

Improvement of real-time motion tracking with daily optimized registration of cine MRI on MR-Linac

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Purpose

- Real-time high soft-tissue contrast MRI from MR-Linac (Unity, Elekta, AB, Stockholm, Sweden) offers the opportunity for accurate motion tracking during radiation therapy
- Motion tracking is essential for real-time online MR-guided adaptive radiation therapy
- Successful intrafraction tumor localization facilitates margin reduction and possibility for direct target gating
- Removing variation between 2D and 3D image contrast improves target tracking

Methods and Materials

Algorithms

- Registration performed using gradient descent optimizer to maximize Mutual Information for in-plane translations
- Conventional:
 - Cine registered to appropriate slices from 3D volume (Figure 1a)
- Template-based:
 - Template image generated to remove bias influence of 3D to 2D contrasts (Figure 1b,c)
 - Cine registered to template image

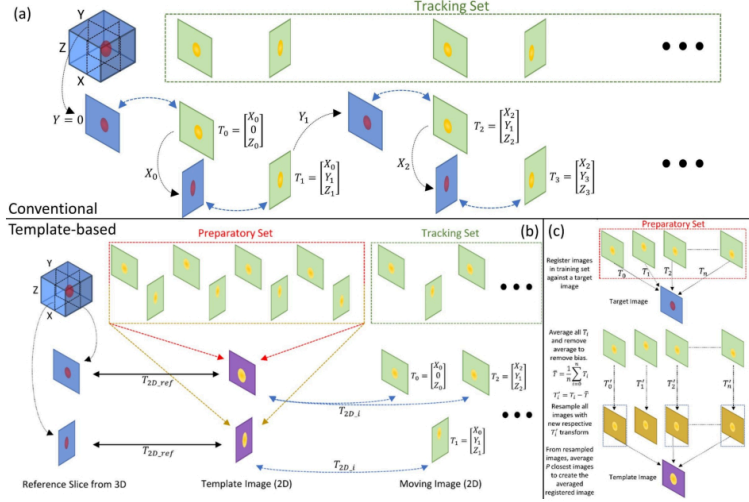


Figure 1. Schematic of registration algorithms for internal target tracking.

Acquisition

- 10 abdominal MR datasets for healthy volunteers
- 2D and 3D MRI collected on MR-Linac
- 3D – Respiration-gated T2
- 2D – T2/T1-weighted bTFFE
- Planar temporal resolution of 2D – 0.6 s for > 60 s
- Target contoured on pre-tracking 3D image
- Ground-Truth target motion contoured on 2D Cine
- Research software (Elekta AB) to track the motion by registration of 2D MRI to 3D volume using conventional and template-based algorithms
- Accuracy of registration determined by standard deviation of the error (SDE)

Analysis

Conclusion

- Demonstrated the improvement of our tracking algorithm when a template image is generated from the daily cine imaging
- Percent difference improvement is reported and can correspond to millimeter values up to 9 mm for SDE and 27 mm for the 90% error range
- Work is ongoing to bring the template-based approach to the clinic for thorough testing

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Results

- Unlike CT, MR intensity is not standardized
- Organ intensity may vary patient-to-patient or fraction-to-fraction
- Abdominal cine MR for volunteers using the same protocol can be seen to differ quite significantly (Figure 2)

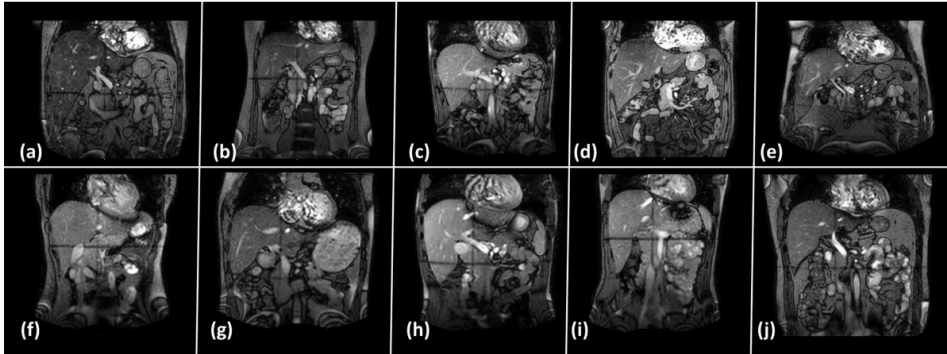


Figure 2. Coronal cine MR images showing intensity variation between volunteers.

