Gamma-Ray Tomography for Field Application

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Introduction

❖ In field application one is not interested in detailed flow description; basic idea of presence/absence of flow mal-distribution often will suffice

❖ Challenges: restriction of access to the vessel; the need to adjust CT setup to the column external piping and instrumentation; need to carry out studies at significant heights on a large diameter column with a high attenuation media; reduction in scan time; need for portable, easily to installed and removed system

❖ γ –ray tomography, which is suitable for opaque, high attenuation media and steady state flow conditions seems to be most appropriate technique for field application (Darwood et al., 2003)

Focus of This Work

❖ Achieve: - reduction in scan time

- guidelines for the best data collection methodology

❖ Key Questions to Answer:

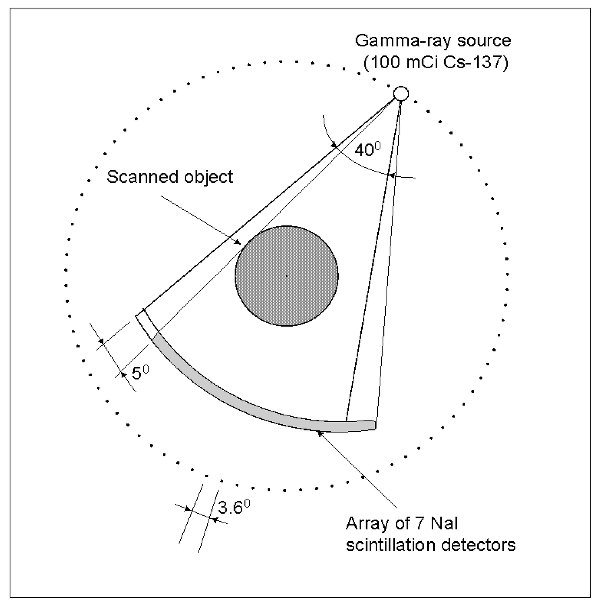
- What is the correlation between image quality and the amount of data used in the process of reconstruction?

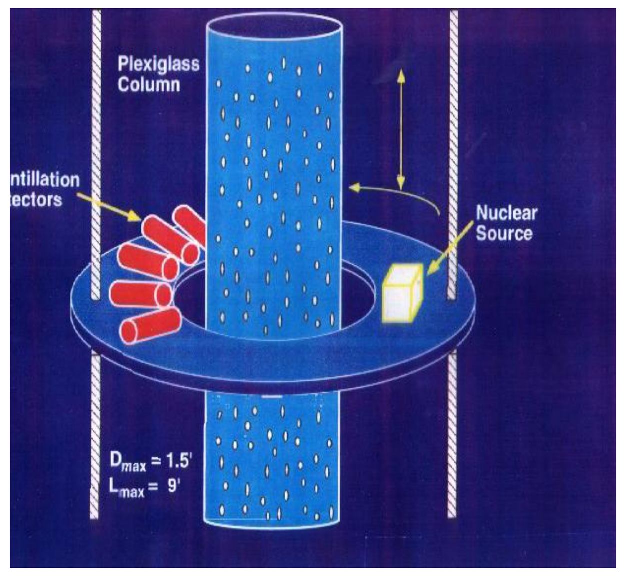
- What is the optimum way to obtain the data in order to minimize the introduced error?

Gamma-ray tomography

❖ Process of imaging of cross-sectional area (i.e. obtaining phase distribution) consists of scanning and reconstruction

❖ During a scan, the column is placed between gamma-ray source and an arrangement of scintillation detectors



