ProbeSight: Video Cameras on an Ultrasound Probe for Computer Vision of the Patient's Exterior

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Purpose

Medical ultrasound typically deals with the interior of the patient, with the exterior left to that original medical imaging modality, direct human vision. For the human operator scanning the patient, the view of the external anatomy is essential for correctly locating the ultrasound probe on the body and making sense of the resulting ultrasound images in their proper anatomical context. We are now interested in giving vision to the transducer, by mounting video cameras directly onto the ultrasound probe. This could eventually lead to automated analysis of the ultrasound data within its anatomical context, as derived from an ultrasound probe with its own visual input about the patient's exterior.

Methods

Our present embodiment of this concept consists of an ultrasound probe with two color-video cameras mounted on it, with software capable of locating the surface of an ultrasound phantom using stereo disparity between the two video images. The separate viewpoints of cameras allow triangulation of the 3D coordinates of observed points, revealing both the shape and position of the surface relative to the ultrasound probe in 3D in real time. We use OpenGL's real-time rendering to display both the 3D surface and the ultrasound data slice, each displayed in the correct spatial relationship relative to the other. Most recently, we have added the use of 2D optical flow to establish temporal correspondences for the tracked 3D points across successive video frames, which will enable tracking the full 3D movement between the probe and the patient's exterior. We have performed initial testing of our system using an ultrasound phantom, upon which a sheet of checkerboard tracing paper has been laid in order to add visible features to the phantom. The tracing paper was saturated with ultrasound gel so as not to interfere with the passage of ultrasound.

Results

We have successfully demonstrated real-time 3D rendering of the phantom's surface with the ultrasound data superimposed at its correct relative location. The RMS error for our system's distance measurements is ±1 mm. We are also accurately tracking points on the surface over time, and are now working to track the probe's trajectory over time. In the future, we will additionally use structured-light to improve our stereo system's robustness, enabling us to move from a flat phantom to the curved, deformable surface of human skin.

Conclusions

We believe this research represents important preliminary steps towards a clinically useful approach in merging visual and ultrasound data in real time as the ultrasound probe is moved over the surface of the patient. Eventually, automated analysis of these registered data sets may permit the scanner and its associated computational apparatus to interpret the ultrasound data within its anatomical context, much as the human operator does today.