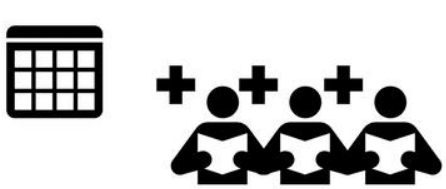
Laboratory for Percutaneous Surgery

Object detection to compute performance metrics for skill assessment in central venous catheterization

Olivia O'Driscoll, Rebecca Hisey, Daenis Camire, Jason Erb, Daniel Howes, Gabor Fichtinger, Tamas Ungi

Queen's University

Competency-based medical education





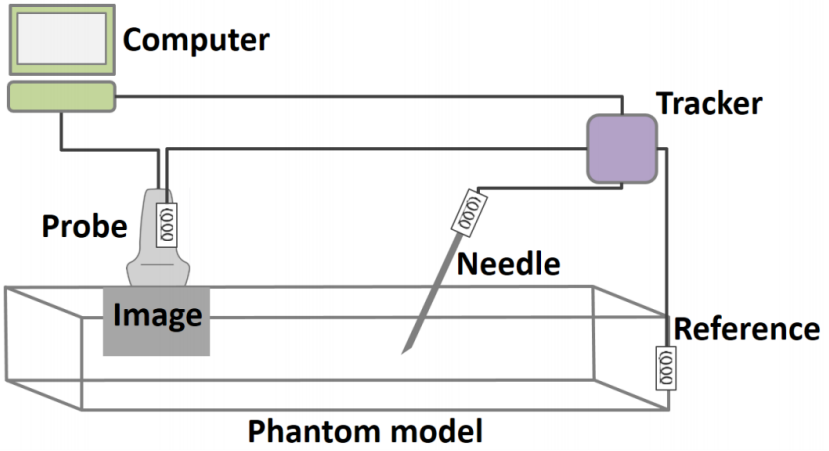
	TRADITIONAL Instruction	COMPETENCY-BASED Instruction
Structure	Time-based	Learner-centered
Teaching mode	Group learning	Individualized
Assessment Method	Summative, high stakes	Mastery-learning, perfomance-based
Pace	Faculty-paced	Self-paced
Program completion	Finish when required courses are passed	Finish when mastery of courses is demonstrated

https://www.canadastudynews.com/2017/07/07/queens-university-canada-competency-based-medical-education/

Computer-assisted assessment

- Automates evaluation
- Often relies on tracking of tool motion





Holden, M. et al. "Machine learning methods for automated technical skills assessment with instructional feedback in ultrasound-guided interventions," International journal of computer assisted radiology and surgery, 1993-2003 (2019).

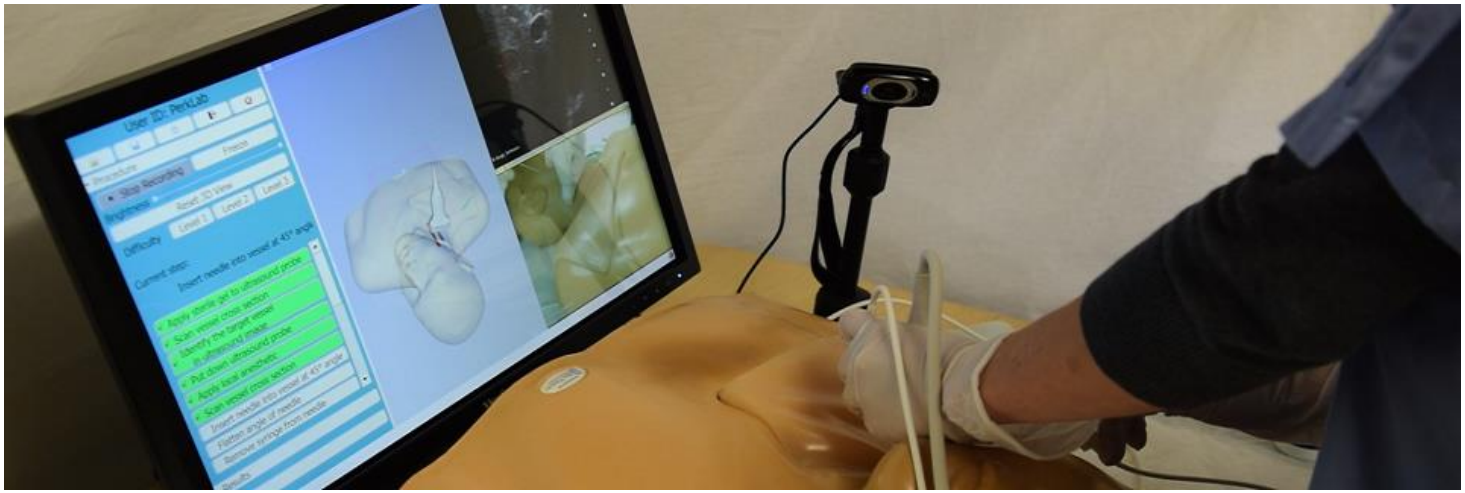
Optical Tracking



https://orthofeed.com/2019/03/12/smith-nephew-acquires-brainlab-orthopaedic-joint-reconstruction-business/

