Optimizing Cath Lab Workflow: Deep Learning for Phase Recognition, Procedure Duration Prediction, and Scheduling Efficiency

Emanuele Frassini[1], Teddy S. Vijfvinkel[1,2], Rick M. Butler[1], Maarten van der Elst[1,2], Benno H. W. Hendriks [1,3], John J. van den Dobbelsteen[1]

[1]Delft University of Technology, Delft, The Netherlands

[2]Reinier de Graaf Hospital, Delft, The Netherlands

[3]Medical Systems, Philips Medical Systems, Best, The Netherlands

e.frassini@tudelft.nl

Aims: In cardiology, coronary artery disease is anticipated to rise by 40% by 2040 [1]. Thus, efficient workflow management in the cardiac catheterization laboratory (cath lab) is important to optimize healthcare delivery and maintain affordability. Automated recognition of procedural phases and accurate prediction of procedure end times can significantly enhance scheduling efficiency, reduce turnover time, and minimize non-clinical workload [2]. The aim of this study is to (1) develop deep learning models to classify workflow phases of coronary angiograms (CAGs), (2) predict procedure end times using clinical phases derived from video analysis, and (3) validate a statistical simulation tool to explore scheduling scenarios in a multi-cath lab environment at Haga Hospital.

Materials and Methods: We collected a dataset of video recordings (Fig. 1), clinical data, and system log data of 222 CAG procedures. Each procedural phase was annotated by a medical expert based on clinically relevant time points. Feature extraction from video images was performed using a Scaled-YOLOv4 object detection algorithm, followed by classification with Long Short-Term Memory (LSTM) and LSTM-Fully Convolutional Network (LSTM-FCN) models. For procedure end-time prediction, deep learning models—including InceptionTime, LSTM-FCN, LSTM with attention mechanism, and Transformer—were evaluated using phase-based input data. Prediction accuracy was assessed using Mean Absolute Error (MAE) and Symmetric Mean Absolute Percentage Error (SMAPE). Additionally, a Monte Carlo simulation tool leveraging three years of retrospective data was used to analyse scheduling scenarios and the impact of real-time duration predictions on turnover time.

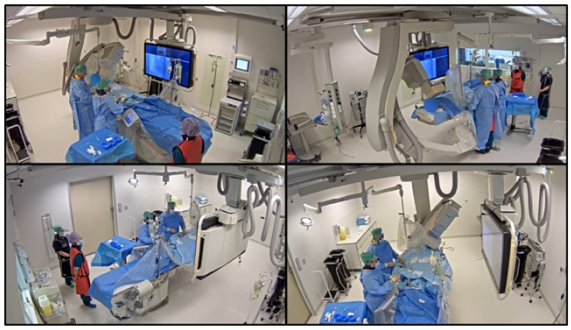

Fig. 1 Example of the video images we recorded during a diagnostic cardiac catheterization performed at Reinier de Graaf Hospital, which were used to annotate the workflow steps. Patient and staff have been anonymized.

Results: The LSTM model achieved a weighted accuracy of 91.3% in classifying workflow phases, similar to LSTM-FCN (90.8%) while being 2.2 times faster and requiring 40% fewer parameters. For procedure end-time prediction, InceptionTime and LSTM-FCN achieved the highest accuracy, with MAE below 5 minutes and SMAPE under 6%. An ensemble approach further improved prediction reliability. The simulation analysis provided insights into optimizing scheduling and reducing turnover time.

Conclusions: This study demonstrates the possibility of using deep learning models for procedure phase detection and duration prediction in the cath lab for automatic workflow recognition. These models, integrated into clinical scheduling systems, could enhance operational efficiency by dynamic scheduling optimization. Future work will focus on validating the simulation tool's impact on scheduling decisions and further refining predictive models to improve real-time workflow management in multi-cath lab environments.

References:

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