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Registration of Patch Optical and MRI or CT Imagery for Real-time 3D Organ Tracking

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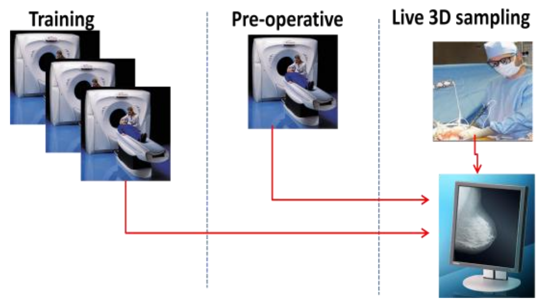
Electrical and Computer Engineering, University of Minnesota

Objective

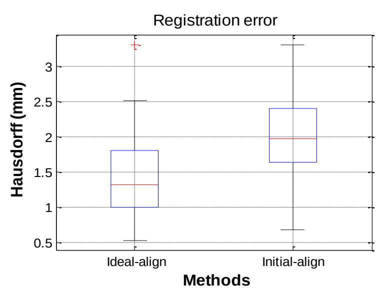
3D organ tracking is critical for image guided surgery since deformations due to tissue movement significantly deteriorate the precision of the preoperative images. This paper presents a new approach to track the 3D deformation of an organ in real-time by registering limited view optical images and MRI or CT scans.

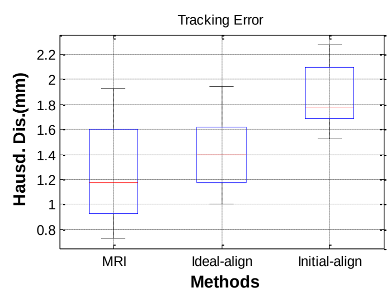
Approach

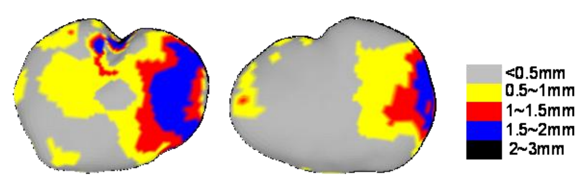


As shown on the right, the live surface samples acquired with a laparoscopic or endoscopic camera featuring 3D imaging is registered and then used to update the 3D organ images on a computer screen. The design principle of the real-time 3D visualization approach relies on our recent discovery that it is possible to identify sparse and structured representations of the entire surface using limited data acquired from a restricted view, because organs deform in limited ways due to their mechanical properties. The registration during training involves: (i) eliminating the linear transformation between 3D deformations in training set; (ii) finding the pixel-wise correspondence across the different deformations. A method that aligns the spherical harmonic coefficient pairs to match the ridges of the first order ellipsoid is applied in this design. Registration during tracking also involves two steps, including (i) elimination of linear transformation, and (ii) fine tuning. The latter aims to find the optimal patch for tracking by selecting the location yielding minimum reconstruction error at the know positions.

Preliminary Results







Registration error is first evaluated as shown in the left box-plots using three freshly excised porcine kidneys. The error between the ground truth MRI and the 3D optical images (i.e., "initial-align") is 2.1 ± 0.64 mm when the 3D data is aligned to the initial MRI set with the proposed approach. We note that this error level is comparable to the best intra space registration errors reported in the literature. In contrast, the ideal-case registration error between the ground truth MRI and the 3D optical images (i.e., "ideal-align") is 1.4 ± 0.67 mm. For the tracking error, in the "MRI" reconstruction, samples are retrieved from MRI scans as the ideal scenario for comparison. Samples from optical images using "ideal-align" and "initial-align" registration are evaluated respectively as shown in the right box-plot. Errors for three cases are: 1.30±0.45 mm, 1.44±0.40 mm, and 1.88±0.36 mm. Therefore the maximum reconstruction error is below 3 mm. The image of color-coded error field shows that the hidden side (left) has less error than the exposed side (right).

Conclusion

We report an approach of using a single MRI scan for real time 3D visualization of organ deformations from limited view of optical imagery. The preliminary experiment utilized 3D MRI scans with a 1.3 mm resolution and real time limited view single side optical imagery with 0.38 mm resolution. The results show that this new 3D tracking procedure achieves a spatial resolution better than 3 mm on the hidden side of the organ and better than 1.7 mm on the partially observed side of the organ.