Central Line Tutor

- Measures workflow compliance using image classification



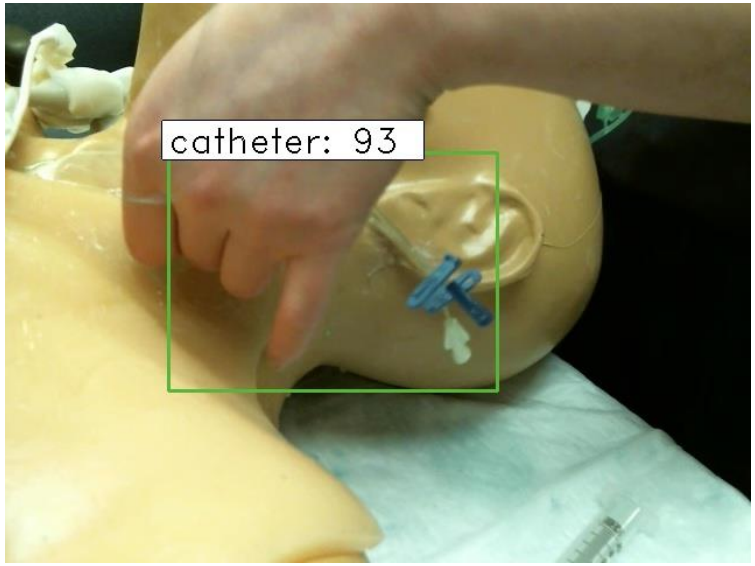
Hisey, R. et al. "Real-time workflow detection using webcam video for providing real-time feedback in central venous catheterization training," Proc. SPIE 10576, Medical Imaging 2018: Image-Guided Procedures, Robotic Interventions, and Modeling, 1057620 (2018)

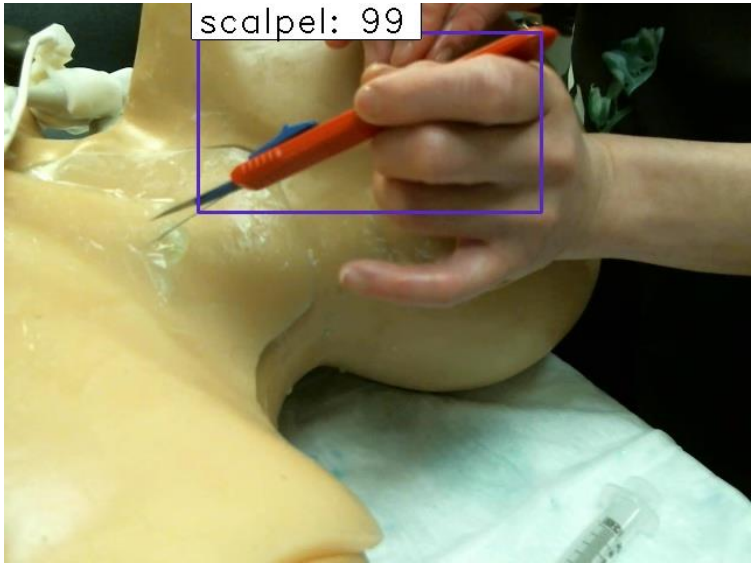
Purpose

Is object detection an effective method to compute performance metrics for skill evaluation?

