ICC Chiba Color Experts' Day 2013

4D-MRI Reconstruction of Thoracoabdominal Organs

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Outline

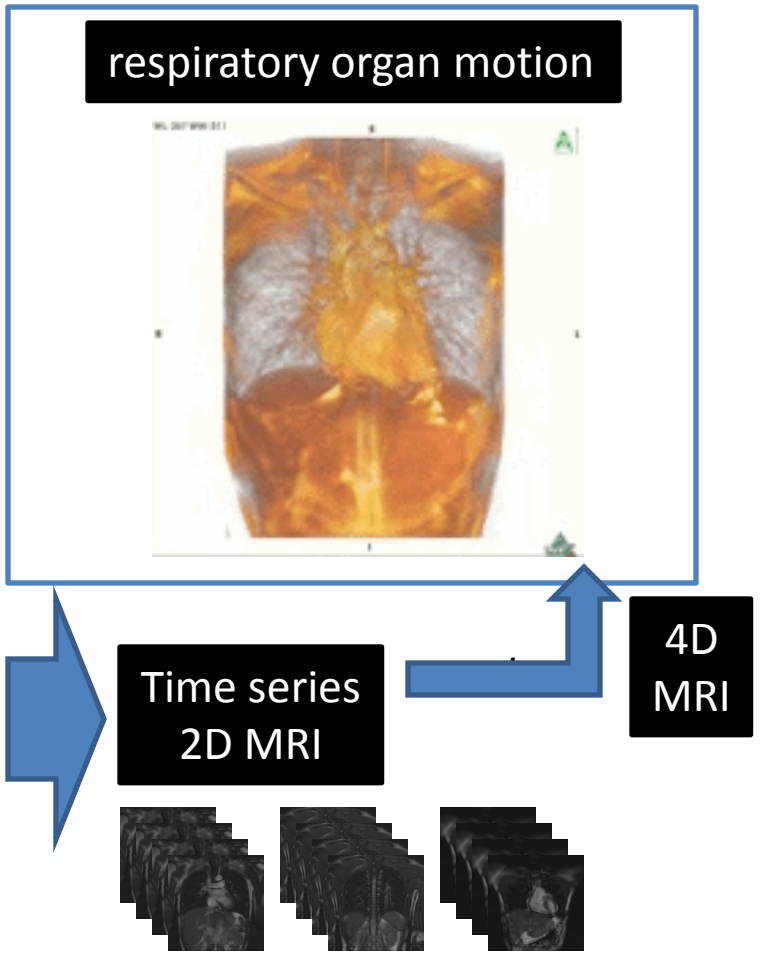
- Background
- Methodology
- Results
- Conclusion

Background

- Understanding respiratory organ motion can be useful in many clinical applications:
  - ✓ locating the tumors position in radiotherapy planning,
  - ✓ examining pulmonary diseases,
  - ✓ analyzing some irregularities in respiratory.

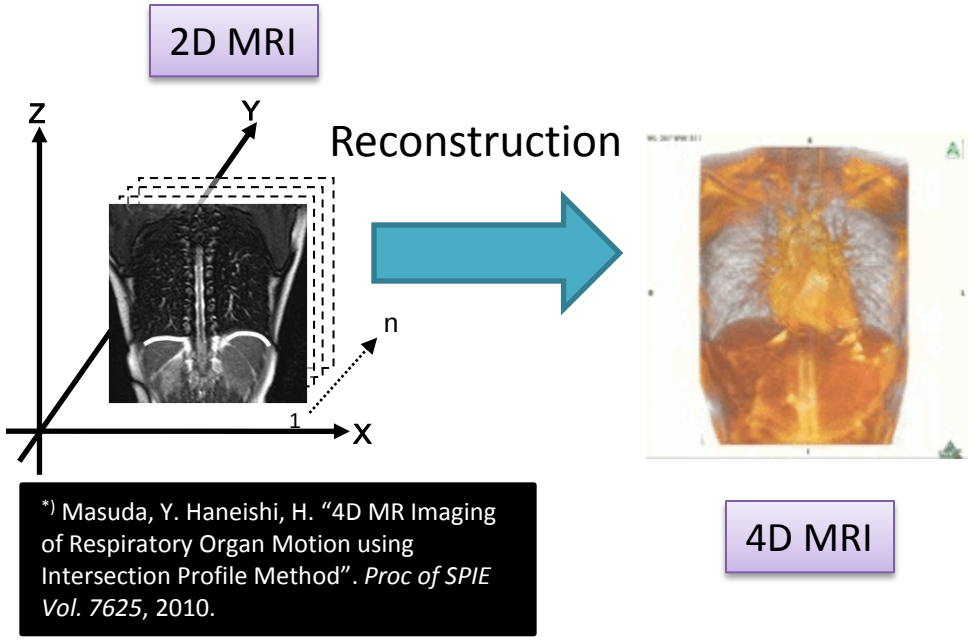
However, to capture “real-time” 4D MRI using current MR Scanner is **not possible**.

