Evaluation of a Free-Form Intensity Based Deformable Registration Method Using the POPI Model

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Purpose

Our goal is to evaluate the accuracy of a free-form intensity-based deformable registration method using the POPI model.

Methods

Five subjects with 4DCT datasets from the POPI model (1-2) were used to assess deformable registration accuracy. Each subject contained 100 or more identified landmark points that corresponded between the end-inspiratory and end-expiratory phases. The 0% phase was registered to the 50% phase first using a rigid alignment followed by a commercially available free-form intensity-based deformable registration (MIM Software, Cleveland, OH). Landmark displacement was measured after the rigid registration (initial displacement) and the deformable registration (residual error). A single subject (POPI2) with significant initial displacement was also registered using an interactive tool to influence the deformation by locking local alignments to help guide the deformation. Error was measured with and without using the tool for this subject.

Figure 1a
Patient 1 displaying typical respiratory motion between 0% and 50% phase.

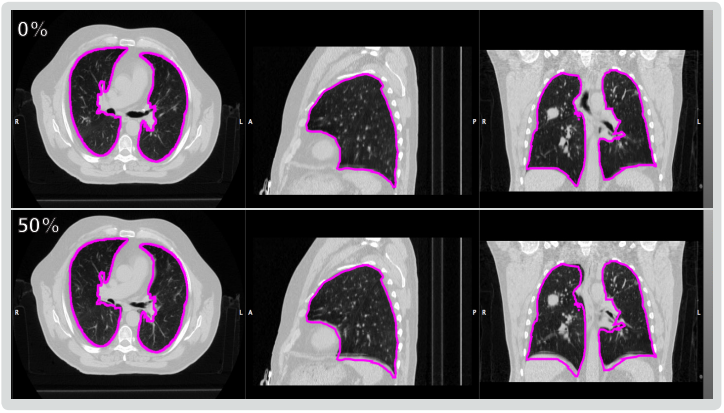


Figure 1b
Patient 2 displaying significant respiratory motion between 0% and 50% phase.

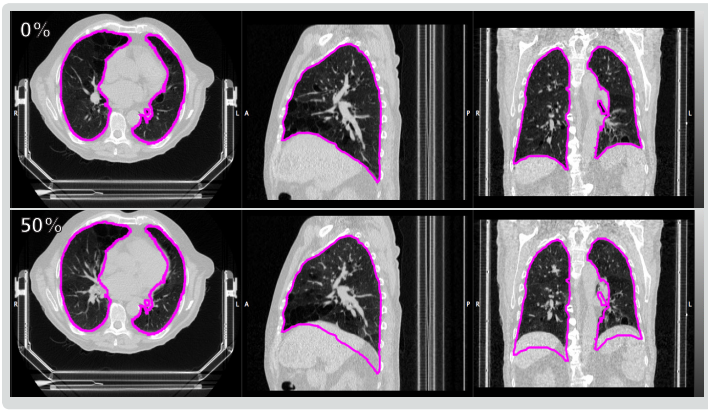
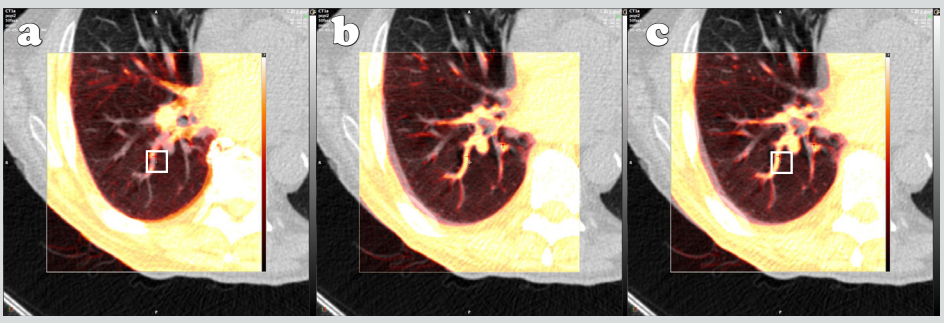


Table 1
Initial Displacement vs Mean Residual Error

Mean (SD)	POPI1	POPI3	POPI4	POPI6	POPI2 (no LA)	POPI2 (LA)
Initial displacement (mm)	5.73 (2.61)	7.67 (5.05)	7.33 (4.89)	6.68 (3.68)	14.4 (7.20)	14.04 (7.20)
Residual Error (mm)	1.11 (0.65)	1.65 (2.70)	1.72 (3.34)	1.04 (0.92)	4.59 (6.84)	1.24 (0.98)

POPI2 shows results with no locked alignments (No LA) and after locking 7 local alignments and rerunning the deformation using Reg Refine (LA). Reg Refine was used to correct the registration due to the large amount of initial displacement for this subject which was twice as large as any of the other subjects. None of the other subjects required the use of Reg Refine.

Figure 2
Reg Refine-Based Correction of Deformation



Best fit rigid registration of the source to the target image based on the deformation that occurred within the center sampling box. The center of the box shows the point that was mapped from the source image to the target image at that location. (a) Before Reg Refine, (b) after adjusting the local registration rigidly and "locking" this point, (c) after rerunning the deformable registration using locked points as an input. Note the good correspondence between the source and target within the sampling box after Reg Refine-based deformation.

Results

The average initial displacement prior to deformable registration ranged from 5.7 mm to 14.0 mm. The mean (SD) residual error after deformation ranged from 1.0 mm (0.9) to 1.7 mm (3.3) for four of the five subjects. For POPI2 the initial residual deformable error was 4.6 mm (6.8). Using seven local alignments to guide the deformation the error for POPI2 decreased to 1.2 mm (1.0). The average error across all 5 subjects was 1.3 mm (2.0).

Conclusion

A free-form intensity-based deformable registration method was found to provide good accuracy with an average error of 1.3 mm. A method for locally guided deformation allowed for the accurate registration of a challenging case with significant respiratory motion.

References

1 Vandemeulebroucke J, Rit S, Kybic J, et al. Spatiotemporal Motion Estimation for Respiratory-correlated Imaging of the Lungs. Med Phys 2011; 38(1):166-178

2 http://www.creatis.insa-lyon.fr/rio/popi-model/