Object detection

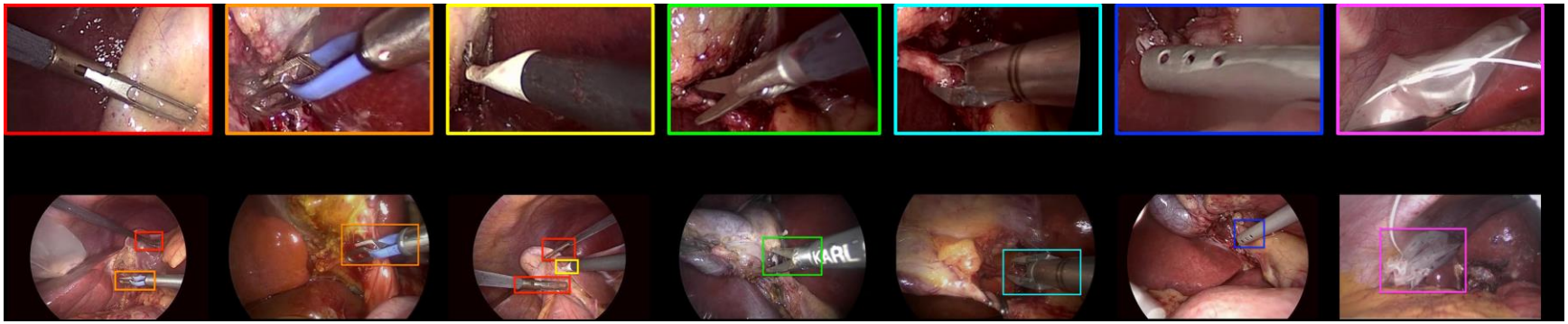
- Identifies what & where
- 2 families: YOLO & R-CNN





Two sample network output images

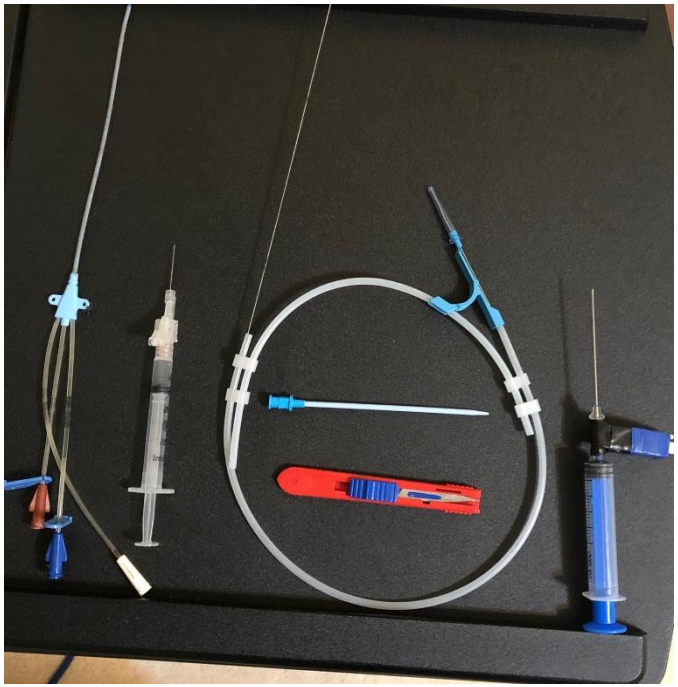
2016 M2CAI Tool Presence Detection Challenge



Jin, A, et al. “Tool Detection and Operative Skill Assessment in Surgical Videos Using Region-Based Convolutional Neural Networks.” 2018 IEEE Winter Conference on Applications of Computer Vision (WACV), 691-699 (2018).