- Long acquisition time.
- Image resolution problems.
- Respiratory motion can cause noise/artifacts.



Background

- 4D MRI Reconstruction



*) Masuda, Y. Haneishi, H. "4D MR Imaging of Respiratory Organ Motion using Intersection Profile Method". *Proc of SPIE Vol. 7625*, 2010.

4D MRI Reconstruction

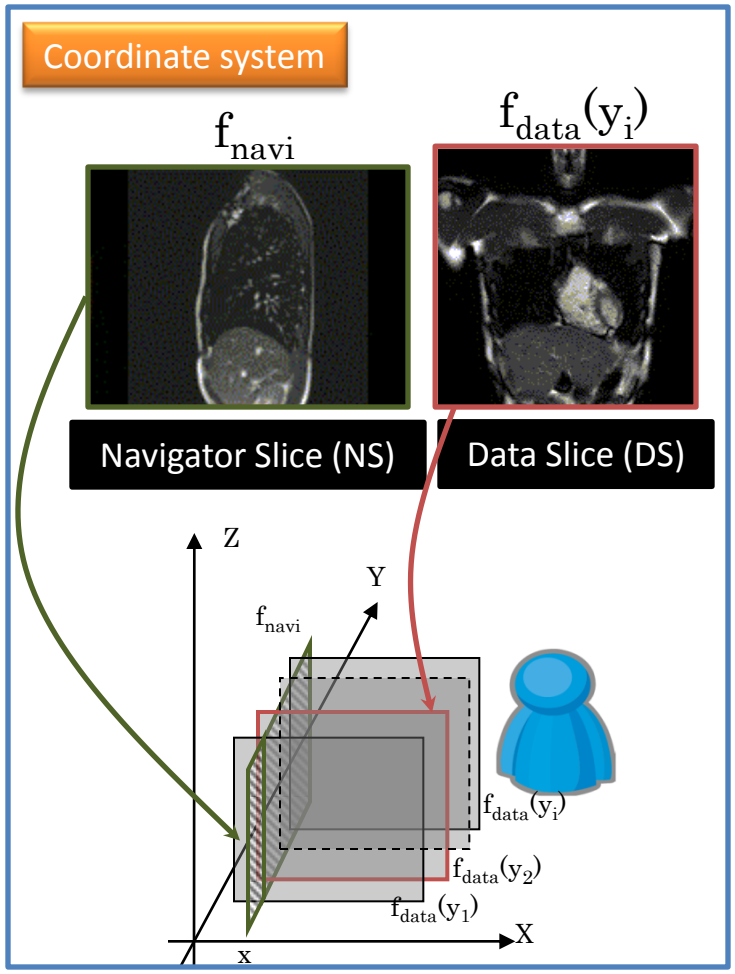
Some issues in 4D MRI reconstruction are:

- Done semi-automatically.
- Total acquisition time per person is about **30 minutes**.

