Software based Framework for Estimating Patient Displacement in Magnetic Induction Tomography

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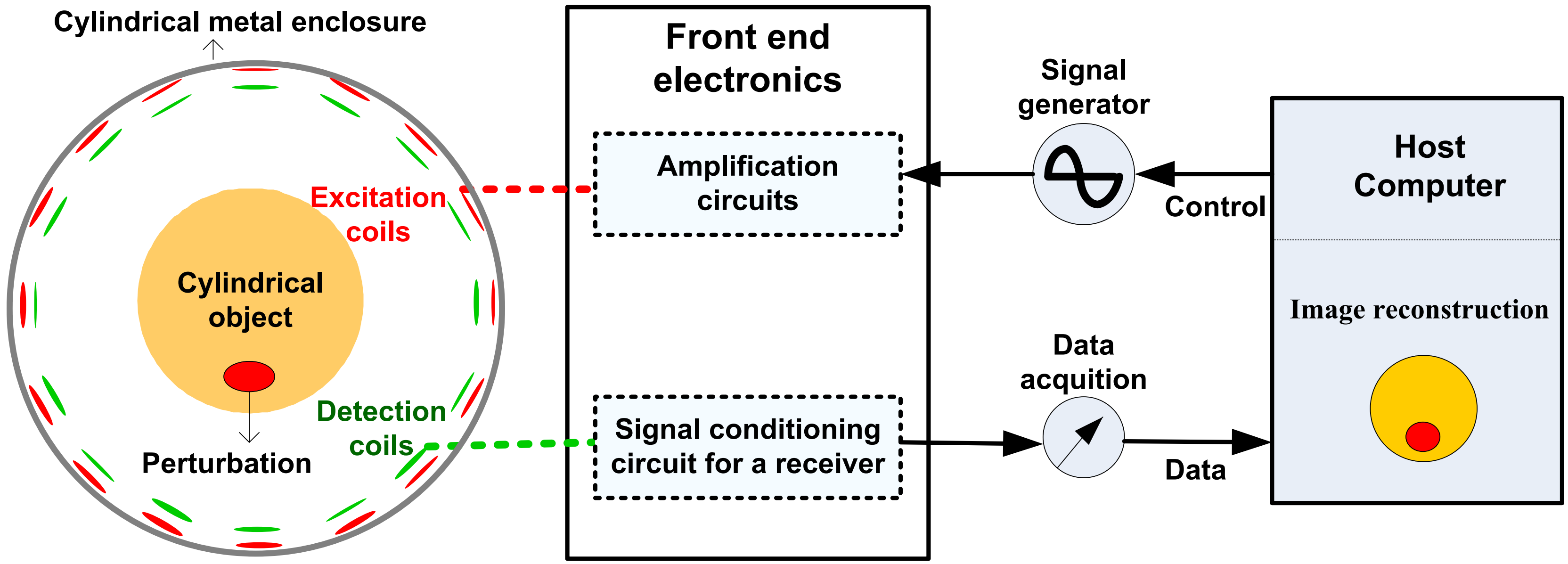
Outline

- Introduction
- Artefact compensation
  - Preprocessing / post processing
  - Adaptive regularization
- Artefact estimation
  - Frequency domain (FFT)
  - Statistical Approach (ICA)
- Conclusion

What is MIT?



Cylindrical metal enclosure
Excitation coils
Cylindrical object
Detection coils
Perturbation
Front end electronics
Amplification circuits
Signal conditioning circuit for a receiver
Signal generator
Control
Data acquition
Data
Host Computer
Image reconstruction

Source of artefacts / Need in MIT

Parameters - cause the change in measured signal (amplitude/**phase**)

- **Object -** movement, rotation, expansion, sweet
- **HW** – drift, temperature, noise

Other issues:

- **SW** – mesh error, model mismatch, regularisation parameter

Classification of **artefacts**?

