Comparison of convolutional neural networks for central venous catheterization tool detection

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Introduction: Central Line Tutor is a program for training ultrasound-guided central venous catheterization (CVC). The workflow for CVC contains many steps that use multiple different tools (Fig. 1). Feedback has been shown to be essential for trainee learning [1]. By recognizing which tool is being used Central Line Tutor is able to give trainees feedback about their compliance to proper procedure workflow in real-time. The purpose of this work is to evaluate the use of convolutional neural networks (CNN) to recognize the tools used in CVC compared to a previous colour based method [2].

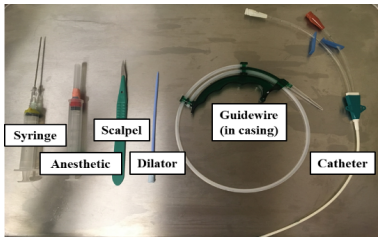

Figure 1. Tools used for central venous catheterization.

Methods: Two different CNNs were evaluated for this work: Inception_v3 and MobileNet. These networks were selected as they provide a balance between accuracy and size. MobileNet especially is designed to be run efficiently on mobile devices and embedded systems [3]. Each of these networks was pre-trained on the ImageNet dataset and used transfer learning to recognize the tools used in CVC. The final layer of each network is a fully connected layer that was retrained on a database of 100 000 images collected of the CVC tools using the Central Line Tutor setup. In order to evaluate these networks recordings were obtained of seven medical residents performing CVC on the Central Line Tutor setup. Each of these recordings is broken down into individual frames and we compared the frame-by-frame accuracy of each of these networks. None of these images were available while the networks were trained. We also compared these networks to a previous colour-based method which uses a sliding window to locate the region of the image that best matches a 30 pixel x 30 pixel image of the tool.

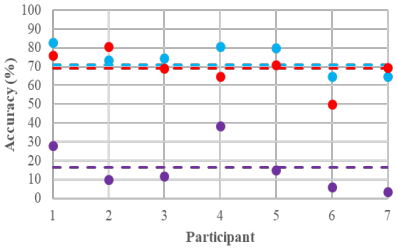

Figure 2. Accuracy of histogram (purple), Inception_v3 (blue), and MobileNet (red). Dotted lines represent the average across all frames.

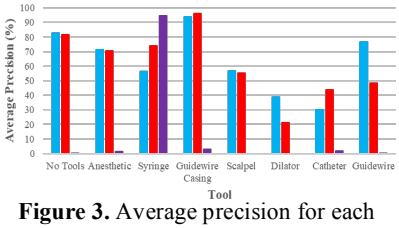

Figure 3. Average precision for each tool for histogram (purple), Inception_v3 (blue) and MobileNet (red).

Results: Inception_v3 achieved a frame-by-frame accuracy of 71% (Fig. 2). MobileNet had slightly worse performance, achieving only 69% accuracy. The colour-based approach was only able to achieve an accuracy of 16%. The guidewire casing was the best recognized tool by each of the CNNs. The syringe was the best recognized tool using the colour-based method.

Conclusions: Both CNNs substantially outperformed the colour-based method. This is due to the fact that CNNs recognize objects using multiple different features rather than just colour. There was very little difference in the accuracy of Inception_v3 compared to MobileNet. Further work will be done to establish whether the efficiency of MobileNet's computation is worth the slight reduction in accuracy.

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