

Ultrasound Volume Stitching

Christian Wachinger^{1,2}, Wolfgang Wein^{1,2}, and Nassir Navab¹

¹ Computer Aided Medical Procedures (CAMP), TUM, Munich, Germany

² Imaging and Visualization Dept., Siemens Corporate Research
Princeton, NJ, USA

1 Motivation

The recent introduction of 2D array ultrasound transducers on the market will soon make instantaneous volumetric ultrasound acquisition available in the clinical practice. Moreover, the CMUT³ technology, which is currently in the phase of prototyping, will offer superior and efficient volumetric ultrasound imaging. But one drawback that remains is the limited field-of-view (FOV) of the acquired images. Toward this end, volume stitching, meaning the fusion of information from several acquisitions, may be an adequate technique to address this issue. Next to the extension of the FOV, this method also has the capability of improving the overall quality of the imaged scene by e.g. reducing occlusions. A first step to make the stitching possible is the correct alignment of the volumes, which we focused on in our work.

2D image mosaicing has already been available for a while and studies showed its clinical values. It helps, among others, to easier understand the spatial relationship among structures, enables the size and distance measurements of large organs, and due to the increased number of features in the compounded view, ultrasound images can be easier understood by experts not used to ultrasound. But it is not just the improvement of already existing workflows, the creation of high quality mosaics may also create new medical applications for ultrasound that do not yet exist at all or are reserved for other modalities.

2 Problems statement

In the field of ultrasound registration, the alignment of multiple volumes is calculated by a sequence of pairwise registrations. This poses problems because registration errors can be accumulated, leading to a non-consistent global alignment. Another problem is the overlap dependency of the similarity measures, which make the pairwise registration prone to misregistrations. As a last point we want to mention the problems lying in the interface enhancing nature of the ultrasound images, making images from the same scene but from different viewing angles not necessarily look the same. This is especially the case if there are structures in the scene with a high acoustical impedance like bones, yielding a complete reflection of the beam and therefore occlusions.

³ Capacitive Micromachined Ultrasound Transducer

3 Method

We developed two registration approaches, differing from the standard sequential pairwise alignment, to address the above mentioned issues, arising from ultrasound mosaicing. The first method is based on a set of pairwise registrations that have to be calculated, followed by a Lie group normalization to deduce the correct global alignment. This technique has before been used for the alignment of 2D optical images. The second method that we are using is a simultaneous registration. Simultaneous registration is frequently used for population studies. The reason for choosing this approach is twofold, like the problems occurring during registration. First, the accumulated registration error that was treated in a separated normalization step by the above mentioned registration approach, is now handled intrinsically during the registration. Second, the multivariate similarity measures create more robust cost functions for the optimizer to run on because each image is put into its global context trying to get the maximum out of the depicted structures.

Due to the high computational complexity of the simultaneous registration, we developed a closely related variant, referred to as semi-simultaneous registration. This method still uses multivariate similarity measures, but differs in its optimization strategy. The n times 6 dimensional parameter space is split up into six dimensional spaces, which is iterated over. This variant has lower computational complexity.

Additionally, we used four different methods for the detection of occlusions; two of them are based on the calculation of the variance along one ultrasound beam, one directly considers the intensity values, and the last one is based on finding the robust maximum along the beam. The detection of the occlusion was necessary, because if not treated, its influence can corrupt the whole alignment process. Another pre-processing step that was done on the ultrasound data was the reduction of speckle noise by Gaussian smoothing and down sampling.

4 Results

We want to present the results of the stitching algorithm for two data sets. First, the alignment of several images taken from a clay model of the human spine, that was too large to be completely captured in one image. Therefore, 12 successive volumes with about 3 cm displacement were acquired. A picture of the clay model and the fused models can be seen in figure 1, 2, and 3, respectively. Even in this linear stitching case, the simultaneous registration showed better performance than the standard pairwise registration.

A second experiment was done on six volumes acquired from a heart clay model in the water bath from six different angles. The imaging setup is shown in figure 4. Extensive experiments were performed on this data set, which enabled a pretty good characterization of the proposed registration strategies. The standard pairwise registration lead to a large accumulation error, that could be correct to some point by the successive Lie group normalization. The simultaneous registration methods performed better, but led to a higher computational

cost. In detail, the full-simultaneous registration produced a result of higher quality.



Fig. 1.

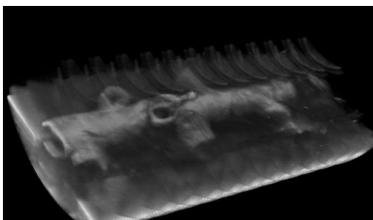


Fig. 2.

5 Conclusion

We have described three registration strategies for ultrasound stitching which are put into relationship to the standard pairwise sequential one. Our experiments clearly show that these advanced strategies are necessary to address the problems that can occur during ultrasound stitching. The best registration result was obtained with the simultaneous approach but this comes with a high computational cost. We also developed heuristics for shadow detection, which are crucial for obtaining good registration results.

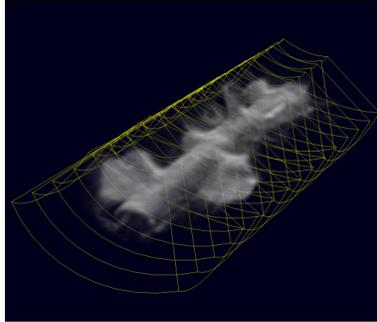


Fig. 3.

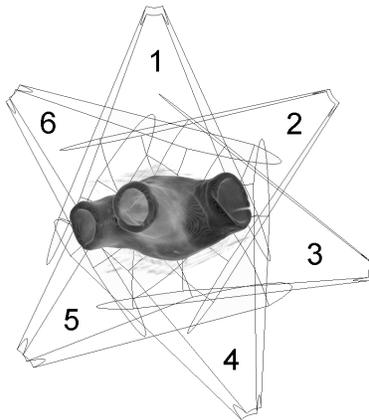


Fig. 4.