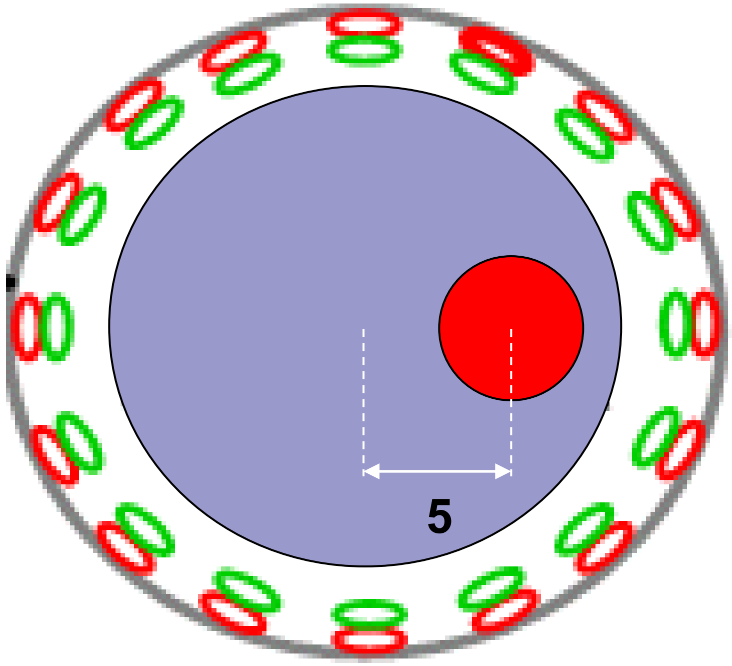
- blurring, ghosting, dislocation of objects, geometric distortion
- A great **need** for movement compensation in clinical applications of MIT
- Movement estimation is a **complex problem** due to **3 translations** and **3 rotations**.

Software approaches

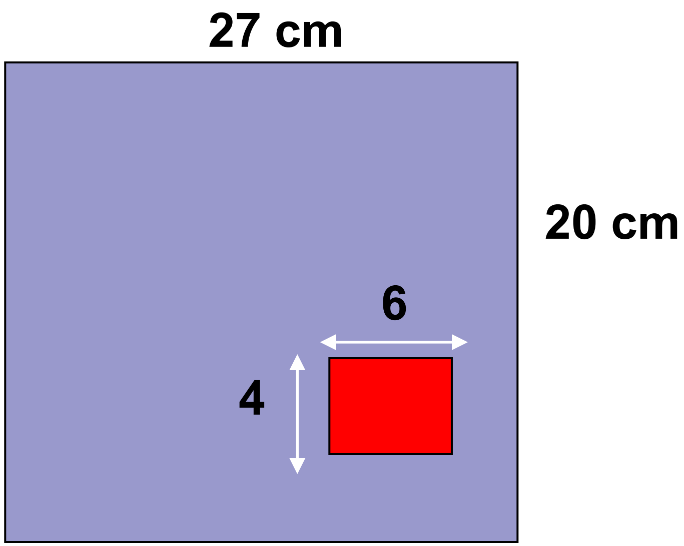
Elimination of movement artifacts based on given *a priori* information – the size of dislocation.

- Pre-processing based on simulated signals (time domain)
- Post-processing based on reconstructed images (spatial domain)
- Movement estimation (FFT / ICA)

Target object (small cylinder)

