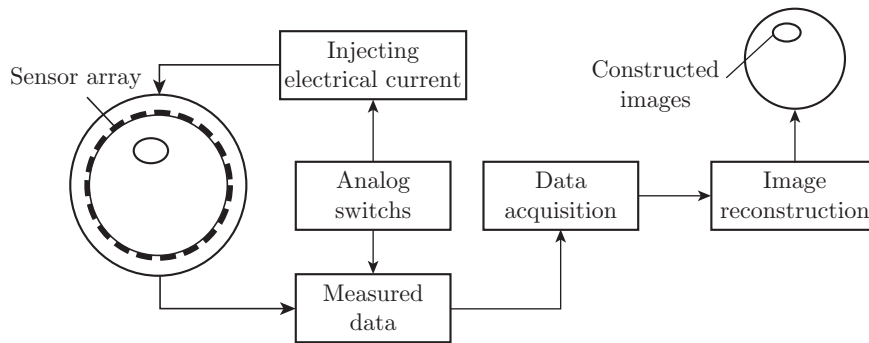


Fig. 1: The composition of ERT system

The electrical conductivity  $\sigma$  and electrical potential distribution  $\Phi$  are governed by the Maxwell relations in ERT, leading to the equation:

$$\nabla(\sigma \nabla \Phi) = 0. \text{ in } \Omega \quad (1)$$

where  $\Omega$  represents the sensing field, boundary conditions for Eq. (1) are calculated as follows:

$$\sigma \frac{\partial \Phi}{\partial n} = \begin{cases} I \\ -I \end{cases}, \text{ in } \partial\Omega_+, \partial\Omega_- \quad (2)$$

$$\partial + z \cdot \sigma \frac{\partial \Phi}{\partial n} = V. \text{ in } \partial\Omega \quad (3)$$