Towards ProbeSight: Integration of a prior high-resolution 3D surface map into a probe-mounted camera system to locate the ultrasound probe relative to the patient

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Purpose

We are developing techniques for guidance of ultrasound probes with respect to the exterior of the patient using a video camera mounted on the probe. This method will permit the reconstruction of 3D ultrasound data as the probe is moved, as well as the comparison of a real-time ultrasound scan with previous scans from the same anatomical location, all without using external tracking devices.

Methods

Our embodiment of this concept involves three parts: acquisition of a high-resolution multi-camera surface map, projecting the surface map to simulate various camera views, and 2D matching between the projected surface map and actual the camera image. First, a preoperative scan is acquired using a Vectra multi-camera system to yield the 3D shape and high-resolution appearance of the external anatomy. For our initial experiments, we used a textured phantom, in the form of a model dinosaur, instead of a real patient. One video camera was mounted directly on the probe to display a real-time image during the scan. The 3D surface map was then properly rendered to simulate the 2D image that would be seen by the camera from a particular point of view. The actual optics of the camera has been modeled, including focal length, lens distortion, and location of entrance pupil. Finally, given a metric for matching the rendering of the surface map to the real-time camera image, we can find the best match among all possible camera viewpoints, so that the current probe's pose can be determined relative to the anatomy. We used a *normalized mutual information* (NMI) metric for the image matching process, which is better suited than normalized correlation for our purposes, since it can accommodate differences in background without prior segmentation.

Results

We used external optical tracking (Micron) to predict the projection of the surface map that would correctly match the actual image from the camera. Using this ground truth, we tested the accuracy of our image matching procedure by deviating along each of the six degree of freedom (DOFs) from the correct viewpoint, projecting the surface map from each new viewpoint, and computing the NMI metric between it and the actual camera image. Along each DOF, the NMI metric showed a clear maximum at the ground truth viewpoint.

Discussion

With the present results, we have only demonstrated the accuracy of our projection method and the specificity of our matching process. In real applications, the challenge of efficiently searching the 6-DOF space for the correct image will need to be addressed, since this space is very large. We are currently using an inertial navigation system mounted on the probe to reduce the search space, based on orientation and linear acceleration from one video frame to the next.

Conclusion

The major contribution described in this abstract is the use of a previously acquired high-resolution 3D surface map, against which a real-time camera image can be matched, to provide anatomical coordinates for an ultrasound probe or surgical tool to which the camera is mounted. We foresee the use of such systems having broad clinical impact on diagnostic and interventional procedures.