Evaluation and Validation Methods for Intersubject Non-Rigid 3D Image Registration of the Human Brain

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Abstract: Accuracy of a non-rigid image registration algorithm is one of the major concerns in developing brain atlases and functional databases for minimally invasive neurosurgery planning and guidance. We present two approaches to the qualitative and quantitative evaluation of non-rigid image registration algorithms. The first is based on a set of 43 anatomical landmarks, the other on visual inspection software. MRI brain images of 12 subjects and the CJH-27 dataset were employed as the source and reference images respectively. For the first method, we identified each landmark in 3D space using the Atamai Surgical Planner (ASP) software. The "gold-standard" coordinates of each landmark in the reference space were estimated by averaging its coordinates after 6 tagging sessions. The registration error was considered as the Euclidean distance between each landmark of a subject after warping to the reference space and the homologous "gold-standard" landmark. For the second method, visual inspection software displaying the spatial change of groups of colour-coded spheres before and after warping with a non-rigid registration algorithm was implemented to evaluate the performance of a non-rigid registration algorithm within homogeneous regions in the deep brain. Our methods were illustrated by assessing and comparing AtamaiWarp and ANIMAL two non-rigid registration algorithms available for us. The average registration error was 1.04mm +/- 0.65mm for AtamaiWarp, and 1.59mm +/- 1.47mm for ANIMAL, and both algorithms treated the interior of homogeneous regions in an appropriate fashion. These results indicate that our landmark based method and visual inspection software can not only facilitate the evaluation of non-rigid intersubject registration algorithms but also be a tool in construction of functional brain databases.
Keywords: non-rigid image registration, validation, landmark, visual inspection, brain mapping

		AtamaiWarp	ANIMAL
Registration Error (mm)	Average	1.04	1.59
	Maximum	2.78	3.89
	Minimum	0.05	0.31
Sd of Registration Error (mm)	Average	0.65	1.47
	Maximum	1.88	5.06
	Minimum	0.13	0.32

Table 1. Average, maximum, and minimum registration errors and standard deviations of AtamaiWarp and ANIMAL non-rigid registration algorithms

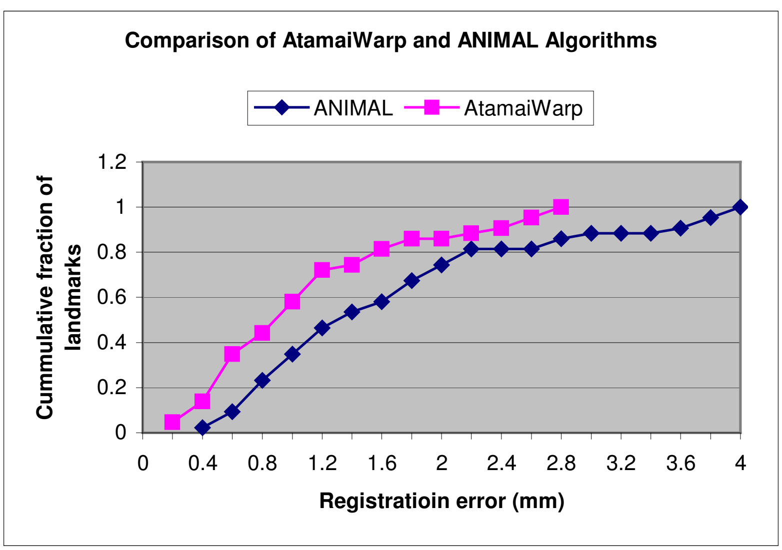

Fig. 1. Comparison of AtamaiWarp and ANIMAL algorithms in registration error, clearly indicating the superiority of AtamaiWarp over ANIMAL. AtamaiWarp registered much more amount of landmarks with less registration errors

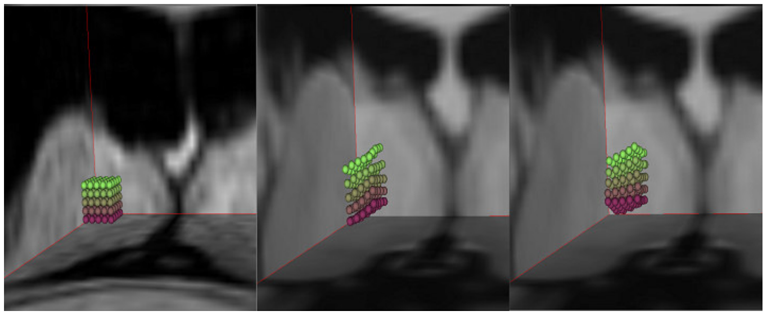

Fig. 2. Left: multi-colour spheres in a subject brain image; Middle: homologous spheres after non-rigid intersubject registration in reference CJH-27 template using AtamaiWarp algorithm; Right:using ANIMAL algorithm. This test demonstrated that while the performance of each algorithm differs slightly, both are “well-behaved”.

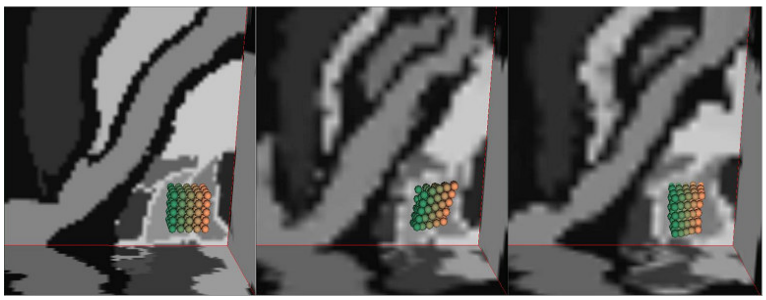

Fig. 3. Left: digitized Schaltenbrand & Wahren atlas in CJH-27 brain template; Middle: atlas non-rigid registered to a subject brain image using AtamaiWarp algorithm; Right:using ANIMAL algorithm. This test demonstrated that while the performance of each algorithm differs slightly, both are “well-behaved”.