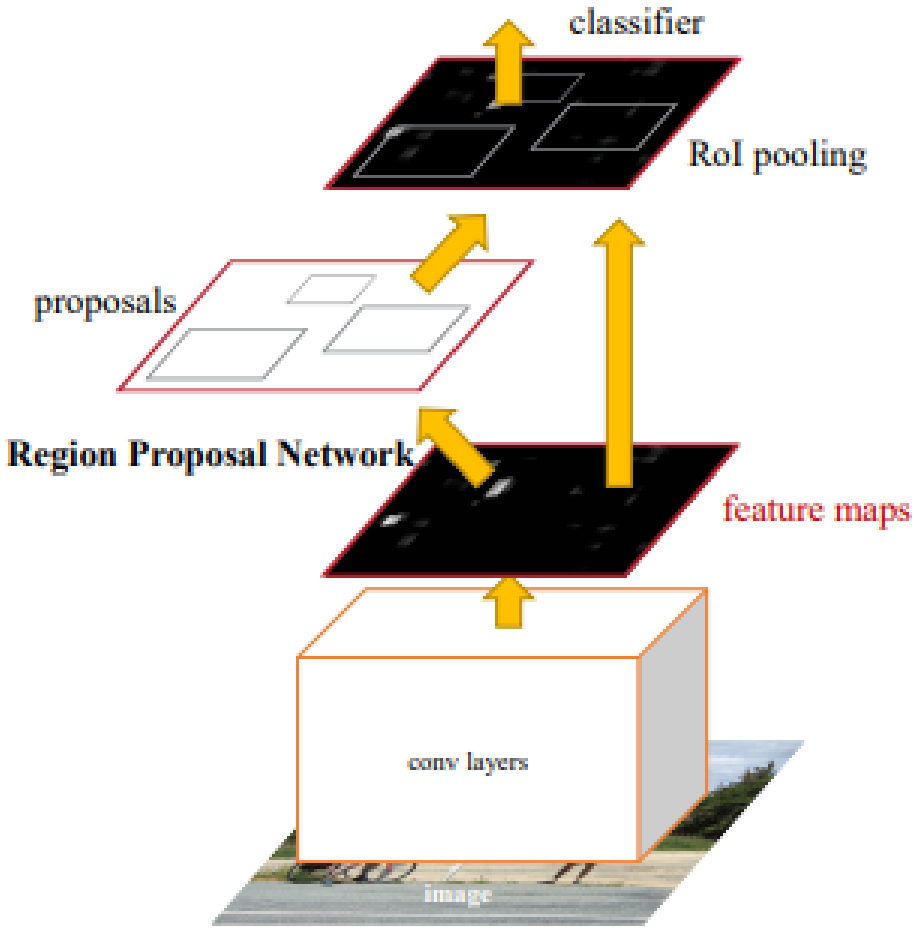
Central venous catheterization

- Common medical procedure
- Novice complication rate up to 35%



Central venous catheterization tools

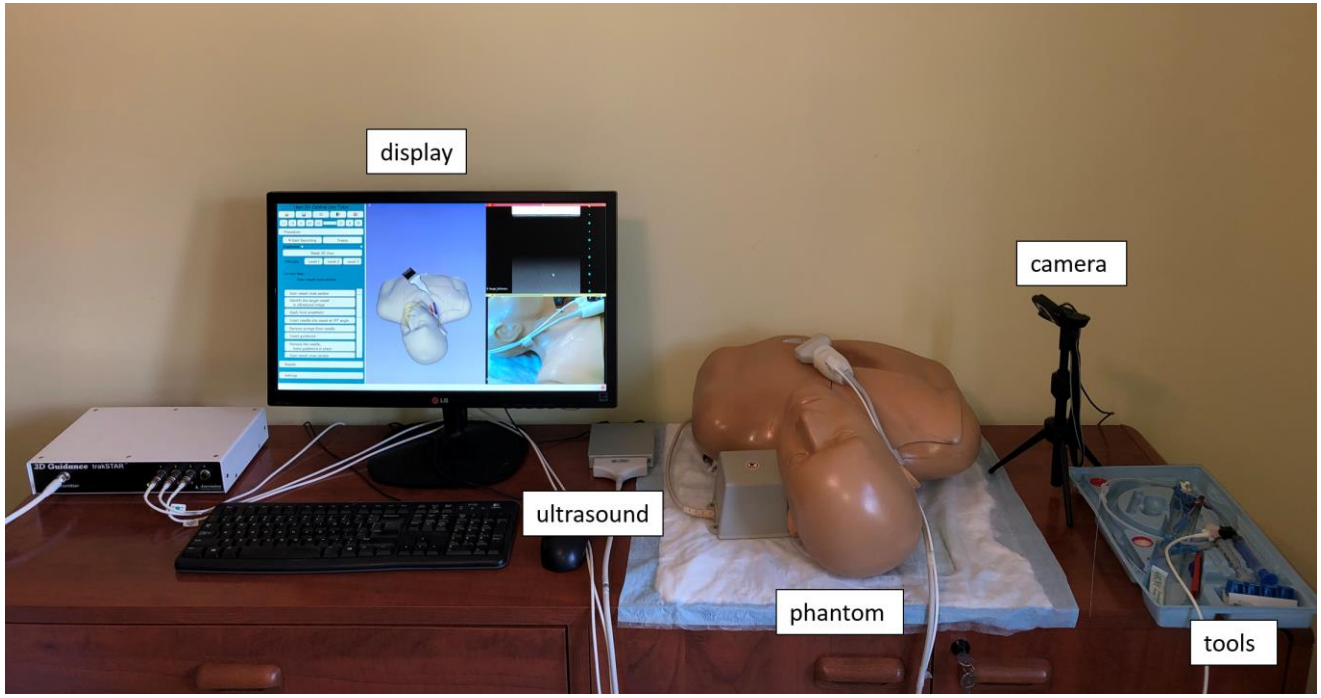
Faster R-CNN



https://www.geeksforgeeks.org/faster-r-cnn-ml/

Dataset