What is needed are:

- ☑ Simplify 4D MRI using statistical modeling.
- ☑ **Automatic process and reduce time acquisition.**
- ☐ Faster acquisition time of 2D MRI using compressed sensing.

Methodology



Navigator Slice (NS) (f_{navi})	Data Slice (DS) (f_{data} (y_i))
NS is time sequential 2D-MR images in sagittal plane which consists of several hundred frames that forms several respiratory patterns.	DS is time sequential 2D-MR images in coronal plane. One set data slice consists of several slices along the y axis to cover 3D images volume.

DS are set along the Y axis and intersect with a single NS.

- $f_{data}(y_i)$ intersect with f_{navi} at location (x, y_i).
- One set of DS consists of several slices along the Y axis to cover 3D images volume.

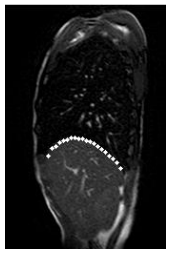
2D Image acquisition

- NS is obtained first at certain X axis location, followed by DS acquisition at location $y_{i\in 1, 2, 3, \ldots, n}$ sequentially.
- The number of frame in NS, varies between 400, 800 and 1200 frames.

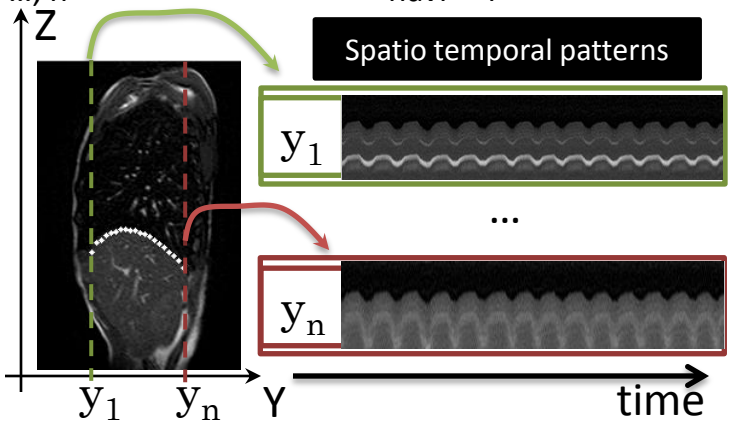
Methodology

1. Extract Respiratory Patterns at NS

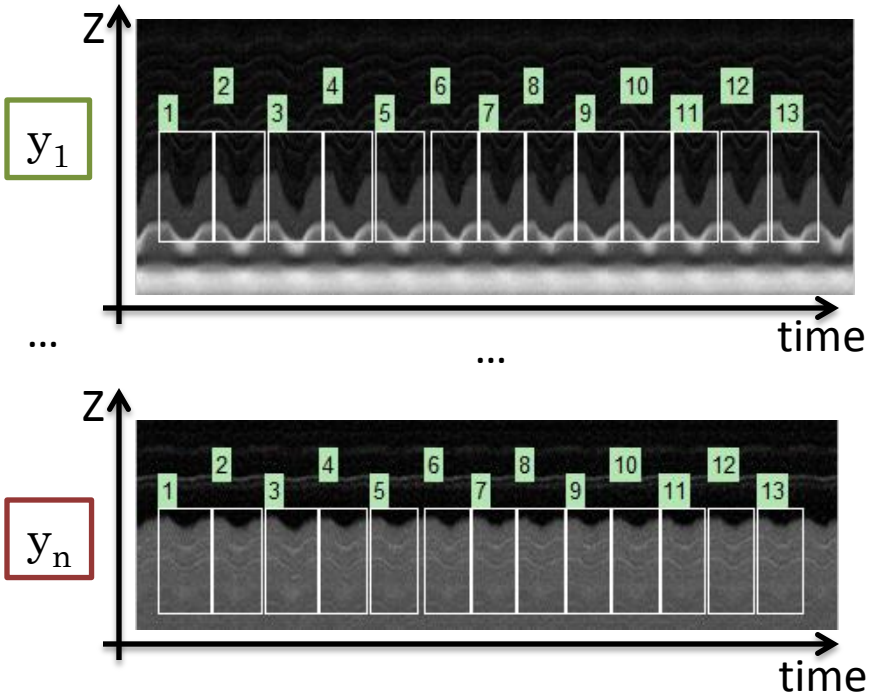
STEP 1 Determine the intersection location of NS and DS.



