A Novel Framework for User-Intervened Correction of Deformable Registration

S Pirozzi, BS[1], JW Piper, BS[1], AS Nelson, MD[1], M Duchateau, MSc[2], D Verellen, PhD[2], M De Ridder, MD, PhD[2]

[1]MIM Software Inc., Cleveland, OH • [2]Universitair Ziekenhuis Brussel, Brussels, Belgium

Purpose

Many studies have been done to characterize the performance of deformable registration algorithms (DIR) in different image sets (1,2,3). Residual registration errors can range from insignificant to even worse than rigid registration. However, these algorithms remain essentially black boxes in the clinic, with little or no ability to improve the registration results on patients where the results are unacceptable. Here we evaluate a novel framework to allow the user to influence the registration algorithm to achieve a more accurate result.

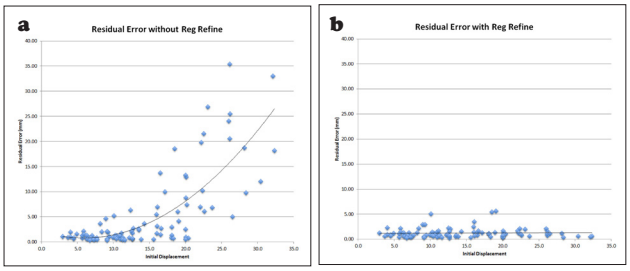
Materials/Methods

A novel framework, Reg Refine, is proposed, wherein a registration can be both evaluated and corrected with user-intervention. In review mode, a visual display of a rigid fusion between the two volumes is shown around a selected point of interest. This rigid fusion is computed as the best approximation to the local DIR, in a least squares sense, constrained such that center of the rigid fusion is the exact transform defined by the deformable vector field at that point. Rigid registration adjustment tools are provided within this framework to allow the user to manually adjust the registration or to execute an automatic rigid registration within a box of interest. The user may then record the preferable rigid registration. When re-executing the DIR, these recorded local rigid alignments are used as inputs in order to influence the algorithm to achieve a local DIR closer to this user-defined result. This process can be performed iteratively until a satisfactory result is achieved, and the final registration computed considers each of the recorded registrations in an order-independent fashion. The 4D dataset used is Patient 2 of the POPI-model (4). The average motion of 100 points of interest was 14.0 +/- 7.2 mm between the 0% phase and 50% phase. After DIR with a commercially available algorithm in a beta version of MIM 6.0 (MIM Software Inc), a user was instructed to review the registration and record several local rigid registrations in areas where the naïve registration was determined to be inaccurate.

Results

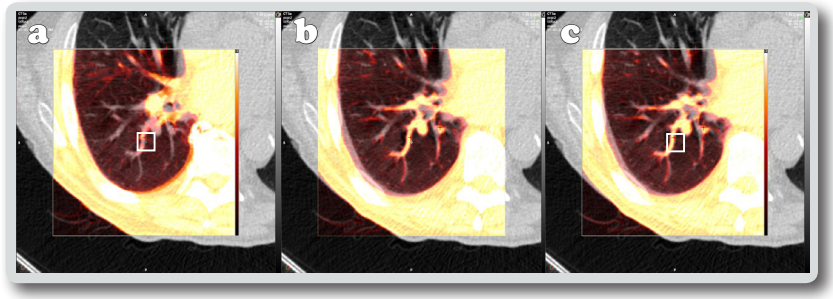
Naïve DIR resulted in a distribution of residual registration errors ranging from 0.3 mm to 35.4 mm (mean 5.1 mm, SD 7.5 mm). The user recorded seven local rigid registrations within the lungs and re-executed the DIR algorithm with these as inputs. The distribution of errors in the final DIR ranged from 0.2 mm to 5.6 mm (mean 1.2 mm, SD 0.9 mm), which was a significantly better result ($p < 0.000001$).

Figure 1
Residual Error With and Without Reg Refine



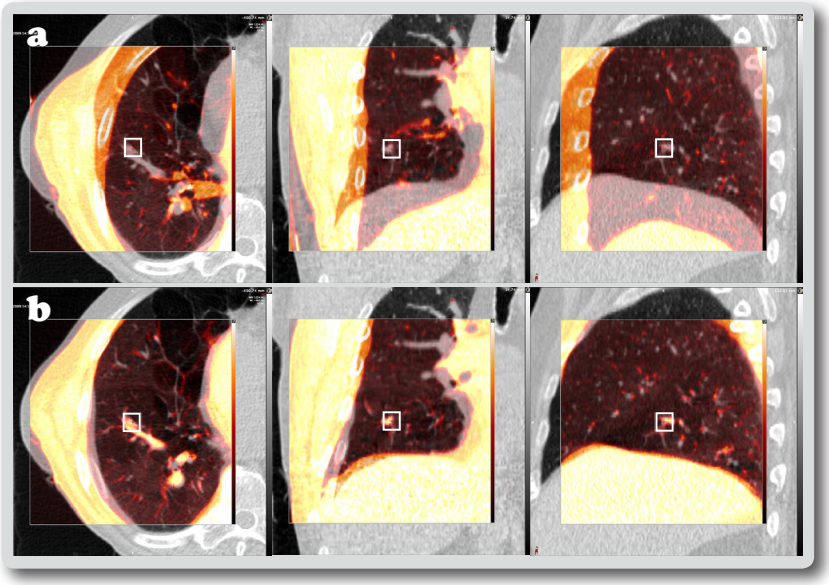
Measurement of residual error of deformable registration versus the initial displacement of points (a) before using Reg Refine and (b) after using Reg Refine. Note the marked reduction in error particularly for points with larger initial displacements.

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.

Figure 3
Impact of Reg Refine Adjustments on Final Deformation



(a) Reg Reveal display demonstrating an area of concerning registration with poor matching between source and target within the sampling box (b) Improvement in deformation for the same target location but after locking local registrations with Reg Refine and rerunning the deformable registration.

Conclusion

This framework represents what the authors believe to be the first clinical environment for iterative user-intervention in a deformable registration workflow based on a process of improving local image registration. Its performance in a challenging dataset suggests that it is an effective tool for correction of deformable registration errors.

References

1 Piper JW. Evaluation of An Intensity-Based Free-form Deformable Registration Algorithm. Medical Physics. June 2007;34(6):2353-2354.

2 Brock KK. Results of a Multi-institutional Deformable Registration Accuracy Study (MIDRAS). IJROBP 2010; 76(2):583-596.

3 Kashani R, Hub M, Balter J, et al. Objective assessment of deformable image registration in radiotherapy: A multi-institutional study. Med Phys 2008;35:5944-5954.

4 http://www.creatis.insa-lyon.fr/rio/popi-model/ Vandemeulebrouke J, Rit S, Kybic J, et al. Spatiotemporal motion estimation for respiratory-correlated imaging of the lungs. Med Phys 2011; 38(1):166-178.

Scientific Session RR - Physics-IGRT Process & Technologies
09/25/2013 - 1:00-2:30pm
Georgia World Congress Center
Room Number: B313