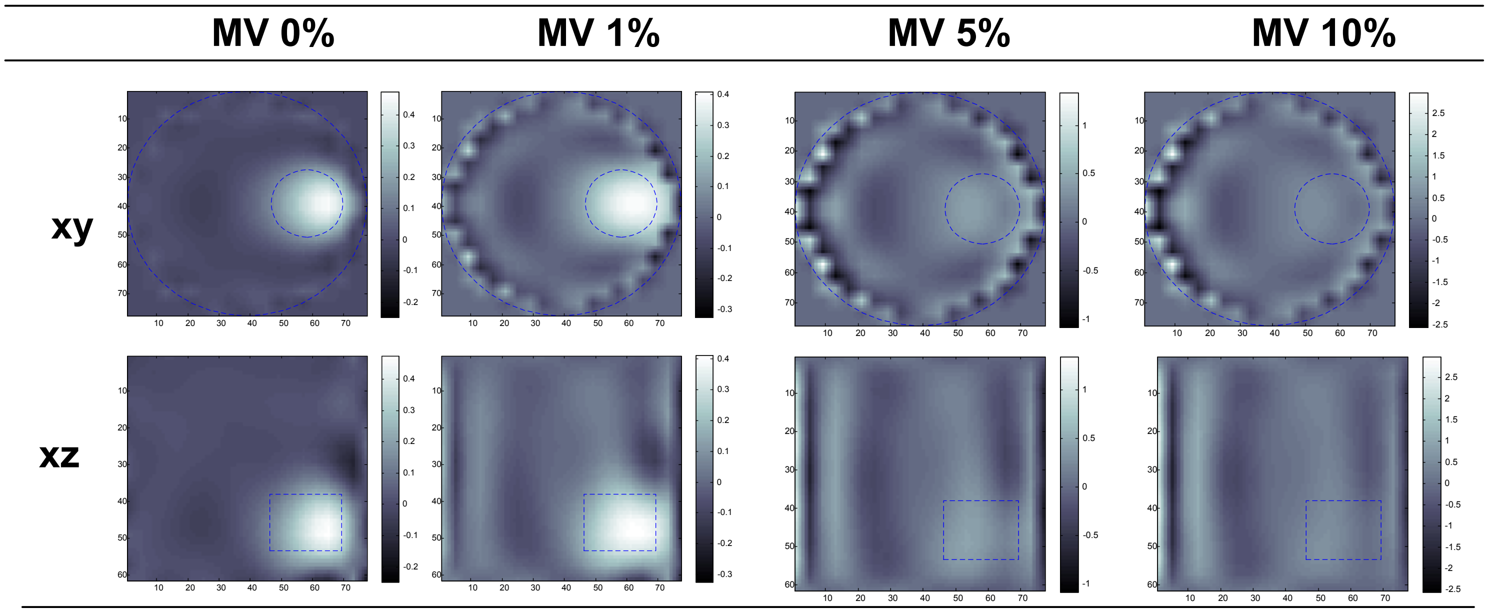


xy cross-section



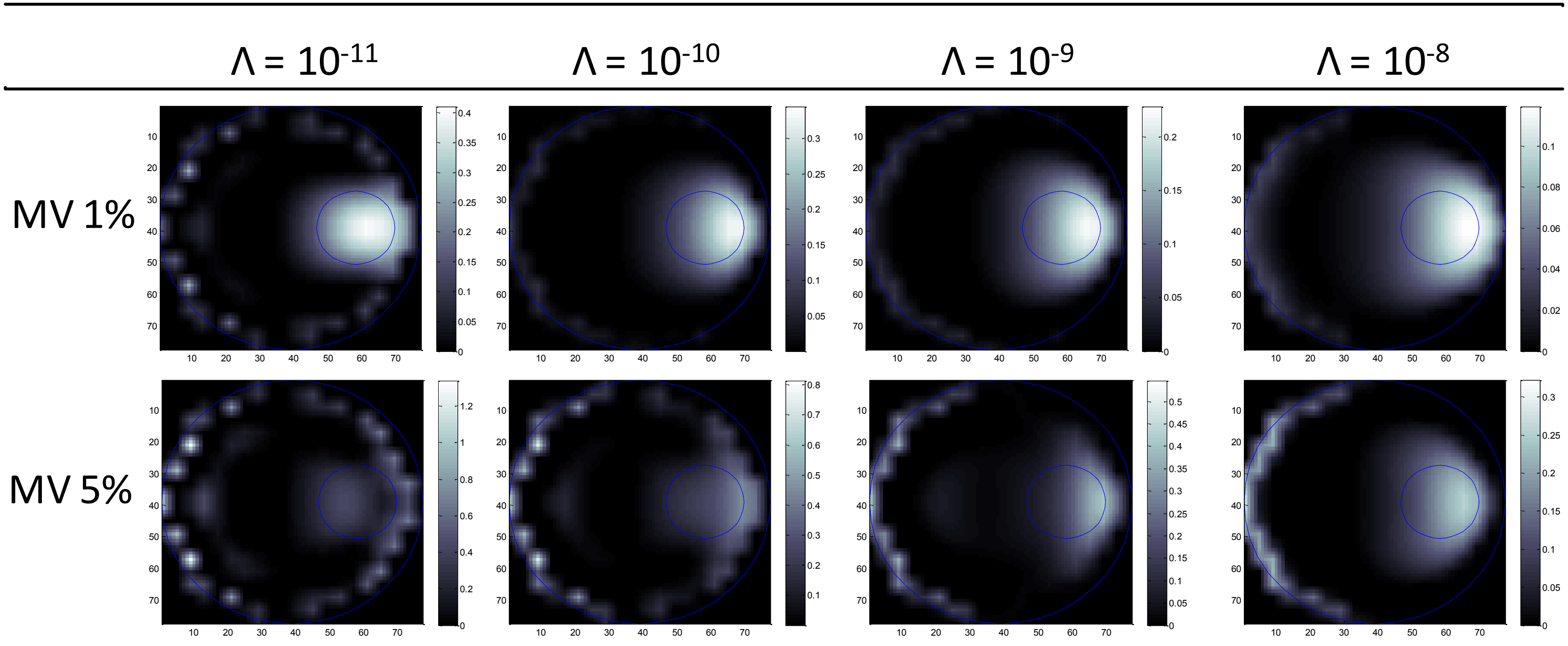
Yz cross-section

Effect of the movement



- There are certain correlation between the distortion (i.e. frequency domain) and the size of movement.
- Movement causes the changes / distortion on signals on both phase and magnitude → **global changes**