STEP 2 Generate *n* spatio-temporal patterns from $f_{navi}(t_{ns})$ at intersection location ($y_{i\in 1, 2, 3, \ldots, n}$), denoted as $S_{navi}(y_i)$



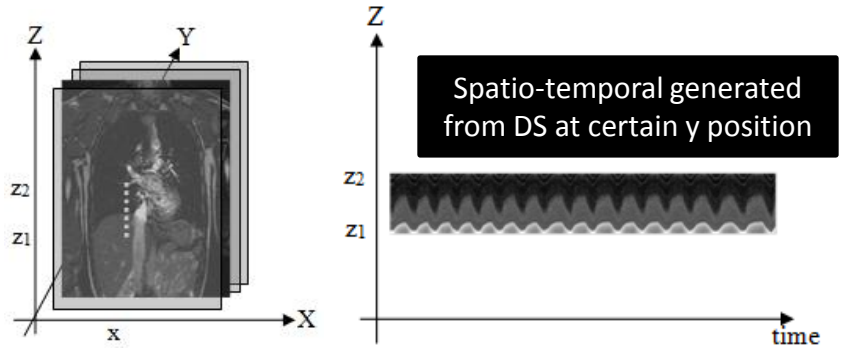
STEP 3 Find respiratory patterns and set region of interest (ROI) based on the diaphragm boundary of all respiratory patterns found in $S_{navi}(y_i)$.



Methodology

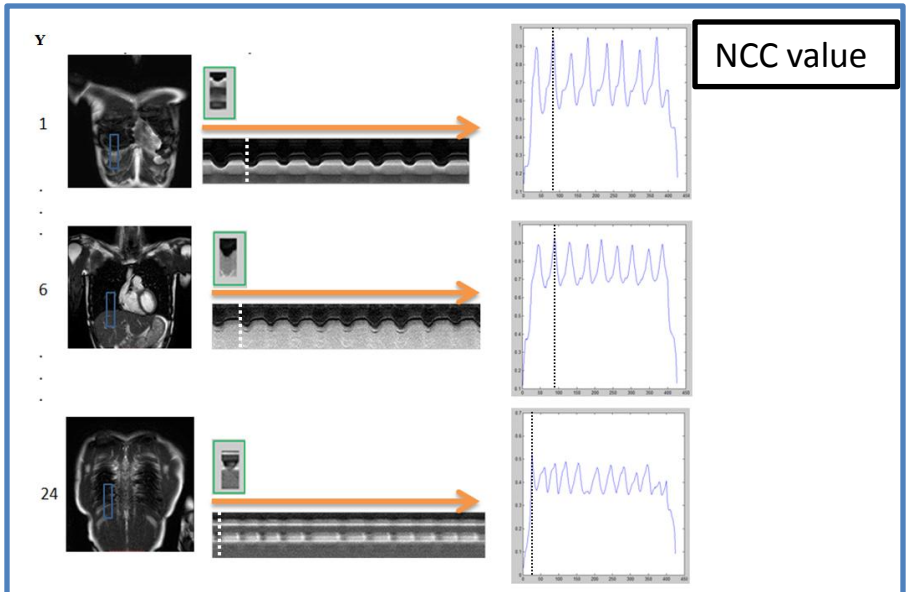
2. Find the best intersection

STEP 4 Generate a spatio-temporal patterns from each DS at intersection location.



STEP 5 Find best normalized cross correlation (NCC) value between each respiratory patterns found in $S_{navi}(y_i)$ and $S_{data}(y_i)$.