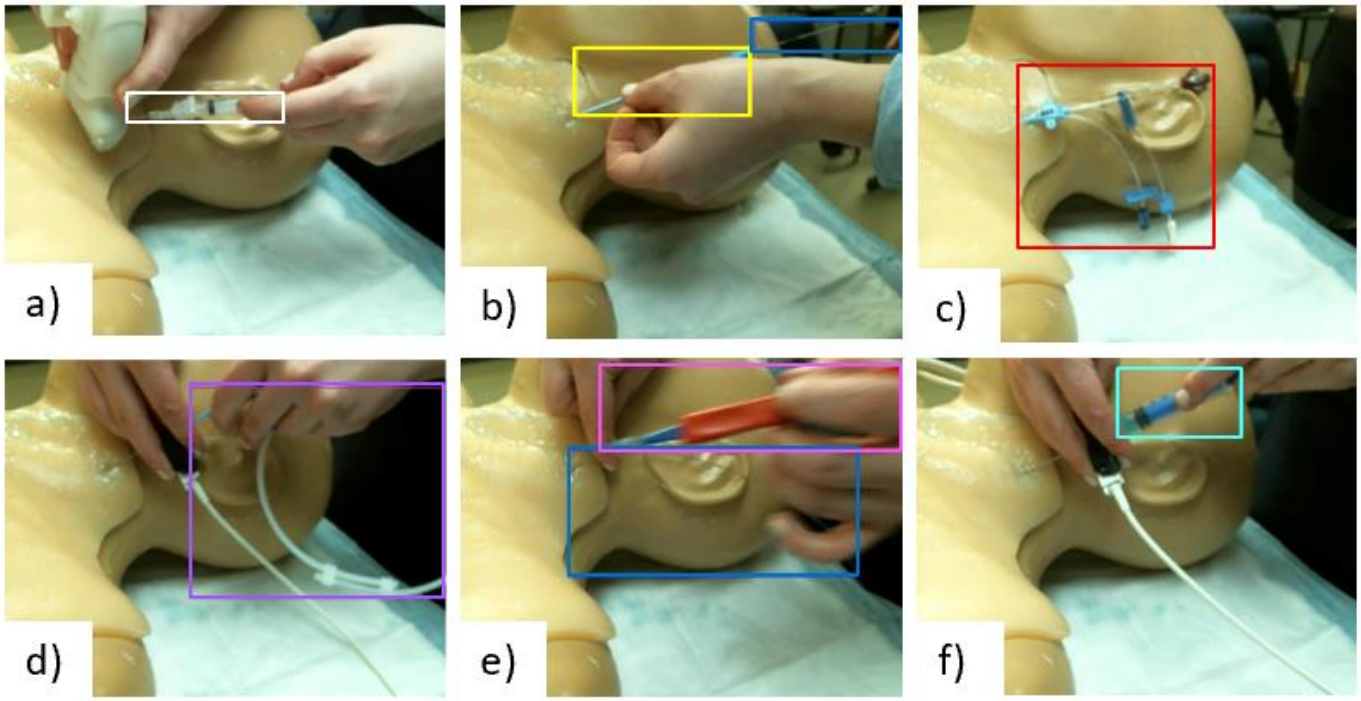
- 4 students each performing 5 trials



The setup on which the dataset was recorded

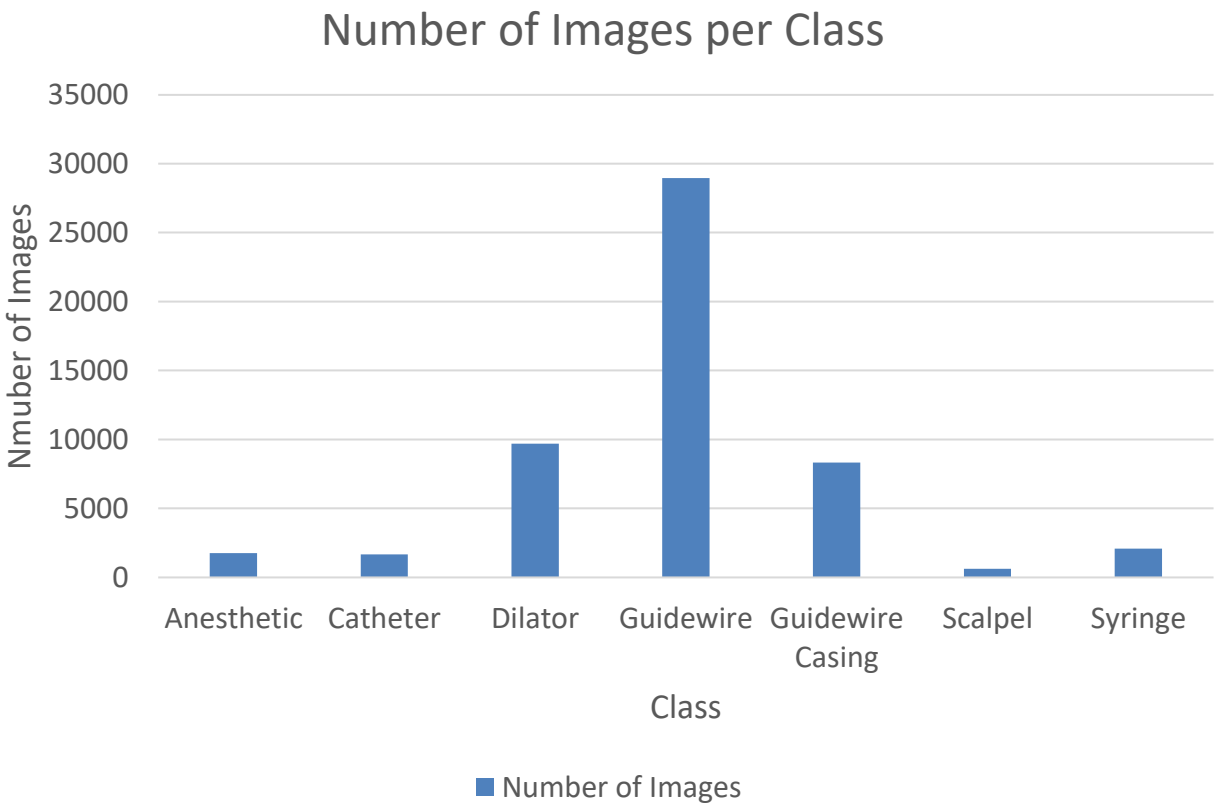
Dataset

- 20 med student recordings -> 55000 images -> 75000 labels



Ground truth labels for each class, a) anesthetic; b) dilator (yellow) and guidewire (blue); c) catheter; d) guidewire casing; e) scalpel (pink) and guidewire (blue); f) syringe

Dataset



The representation of each tool in the dataset

Experiment

- Four fold, leave one user out, cross-validation
  - 12 training videos, 3 validation, 5 test
- Transfer learning improved network performance