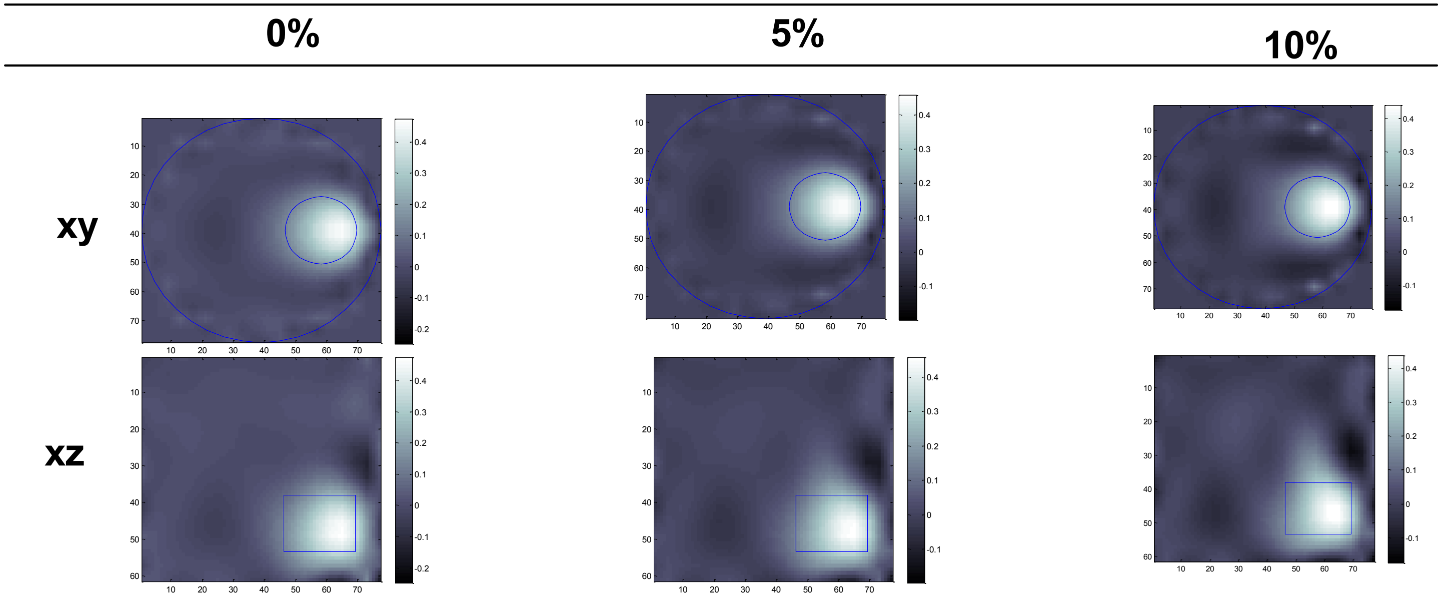
Regularization



- Reduce movement artefacts for small movements (1-2%) by adjusting the regularization parameter
- However, it does not work for larger movements (5%)

Artifact Compensation based on a priori info

Artifact Compensation using both (1) pre-processing (2) post-processing



- Artifacts are eliminated using given *a priori* information –size of dislocation – (may be obtained from video camera or movement estimation).
- **Compensation/elimination**→ recover or reconstruct images using a priori knowledge of shift/rotation

Movement Estimation Approaches

- **FFT** suited for periodic signals / static case– a starting point for movement estimation due to its simplicity and advantages in discriminating signals from noise and artifacts compared to time domain signals.
- **Statistical approach (ICA)** – by training several movements data and known dislocation.

Movement Estimation 1 : FFT Approach

- Frequency domain analysis (**FFT** for initial study)

Why:

- **(i)** FFT allows to measure the phase and amplitude of multi-frequency signals
- **(ii)** Frequency analysis helps to understand better what is happening, i.e. the upper and lower frequency sideband components appear as ghosts either side of the primary image.
- **(iii)** In a Fourier Transform of a sinusoidal signal, the energy is concentrated at the frequency of the signal according to Fourier theory. The initial phase at t= 0 is the phase of the Fourier transform at the point of this energy concentration.

Reason behind the FFT

***We* defined MSR (movement signal ratio) as:**

- ***MSR = (amplitude of movement/ amplitude of normal signal) -*** *for certain key frequency index.*

- MSR value indicates the strength of the distortion due to the movement, which is proportional to the size of dislocation.

Movement Estimation1: FFT method description

Given:

•a reference signal **Vref**

• a signal **Vb** – with bleeding, without movement

•a signal after the movement **Vmv** – with bleeding

Steps: method 1

1. Find the phase change before movement (**Dphib** = (**Vb** – **Vref**)/abs(**Vref**))
2. Find the phase change after movement (**Dphia** = (**Vmv** – **Vref**)/abs(**Vref**))
3. Find the FFT for both **Dphia** and **Dphib**
4. Find the peaks from **Dphia** and use it as an index value due to the movement
5. correlate them using the index value in both **Dphia** and **Dphib** in frequency domain

Steps: method 2

1. Find the phase change after movement (**Dphi** = (**Vmv** – **Vref**)/abs(**Vref**))
2. Find the FFT for both **Vref** and **Dphi**
3. Find the peaks from **Dphi** and use it as an index value due to the movement
4. correlate them using the index value in both **Vref** and **Dphi** in frequency domain
5. Multiply with a certain factor (i.e. * 10)

Movement Estimation 1: Simulation

Original movement	FFT Error (%)	ICA Error (%)
1.3 (1%)	23	70
6.75 (5%)	0.3	16
13.5 (10%)	6	15

- Larger estimation error for smaller movement
- Simulated noise (-60 dB) did not have big effect on the estimation
- For ICA, limited training data set was used in this case. However, the results may improve, if more training dataset is used.

Discussion

- Management strategies
  - minimizing movement artefacts for small movements;
  - compensating for the movements if these are accurately estimated, or
  - taking a new MIT measurement if movements are too severe.
- Absolute reconstruction and frequency difference image reconstruction can be also another way of to reduce the effect of the movement, but frequency difference MIT is challenging due to the frequency dependence of the MIT received signal.
- For our future study, Wavelet will be tested.

References

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