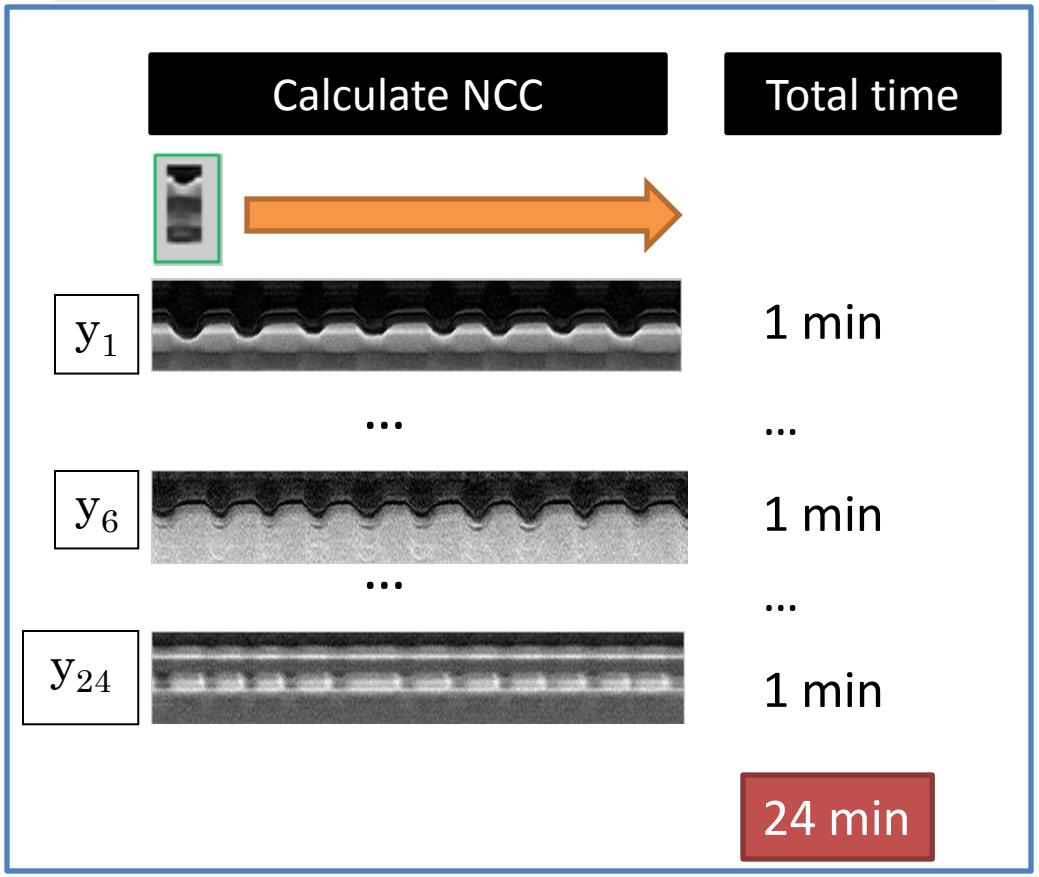
STEP 6 Find the best NCC value from all Y position. Calculate the geomean of all respiratory patterns found. The geomean for *p*-th pattern is expressed as: $G_p = (\prod_{i=1}^{n} N_{i,p})^{1/n}$



