

Methodology for the Quantitative Evaluation of the Elements Cranial Distortion Correction Algorithm

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Purpose

It is well known that geometric distortions in MR images can have a negative effect on the treatment of SRS patients. The Elements Cranial Distortion Correction (CDC) algorithm, which can deformably register MRs to a geometrically sound imaging set, most commonly CT, can help account for those distortions. Evaluation/validation of deformable image registration algorithms is recommended by the AAPM TG132 report, with the preferred methodology to compare DICOM deformable vector files (DVF) [1]. This work aims to evaluate the Elements CDC in this way for use in SRS.

Materials and Methods

To quantitatively evaluate the Elements CDC algorithm, known deformation vector grids were applied to a synthetic MR image from the Brainweb simulated MR database [2]. A synthetic CT from this MR was generated using bulk density assignment. Three distortion maps of linear expansion, linear contraction, and shearing in the sagittal plane were applied to the MR using 3D Slicer [3]. The average distortion magnitude over each map was 2 mm. Images with known distortions were then brought into Elements and the CDC was applied. Resulting DICOM deformable image registration files were exported and the vectors were compared to the known introduced vectors. Vector grid data from the deformable image registration files were extracted/decoded in Python using the 'struct' package.

Results

Through comparison of the known introduced DVFs to the DVFs returned by Elements after correction, it was found that the images were corrected back with an average difference of -0.3 mm in magnitude between the vectors. Using the TG132 criteria, of which each of the X, Y and Z components should have 95% of points within 2 mm of the known distortion, all three corrected images passed this criteria. Additionally, they passed a criterion of 90% of points within 1 mm. It was also seen that the remaining distortion, characterised by the difference in vector magnitude, was comparable to the calculated residual distortion, determined by running the CDC on the original MR image. Vector plots and histograms of these results for the linear contraction case can be seen in Figures 1 and 2.

Conclusion

In conclusion it has been shown that the Elements CDC can be quantitatively evaluated in line with recommendations from the AAPM TG132 report through direct comparison of DVFs by using a digital brain MR and corresponding CT. It has also been shown that, for simple linear deformations, the Elements CDC algorithm passes the testing criteria for deformable image registration laid out by the AAPM TG132 report. This type of quantitative analysis can be included as part of a clinical validation workflow. Future work for this method would include the introduction of more complex, non-linear and clinically relevant distortion maps.