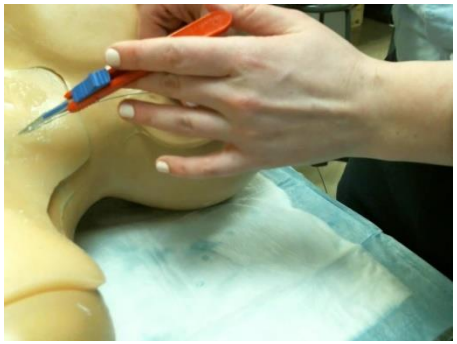
User 1



User 2



User 3



User 4

Performance metrics

1) Tool Usage Time

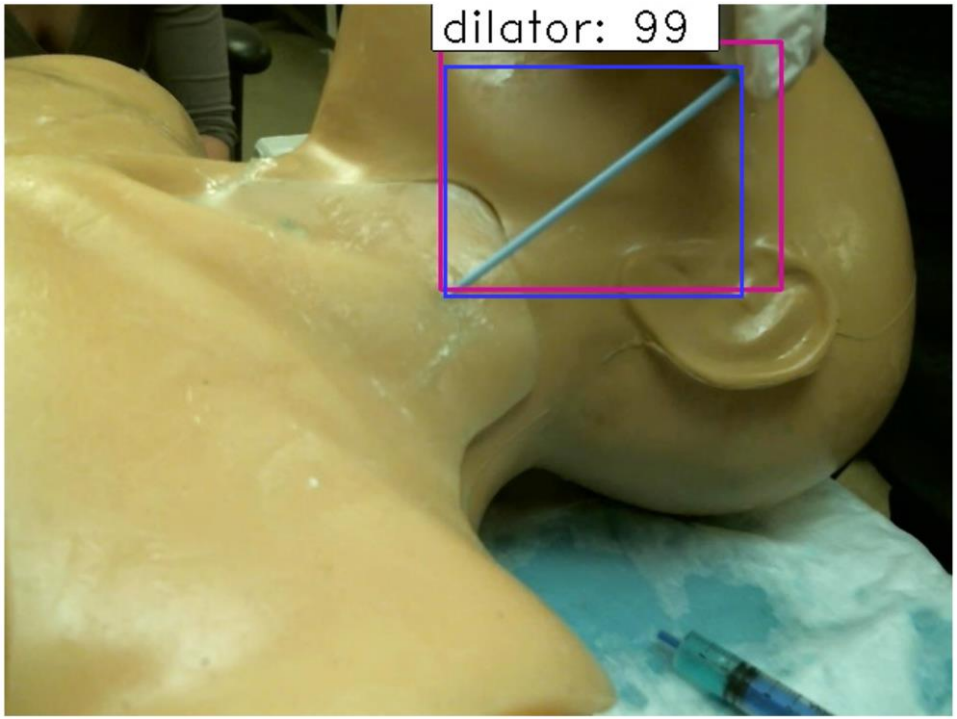
$$usage\ time = \frac{n}{frame\ rate}$$

2) Tool 2-Dimensional Path Length:

$$path\ length = \sum_{i=0}^{N} d(i, i+1)$$

Mean Average Precision

- Mean average precision (mAP)
  - Area under precision/recall curve



Ground truth bounding box (blue) and predicted bounding box (pink)

Results

Fold	mAP
0	0.59
1	0.68
2	0.67
3	0.71
Mean Average Precision	**0.66**

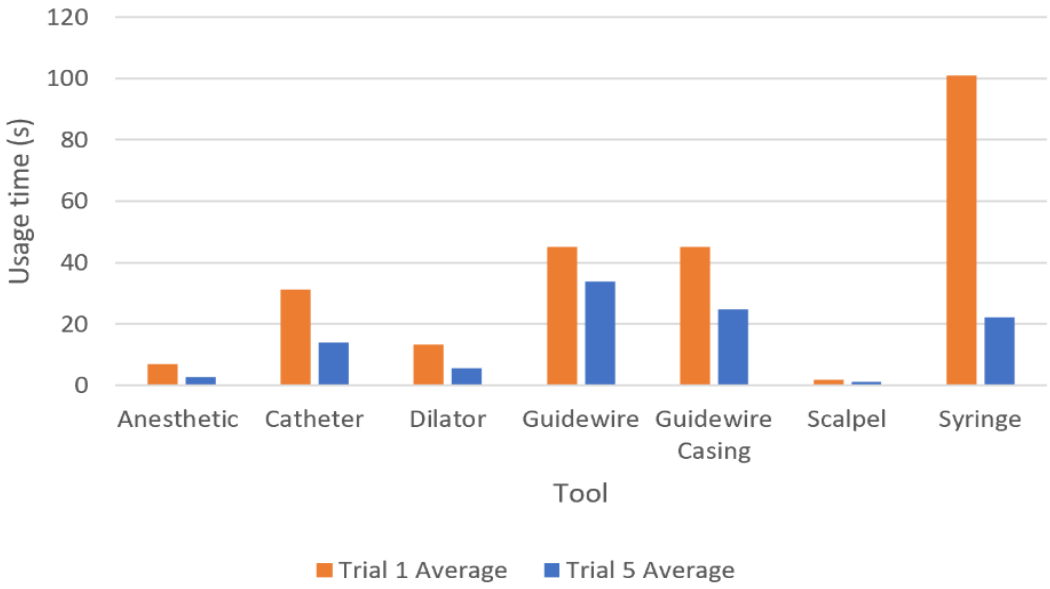
Mean average precision of each fold

Results

Tool	Average Precision
Anesthetic	0.64
Catheter	0.49
Dilator	0.72
Guidewire	0.51
Guidewire casing	0.86
Scalpel	0.50
Syringe	0.92