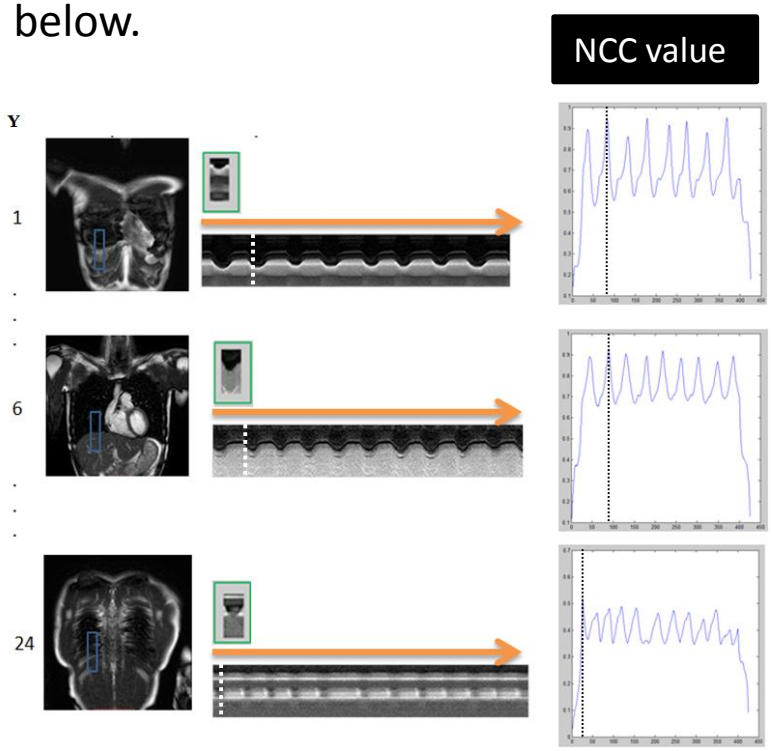
Methodology

3. Time reduction using threshold

Total time required to obtain DS



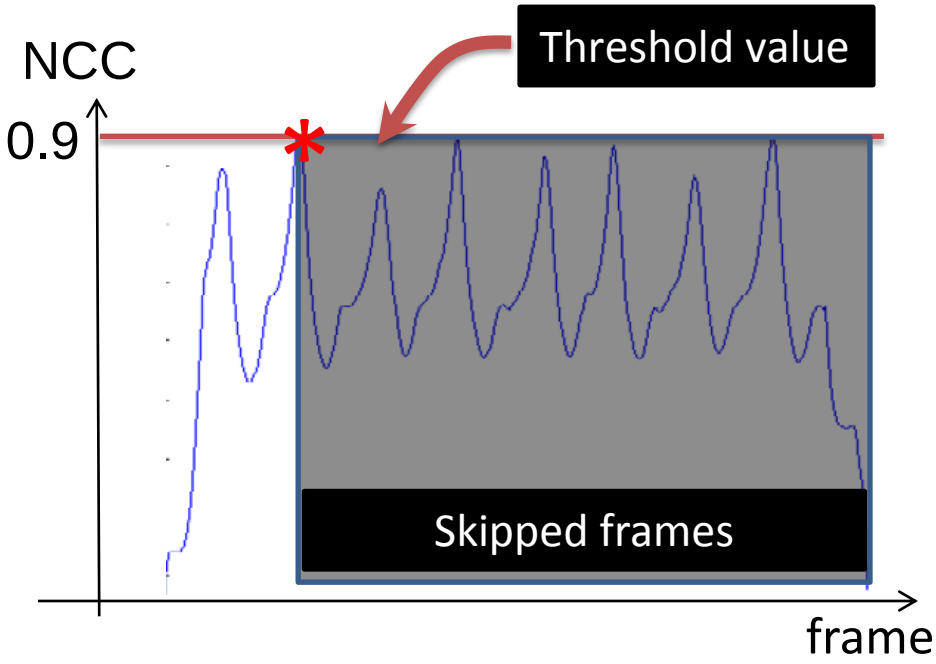
In many y_i positions, the best NCC value can be found in the first one or two hundreds frame, as illustrated below.