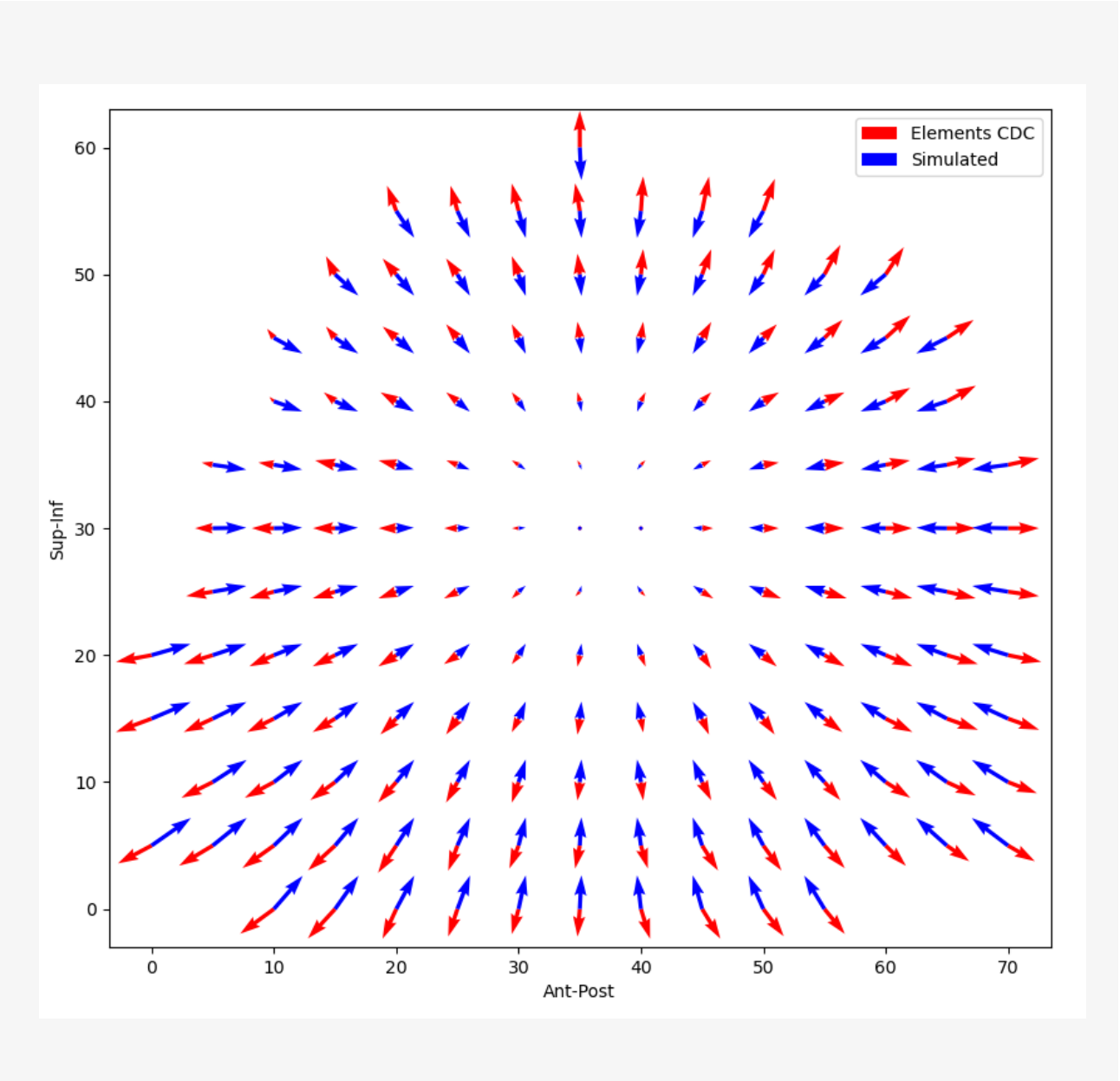


Figure 1 Vector plots in the sagittal plane of the Simulated distortions introduced into the MR images and the resulting vectors returned from Elements after applying CDC for the linear contraction case

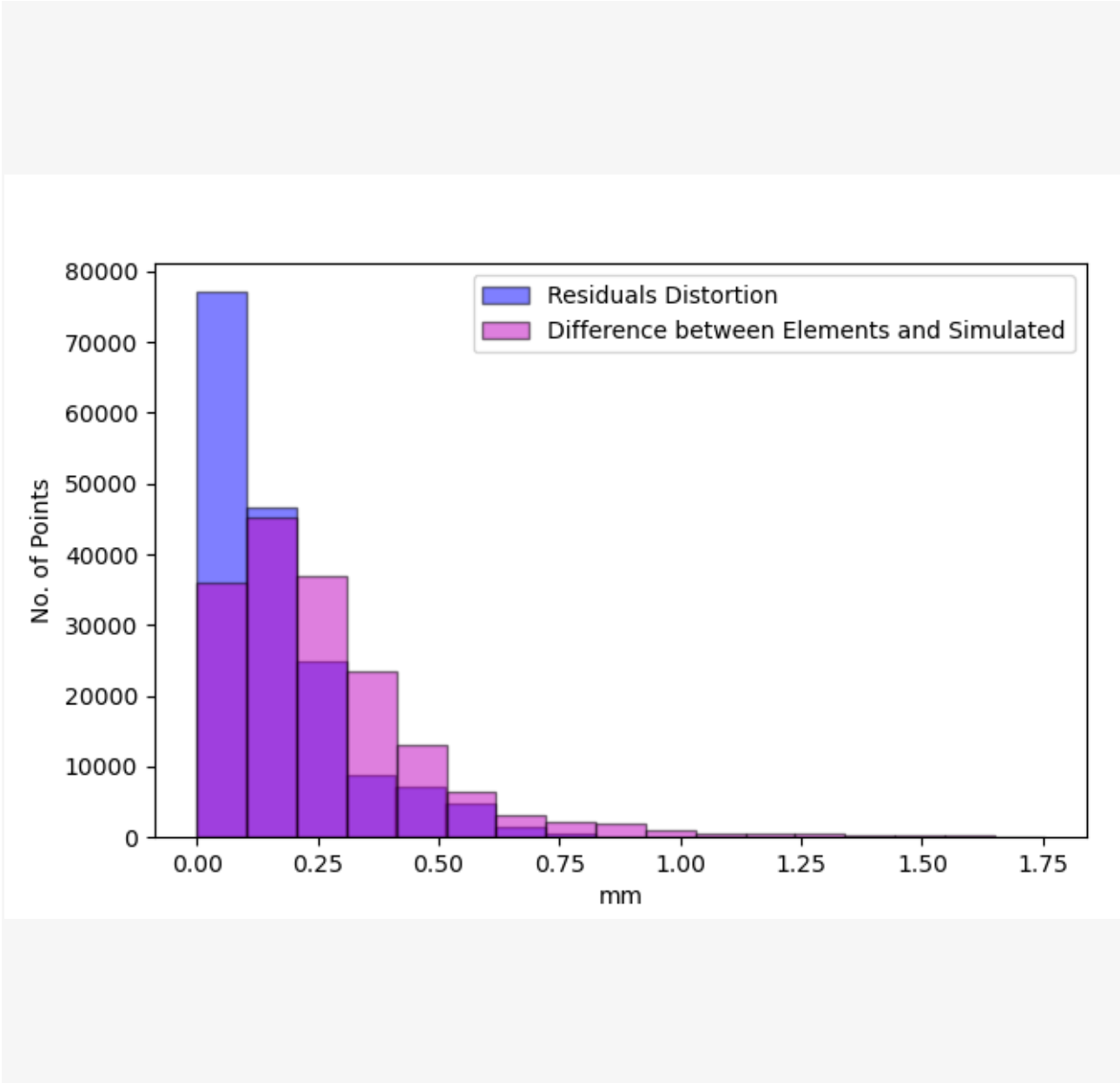


Figure 2 Histograms of the residual distortion of the original MR (light blue) and absolute difference in vector magnitude between Elements vectors and Simulated vectors (light pink) for the linear contraction case

References: [1] Brock et al. (2017), 'Use of image registration and fusion algorithms and techniques in radiotherapy: Report of the AAPM Radiation Therapy Committee Task Group No. 132', [2] Cocosco, Kollokian, Kwan, Evans: 'Brainweb (1997): Online interface to a 3D MRI Simulated Brain Database', [3] Fedorov A. et al. (2012) '3D Slicer as an Image Computing Platform for the Quantitative Imaging Network'