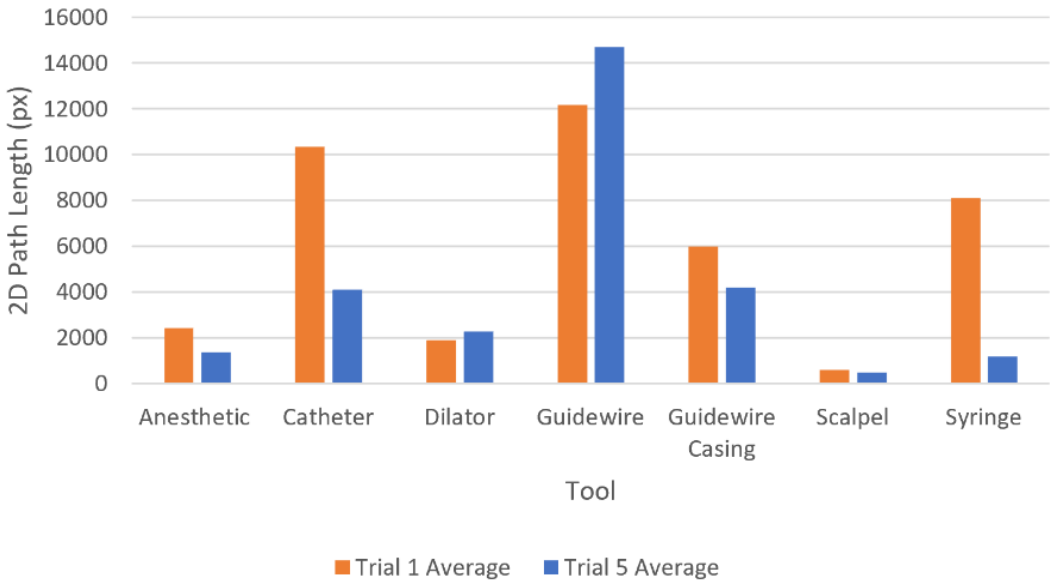
Average precision of each tool

Tool Usage Time



A comparison of the average tool usage time between trials 1 and 5

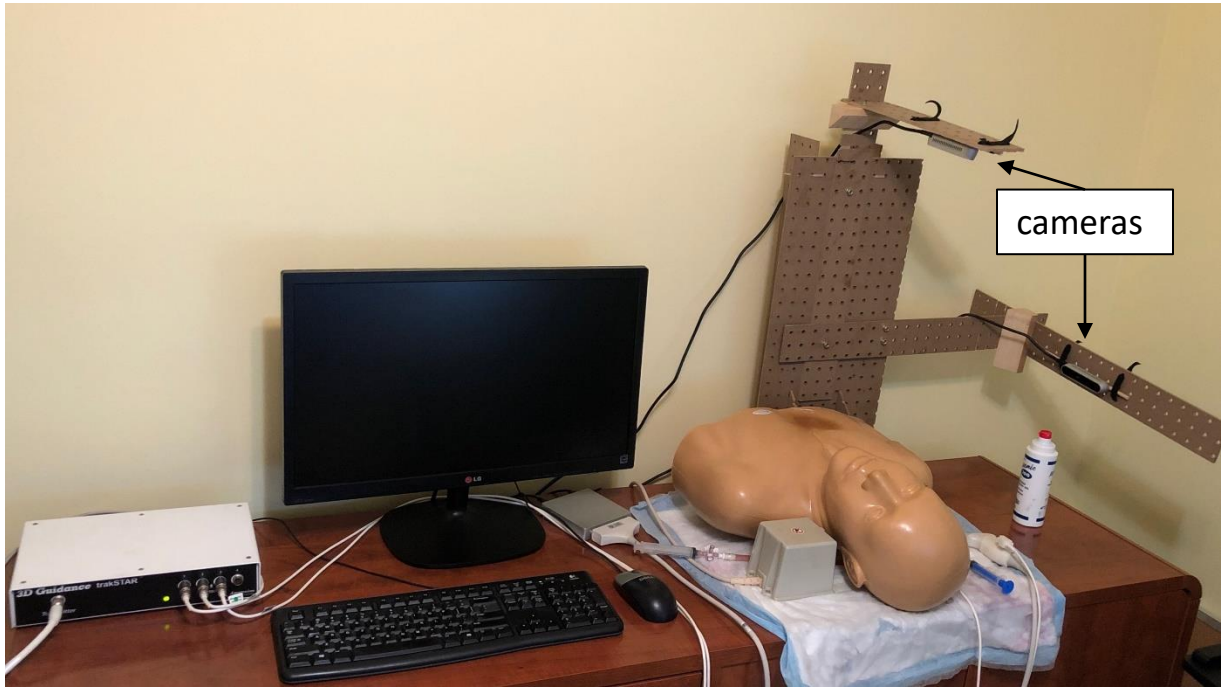
Two-Dimensional Tool Path Length



A comparison of the average tool 2D path length between trials 1 and 5

Conclusions

- Faster R-CNN shows promise as method of skill assessment



The Central Line Tutor Setup

Acknowledgments

This work was funded in part by NIH/NIBIB and NIH/NIGMS (via grant 1R01EB021396-01A1), by CANARIE's Research Software Program, and is supported as a Collaborative Health Research Project (CHRP #127797) by the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Canadian Institutes of Health Research (CIHR). R. Hisey is supported by the Queen Elizabeth II Graduate Scholarships in Science and Technology (QEII-GSST). G. Fichtinger is supported as a Canada Research Chair.