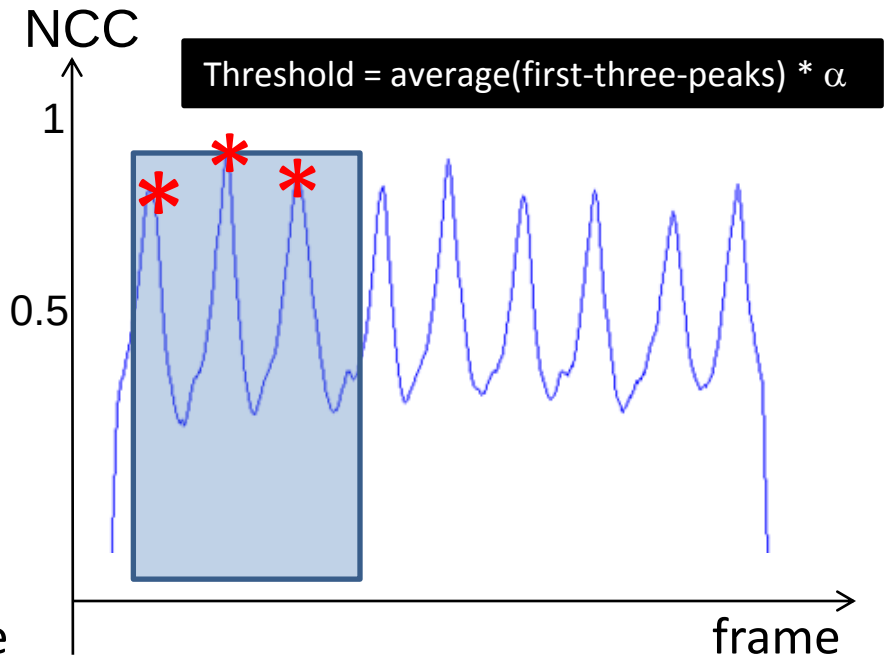
Methodology

3. Time reduction using threshold

Fixed Threshold (FT) method



Adaptive Threshold method



Results

- 4D MRI Reconstruction and volume rendering

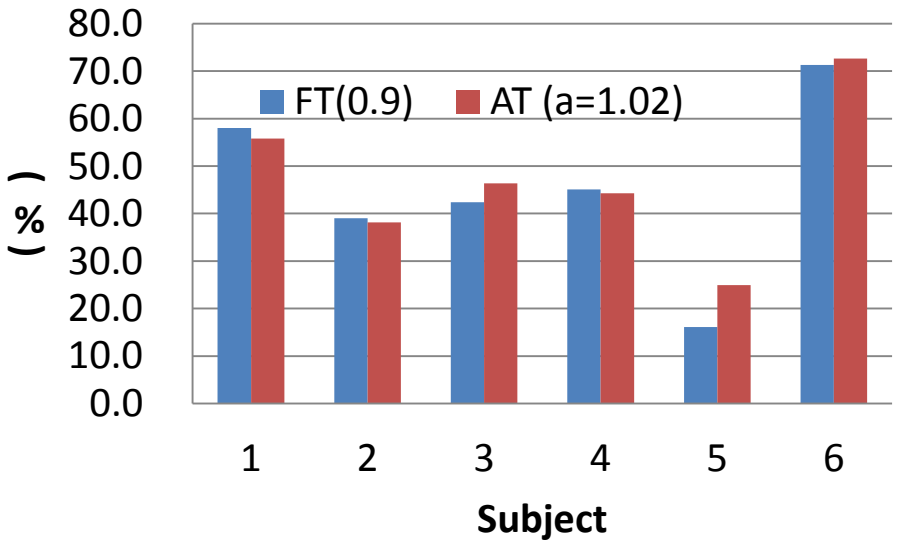
  The reconstructed 4D-MR images were visualized by a volume rendering technique implemented in Osirix

