# Central Line Tutor: using computer vision workflow recognition in a central venous catheterization training system

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**Introduction:** Feedback is an essential component for learning, yet many medical trainees report being dissatisfied at the amount of performance-based feedback they receive. The most commonly cited reason for this lack of feedback is that attending physicians simply do not have enough time. We present here a system for training central venous catheterization (CVC) that is capable of providing trainees with instruction and feedback without needing an expert observer to be present. The system, called Central Line Tutor, uses workflow recognition to provide trainees with prompts about upcoming tasks and visual cues about workflow errors. In this study, we evaluate the accuracy and time delay of our workflow recognition method, and evaluate the usability of the system.

**Methods:** The system is made up of a computer, webcam, central venous access phantom and an electromagnetic tracking system. We use workflow recognition to automatically update an interactive checklist that is displayed to the user, which provides prompts about upcoming tasks and notify users when errors are made. For the majority of tasks, our workflow recognition uses a combination of a convolutional neural network (CNN) and a form of recurrent neural network that uses long-short-term memory (LSTM) units. For tasks that involve the ultrasound probe and needle, we identify them based on their position and orientation which we obtain using an electromagnetic tracking system.

To evaluate our system, we collected videos of 4 medical students performing CVC using the Central Line Tutor system. Each student recorded five trials of the procedure. To train the networks, we divided these videos into individual frames that were labelled with the task that was being performed at that time. Both the CNN and the recurrent neural network were trained separately on this data, using a leave-one-trial-out cross validation scheme for a total of five folds. We evaluate our workflow recognition in two ways: the first is the average number of tasks that the system recognizes, and the second is by measuring the average transitional delay. The average transitional delay is defined as the average number of seconds between when the system recognizes the start of a task compared to a human reviewer. A negative transitional delay indicates that the system recognized the start of the task ahead of the human reviewer. Finally, to evaluate the usability of the system, each of the students was asked to complete a questionnaire about their experience using the system. Participants were asked to rate the usefulness of each of the instructional features of the system on a 5-point Likert scale.

**Results:** The system was able to recognize tasks in the workflow with 96% accuracy and with an average transitional delay of 0.25 ± 6.1s. The average score on the participant survey was 4.6 out of 5 for the system overall (Fig 1). The participants found the interactive task list to be the most useful component of the system with an average score of 4.8 out of 5.

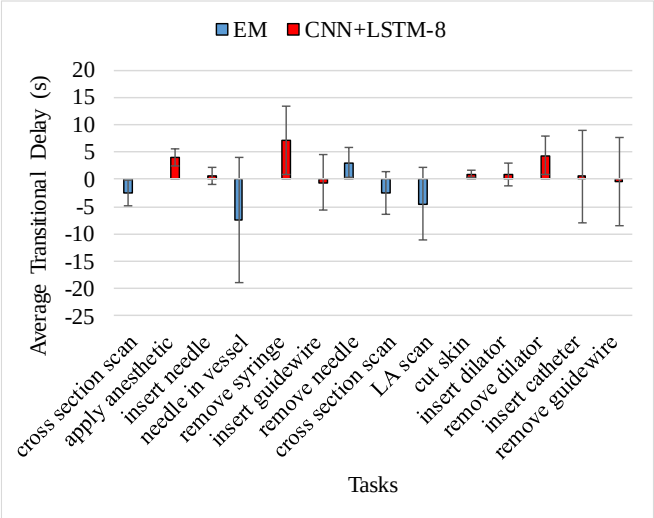


Figure 1. Average transitional delay between central line tutor and human reviewers

**Conclusions:** Overall the system performed well. It was able to reliably recognize tasks in the CVC workflow with minimal delay compared to a human reviewer. The participants were happy with the system and felt that it would improve CVC training without needing an expert observer.

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