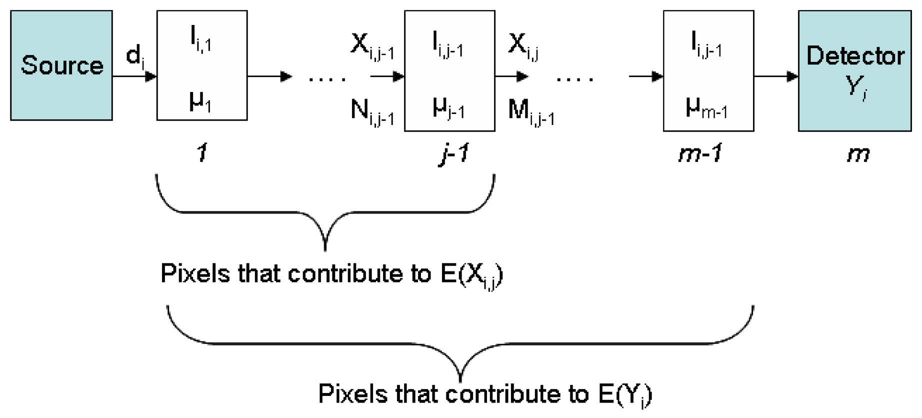


❖ During the scan, the source makes a full circle around the scanned object in step increment of 3.6° and the term **view** is used to indicate fixed source position

❖ **Projections** are different positions of an assembly of detectors towards the source - in any given view, detectors take 25 different positions, in increments of 3.6°

Reconstruction Algorithms

❖ Attenuation – Beer-Lamber's law: $I = I_0 \cdot \exp(-\mu \cdot l)$



Expectation-Maximization Algorithm

$$E(Y_i) = E(X_{i,j})\exp\left(-\sum_{k=j}^{m-1} l_{i,k}\mu_k\right) \qquad E(X_{i,j}) = d_i \exp\left(-\sum_{k=1}^{j-1} l_{i,k}\mu_k\right)$$

$$f(X_{i,j} \mid Y_i) = \exp\left\{-\left[E(X_{i,j}) - E(Y_i)\right]\right\}\frac{\left[E(X_{i,j}) - E(Y_i)\right]^{X_{i,j}-Y_i}}{(X_{i,j}-Y_i)!}$$

$$E(X_{i,j} \mid Y_i) = Y_i + E(X_{i,j}) - E(Y_i)$$

Alternating-Minimization Algorithm

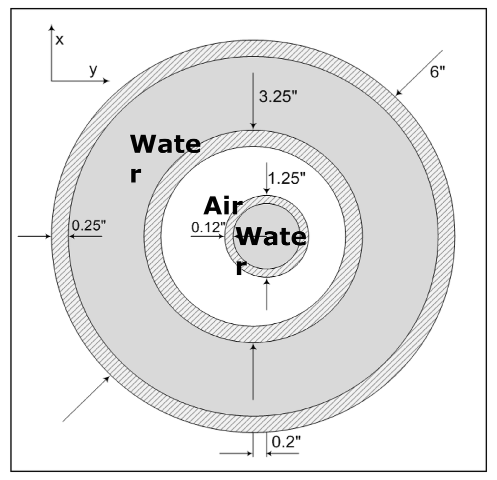
$$I(Y \| q) = \sum_i \left[Y_i \ln\left(\frac{Y_i}{q_i}\right) - (Y_i - q_i)\right]$$

$$\mu_j^{(n+1)} = \mu_j^{(n)} - \frac{1}{Z_j}\ln\frac{d_j'}{q_j'} \qquad d_j' = \sum_{i \in J_j} l_{i,j} d_i$$

$$q_j' = \sum_{i \in J_j} l_{i,j} q_i$$

Test Object and Error Quantification

❖ To examine relation between amount of data used and image quality, test object has been scanned



❖ The error has been quantified then as the average deviation of the binary gated attenuation coefficient value in the image of the reduced scan from the theoretical values

$$error = 100 \cdot \frac{\sum_i abs(\varepsilon_{i,full} - \varepsilon_{i,red})/\varepsilon_{i,full}}{N_{pixel}}$$

Investigation plan

Amount of data used

Number of pixels	Data used, % of full set	Views	Projections per view
80x80 60x60 40x40	5	5	25
		10	13
		14	9
		18	7
	10	10	25
		20	13
		28	9
		36	7
	25	25	25
		48	13
		69	9
		89	7
	50	50	25
		96	13

