Feasibility of a video-based skill assessment method for central venous catheterization

Olivia O'Driscoll[1], Rebecca Hisey[1], Matthew Holden[2,] Daenis Camire[3], Jason Erb[3], Daniel Howes[3], Gabor Fichtinger[1], Tamas Ungi[1]

[1]Laboratory for Percutaneous Surgery, School of Computing, Queen's University, Kingston, Canada
[2]School of Computing, Carleton University, Ottawa, Ontario
[3]Department of Critical Care Medicine, Queen's University, Kingston, Canada

Introduction: Computer-assisted surgical skill assessment methods have traditionally relied on tracking tool motion with physical sensors that measure skill assessment with six degrees of freedom (DOF). For instance, Clinkard et al. used EM tracking to compute metrics for central venous catheterization (CVC), including the path lengths and usage times of the needle and ultrasound probe. These tracking systems can be expensive, bulky, and can impede tool function. Instead, this study focuses on a low-cost, video-based alternative to current physical tracking systems for surgical skill assessment. We determine the feasibility of using metrics computed with object detection by comparing them to metrics computed with the gold standard of computer-assisted skill assessment.

Methods: We recorded tracking and video of four novices and four experts performing 13 CVC trials each on a phantom. Since path length and usage time from 6 DOF tracking have previously been shown to correlate with skill in CVC, we compute both using the video-based object detection method and the EM tracking-based method presented by Clinkard et al. The EM tracking-based method serves as a ground truth to assess the feasibility of our video-based method.

We computed the ultrasound probe's and syringe's path lengths and usage time using two different methods. EM tracking-based metrics were computed using the Perk Tutor extension of 3D Slicer. For the video-based method, a Faster Region-Based Convolutional Neural Network (R-CNN) was trained to recognize the ultrasound probe and syringe. The video-based metrics were computed from the network's bounding box predictions. A Spearman rank correlation was performed between all the metrics computed by both the tracking-based and the video-based methods. Since the usage time and path length metrics are generally correlated with the procedure time, we compared the correlations between the opposite metrics for both tracking methods. This tested how well the video-based metrics captured the corresponding EM-tracked metrics.

The EM-tracked and video-based metrics' values were both normalized for comparison on the same axes. The correlation used the unnormalized values.

Results: Figure 1 shows the decrease in metrics over 13 trials for both the experts and novices, as computed by both methods. The path lengths had a rank correlation coefficient of 0.22 for the syringe ($p<0.03$) and 0.35 ($p<0.001$) for the ultrasound probe. For the usage times, the correlation coefficient was 0.37 ($p<0.001$) for the syringe and 0.34 ($p<0.001$) for the ultrasound probe. The alternately paired metrics had insignificant correlations.

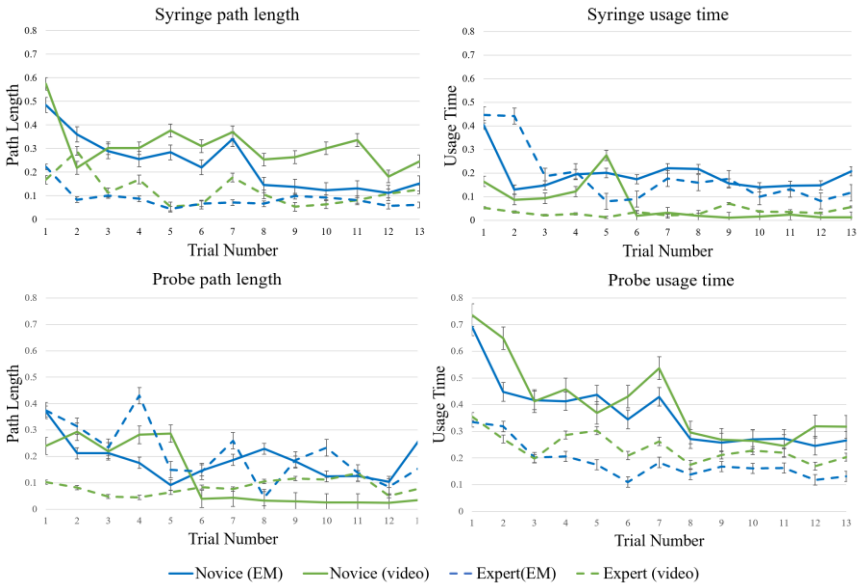

Figure 1. The normalized performance metrics for the syringe (top) and the probe (bottom), as computed by tracking and video-based methods.

Conclusions: There was a significant correlation between the three DOF, in-plane, metrics from video and the six DOF metrics generated by EM tracking. EM tracking has previously been validated against trainee skill, so results reveal that object detection is promising as a skill assessment method. Further, the correlation was stronger between the matching metrics versus the alternately paired metrics, suggesting that the video-based metrics are indeed measuring the same attributes of skill as are measured with the EM-tracked metrics. These results are encouraging and show promise that an inexpensive camera can provide a similar assessment of skill comparable to current expensive, bulky, six DOF tracking systems

[1] Clinkard, D., Holden, M., Ungi, T., Messenger, D., Davison, C., Fichtinger, G., McGraw, R., "The development and validation of hand motion analysis to Evaluate competency in Central LINE CATHETERIZATION," Academic Emergency Medicine 22(2), 212–218 (2015).