Preliminary study investigating brain shift compensation using 3D CBCT cerebral vascular images

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Introduction

- **Brain shift** phenomenon in a neurosurgical procedure:
  - Time dependent elastic deformation (see **Fig. 1**).
- Image guided navigation systems:
  - Assume rigid behavior of the head and its content,
  - Are not able to recover elastic deformation.

  => **Brain shift affects the accuracy of the neurosurgery.**

Materials and Methods

- The overall brain shift compensation pipeline includes the following steps:
  - Feature extraction,
  - Point matching (**coherent point drift** vs. **robust point matching**),
  - Displacement field interpolation (**thin plate spline** vs. **B-spline**).
- Feature extraction:
  - Use Frangi´s vesselness filter [1] to enhance the vasculature.
  - Extract centerline by using an octree data structure [2].
  - Detect bifurcation points with a 3x3x3 window around each point of the centerline.
- Point matching:
  - Coherent point drift (CPD) [3]:
    - Target point set represents the data points,
    - Source point set represents the GMM centroids,
    - Maximize the posterior probability.
  - Robust point matching (RPM) [4]:
    - Soft correspondence for fuzzy assignment,
    - Least square optimization of an energy function.
- Displacement field interpolation
  - Thin plate spline (TPS) [5]: globally controlled, belongs to the family of Radial Base Functions.
  - B-spline [6]: locally controlled, only use the information in the neighborhood.

Results and Discussion

- Experiment:
  - With synthetic digital phantom data [7].
  - Use relative overlap metric for the evaluation.
  - Calculated both for the entire brain parenchyma and ROI.
  - Additionally, add 20% outliers to evaluate the robustness.
- Results (see **Tab. 1** and **Fig. 2**)
  - Outliers affect the accuracy greatly.
  - B-spline interpolation outperforms TPS.
  - Result of CPD depends on the choice of parameter controlling outlier proportion.

Conclusions

- A feature-based registration pipeline for brain shift compensation with 3D CBCT cerebral vasculature is proposed.
- We compared different point matching methods and interpolation techniques on digital phantom data.

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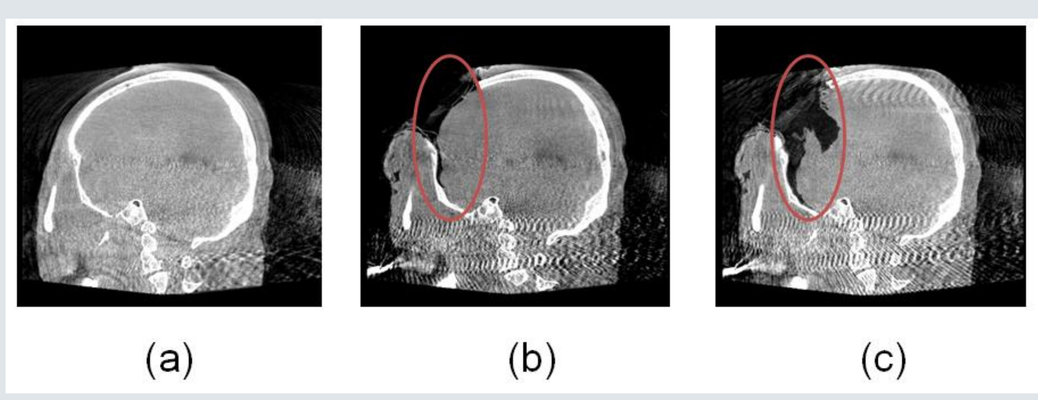

Figure 1: Cone beam CT images acquired during a tumor resection surgery. (a) Preoperative image. (b) After dura opening, a small deformation is visible. (c) After resection, the surrounding tissue undergoes a larger deformation.

	Before	CPD-B-Spline	CPD-TPS	RPM-B-Spline	RPM-TPS
Full brain	0.92	0.94	0.94	0.95	0.93
ROI	0.89	0.93	0.92	0.94	0.90
Full brain (+ Outlier)	0.92	0.85	0.66	0.85	0.65
ROI (+ Outlier)	0.89	0.88	0.82	0.92	0.82

Table. 1.: Relative overlap rate of the entire brain parenchyma and region of interest (ROI) after using different point matching and interpolation techniques.

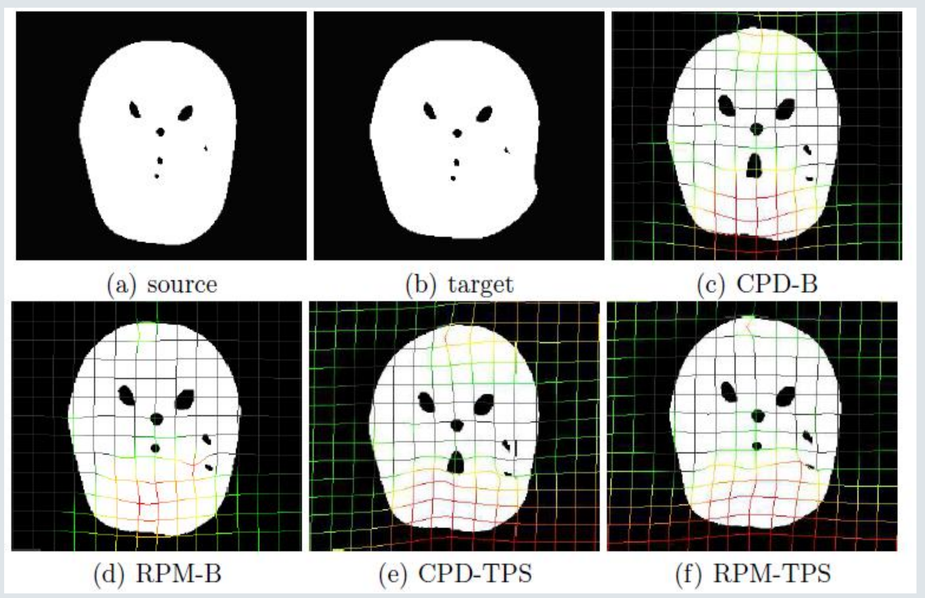

Figure 2.: An example axial slice with displacement field overlay. (a) and (b) are the source and target images, respectively. (c) – (f) are registration result of different methods.

References

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