Algorithms:

❖ Expectation-Maximization (EM)

❖ Alternating Minimization (AM)

Key Results

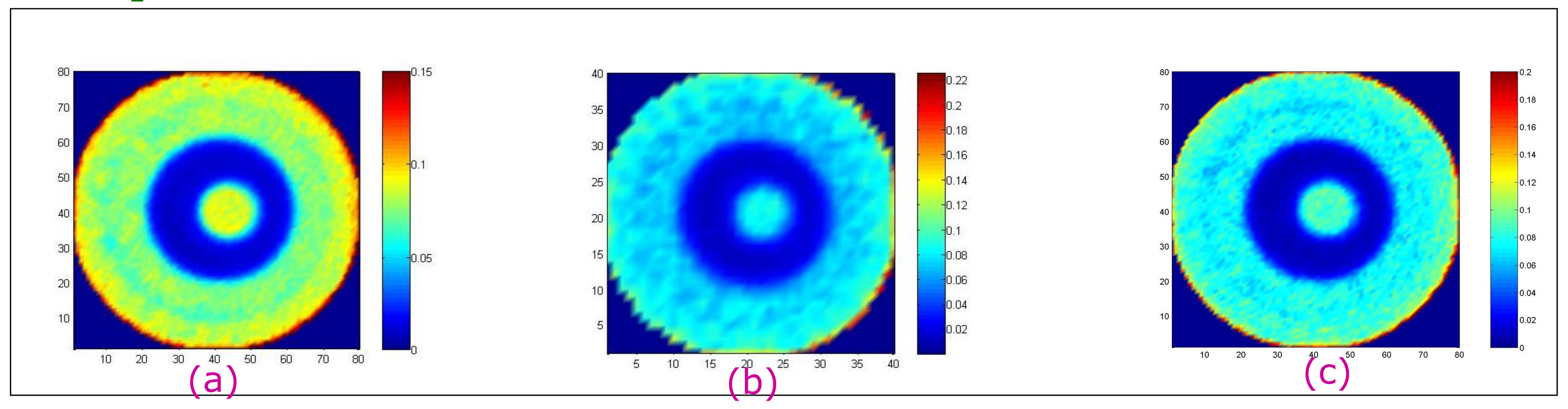
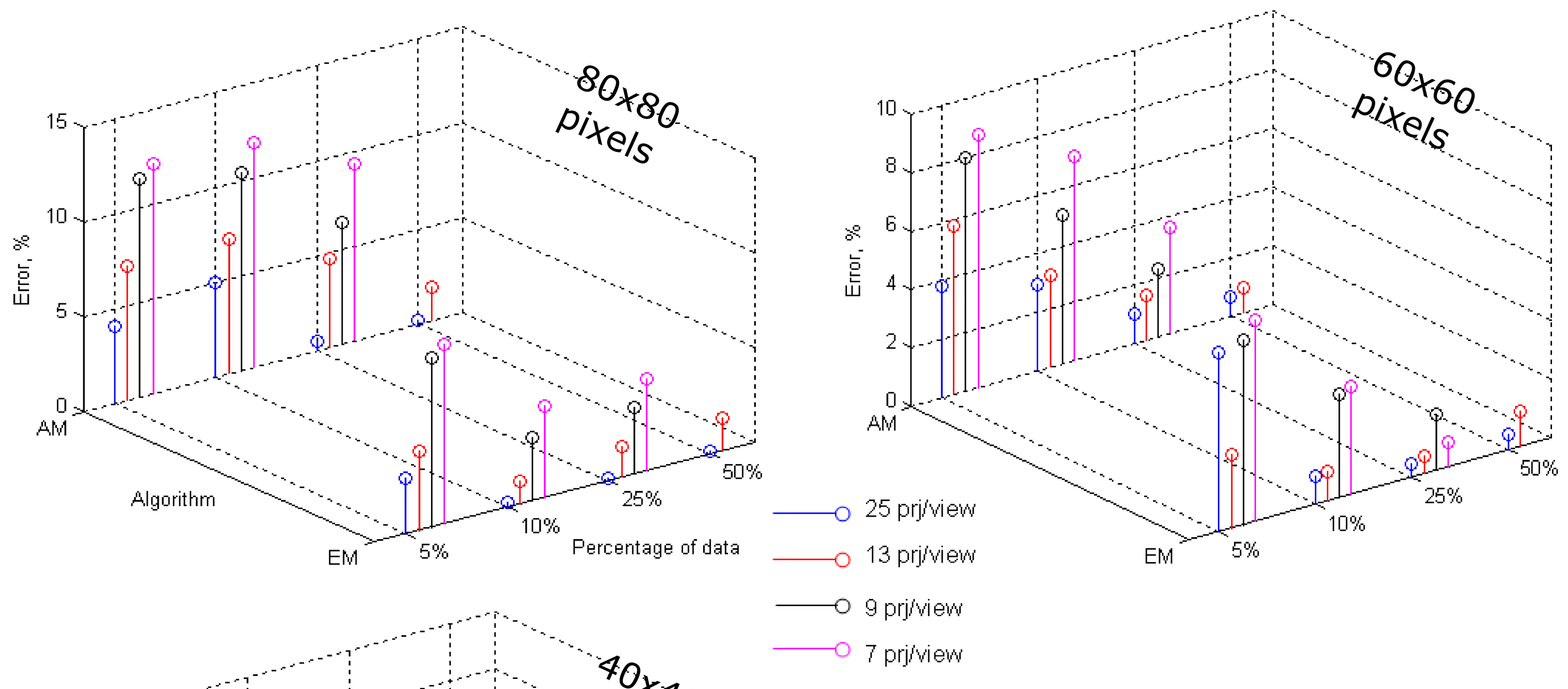
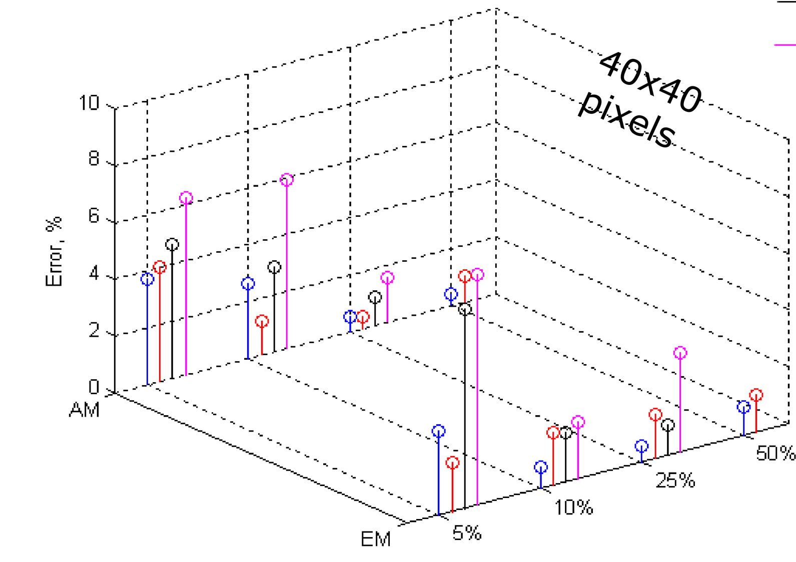