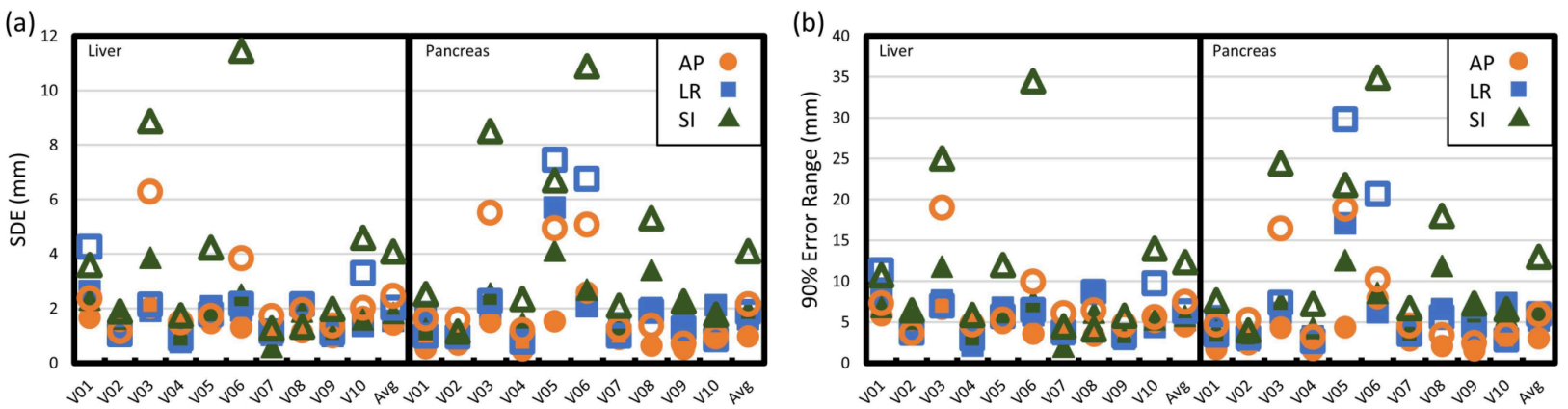


Figure 3. Tracking results for conventional (open) and template-based (filled) tracking algorithms. (a) Liver and pancreas tracking results for each volunteer. (b) Liver and pancreas 90% error range for each volunteer.

- SDE is used as the measure of tracking accuracy
- Template-based (filled) shows an improvement to SDE over conventional (open) approach
- Average improvement to SDE is 0.4 mm (19%), 1.1 mm (49%), and 2.2 mm (54%) in LR, AP, and SI directions
- 90% error range is plotted for each image set where the y-axis indicates the error magnitude to include 90% of points
- Average improvement to the 90% error range is 15, 45 and 53% for LR, AP and SI directions
- Table 1 reports the percent differences between the two approaches showing that, on average, the template-based approach improves the tracking results
- Negative percent differences typically occur for datasets where both algorithms perform reasonably well (SDE < 3 mm)
- Other factors, e.g. motion magnitude, may affect tracking accuracy and must be investigated further

Table 1. Percent improvement of tracking results for the template-based approach compared to the conventional approach. Positive percentage indicates an improvement for the template-based over conventional algorithm.

	Anterior-Posterior	Left-Right	Superior-Inferior
SDE (range) (%)			
Liver	43 (-32 - 68)	24 (-16 - 59)	55 (-37 - 77)
Pancreas	55 (3 - 73)	14 (-145 - 69)	53 (-2 - 75)
90% error range (range) (%)			
Liver	40 (-44 - 65)	17 (-19 - 54)	53 (-45 - 77)
Pancreas	49 (14 - 77)	13 (-158 - 70)	52 (11 - 75)