A-MODE ULTRASOUND-BASED INTRAOPERATIVE REGISTRATION ACCURACY ANALYSIS BASED ON SIMULATION ENVIRONMENT

K. Niu [1], **J. Homminga** [2], **N. Verdonschot** [3]

[1] *University of Twente, Enschede, Netherlands*

[2] *University of Twente, Department of Biomechanical Engineering, Enschede, Netherlands*

[3] *Radboud University Medical Centre, Orthopaedic Research Laboratory, Nijmegen, Netherlands*

INTRODUCTION

In Computer-Aided Orthopedic Surgery (CAOS) systems, A-Mode ultrasound has been proven quite successful in experimental and clinical environments, showing advantages, such as the non-invasiveness and lower time requirements [A.Mozes, 2010]. However the registration accuracy and robustness still need to be improved to provide reliable and stable registration results [C.Amstutz, 2003]. A clearly defined registration methodology/procedure is also important. The number of detected points, the specific locations that these points were obtained from, as well as the amount of noise in the A-mode signal will influence the accuracy of registration. To assess the effects of these parameters and adjust them, a simulation environment based on A-mode ultrasound intraoperative registration procedure provides a feasible way to repeat and to amend a certain mode of ultrasound transducers palpation without time-consuming in-vivo or in-vitro measurements and validations. The quality of the resulting fit was assessed by the error between the true location of the bone and the registered results.

METHODS

In this study, a surface mesh of a healthy subjects femur was segmented based on CT scan[P. Pellikaan, 2014] and to be used to generate a number of various sample point sets to mimic the actual detected points by A-mode ultrasound in operating room. The sample point sets were selected by following the proposed registration methodology. The registration was implemented by using a pre-registration (based on automatically segmented anatomical landmarks on the bone surface), followed by an accelerated Iterative Closest Points (ICP) algorithm and Wobble Optimizing algorithm. The procedures from point selection to final registration was run several times with different variations. First, the number of points in the sample point set was varied between 10 and 30 to capture the needed number of sample points for an accurate fit. Second, we simulated the effect of uncertainty in the ultrasound position by randomly adding noise to the coordinates of each point: no noise, ±1 mm noise, or ±2 mm noise. Third, for every number of points in the sample point set and for every level of noise, the simulation was run 100 times over to capture the robustness of the procedure. In total we thus ran 21 x 3 x 100 = 6300 simulations. After the full registration, the accuracy of the registration was computed by determining the root mean square error (RMSE) between the registered points and the known true position of those points.

RESULTS

The addition of a pre-registration to the ICP algorithm improved the registration quite remarkably. After the registration procedure, the average RMSE could be seen to improve with increasing the number of sample points from 10 (RMSE: 1.23 mm) to 30 (RMSE: 0.11 mm). For sample point sets of 27 points or more, the RMSE reached zero in more than 75% of all cases. The addition of noise to the positions of the points in the sample point set, unsurprisingly, diminished the accuracy of the registration. The RMSE for the case of ten sample points, increased from 1.23 mm for no noise, to 1.68 mm for 1 mm noise, to 2.39 mm for 2 mm noise.

DISCUSSION

The registration accuracy will be improved with the addition of sample points in proposed registration methodology, which followed by restricting to certain regions to ensure a good registration. The influence of noise was assessed by simulation result to provide the information to satisfy the certain requirement of registration accuracy. The future work will continue to test other bones.

REFERENCES

- *A. Mozes et al, Int J Med robotics Compit Assist Surg, 6: 91–101, 2010.*
- *C. Amstutz et al, Arch Otolaryngol Head Neck Surg, 129(12):1310–6, 2003.*
- *P. Pellikaan et al, Biomech, 47(5):1144–1150. 2014.*