Image obtained with:
(a) full data set and 80x80 pixels
(b) 25% of full scan data used and 40x40 pixels
(c) 50% of full scan data used and 40x40 pixels

Error in econstruction

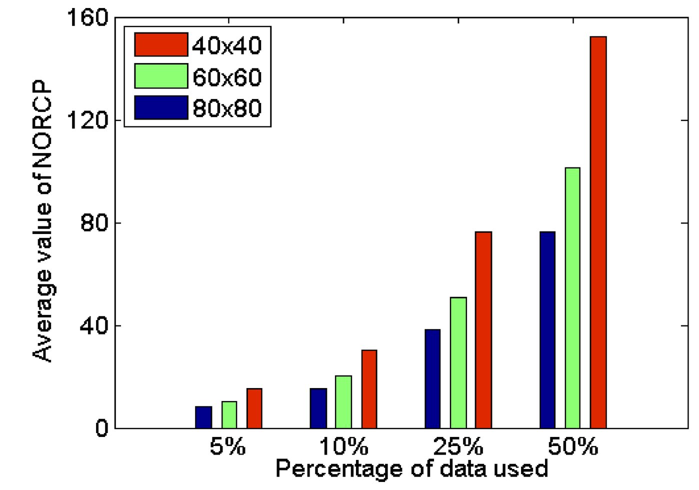




❖ With the reduction of amount of data used, EM algorithm outperforms AM algorithm

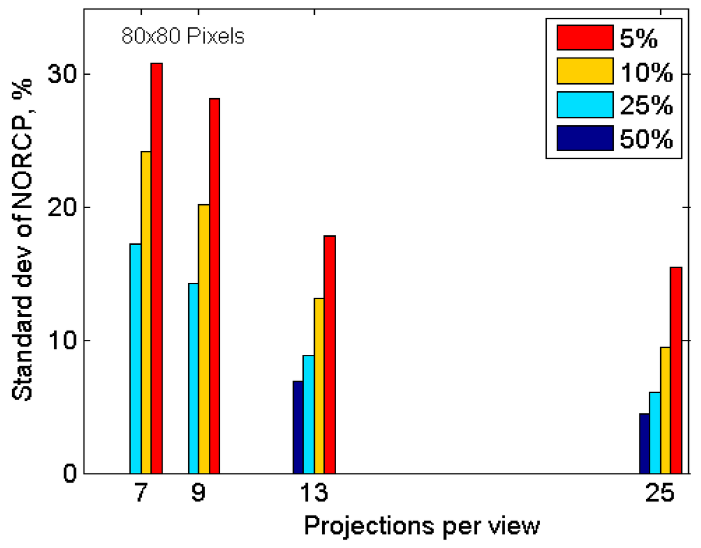
❖ Error reduces with the increase in number of projections used

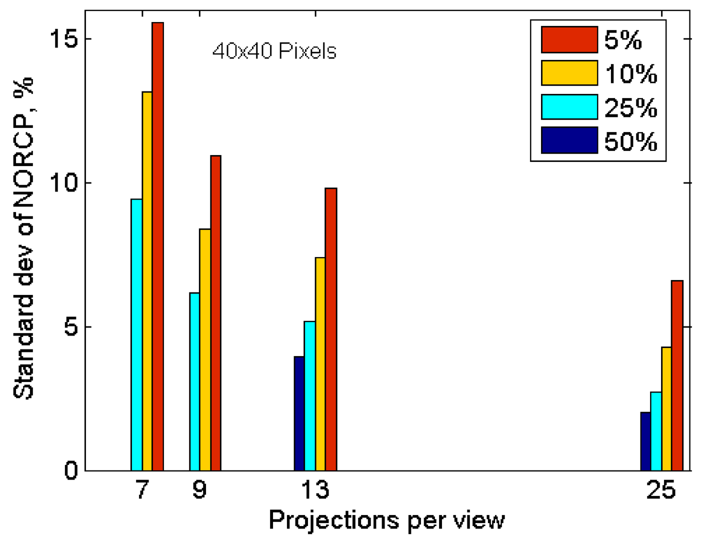
Parameters affecting reconstruction error



❖ NORCP – "Number of rays crossing pixel"

❖ Average value of NORCP is a function of pixel size and percentage of data used





❖ Standard deviation of NORCP decreases with the increase in number of projections per view used in reconstruction and with the decrease in number of pixels used in reconstruction image

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▪ TOTAL