Fixed Threshold

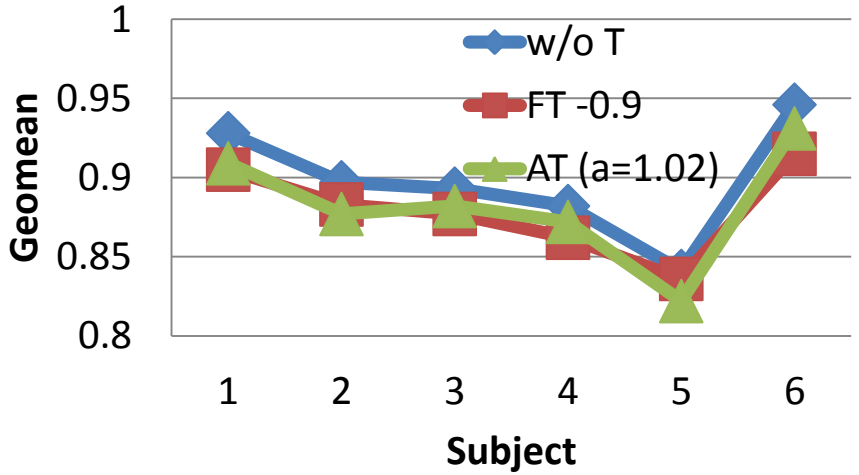
Adaptive Threshold

Results

Percentage of time reduction



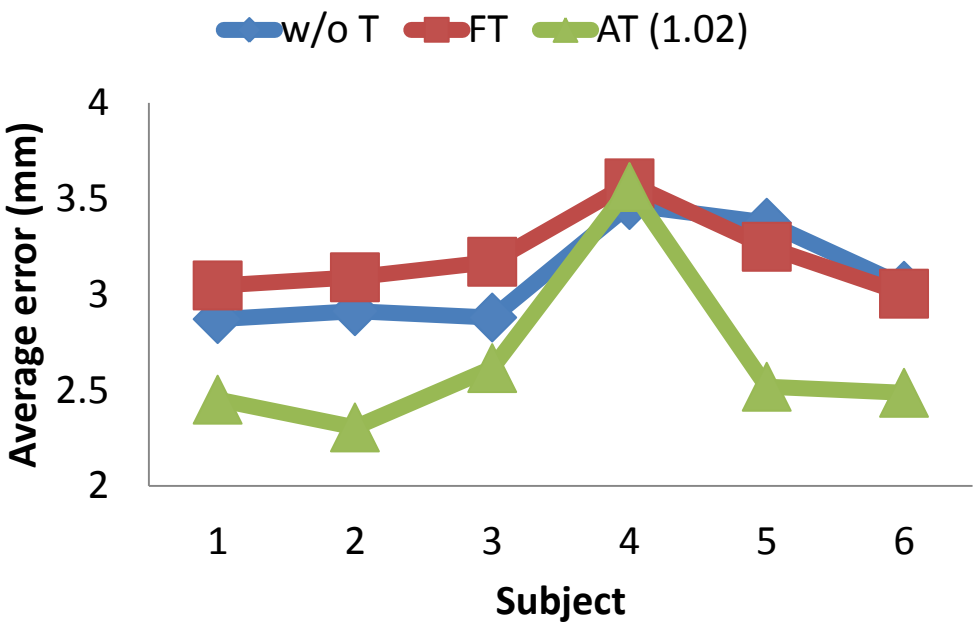
Geomean (quality) of 4D-MRI reconstruction



By applying FT and AT approach, the total time acquisition can be reduced by 45% on average for FT approach and 47% on average for AT approach compared with w/o T approach. However, the trade-off of time reduction is the quality of 4D-MRI reconstruction – as seen in the graph above.

Results

Displacement error in Z axis of 4D-MRI reconstruction



The displacement error range of 6 subjects are 2.9-3.5mm, 3.0-3.6mm and 2.3-3.6mm for w/o T, FT and AT approach respectively.

This error is thought to be a clinically acceptable error, because the typical size of tumors requiring treatment is on the order of tens of millimeters

Conclusion

- 4D-MRI reconstruction using intersection profile method.
- Reduce time acquisition by applying fixed threshold (FT) and adaptive threshold (AT).
- Data acquisition can be reduced on average 45% (FT) and 47% (AT).
- The displacement error of Z position was 3.0-3.6mm (FT) and 2.3-3.6mm (AT), which is implementable for clinical application.

Thank you for your attention

Question?