An automated patient simulator for cardiopulmonary resuscitation training

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Cardiac arrests account for > 30% of mortality worldwide. Early CardioPulmonary Resuscitation (CPR) is an important factor in survival of a cardiac arrest, having up-to-date CPR skills for a large population would be beneficial. However, CPR skills require expensive (maintenance of) training, which relies on either manikins or actors [5]. However, in the case of infants, actors are not possible and manikins lack feedback to either instructors or students. Consequently, CPR performance is hard to evaluate. Recently, smart infant manikins became available that provide visual feedback; however, both students and instructors experience this often as too distracting.

We developed an intelligent infant manikin (see Figure 1), which adopts a closed-loop human-AI system [3]. It provides non-intrusive auditory feedback, which enables to scaffold CPR training. As such, it is a reflex agent: its sensor input determine its feedback [2]. Instructors can personalize the agent, at their disposal, depending on the context, student, or both.

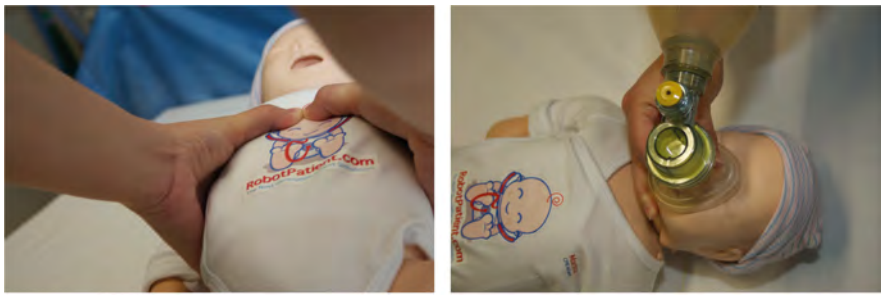

Fig. 1. Compressions and ventilations being performed on the simulator system.

Our manikin differs from existing commercially available automated CPR feedback systems on several aspects, including:

- the ability to provide open and real-time data;
- high level connectivity, with virtually any current mobile device; and
- its modular hardware and software design.

This allows automated real-time auditory feedback, which can be adjusted to the needs of students and instructors. As such, it reduces both students' and instructors' cognitive loads [4]. Currently, our agent provides feedback on the CPR metrics: ventilation volume, compression depth, chest recoil, finger positioning, compression speed, and no-flow time[5].

An commercially off-the-shelf manikin was used as base. Via several iterations that included continuous input of medical educators, the manikin was modified to improve the training experience (e.g., changes to chest and airways). Dedicated hardware was developed to measure the CPR metrics. Its modular design allows scenario-driven patient simulations for advanced life support training.

In 9 CPR sessions, the manikin was tested by 81 nurse trainees and compared with a state-of-the-art commercial manikin. To enable a fair comparison between both systems, in these sessions instructors were not allowed to differentiate between contexts and students. Hence, one of our manikin's major assets was ruled out. Nevertheless, statistical data analysis showed that CPR proficiency improved significantly more when using our manikin than when using state-of-the-art commercial manikins.

The manikin's modular design allows to go beyond a simple reflex agent to a goal-based, and even a utility-based agent [2]. Given the manikin's sensors and effectors, part of this agent will be developed on subsymbolic level (cf. [3]). However, in addition, we foresee that part will be developed on symbolic level, as has shown to be successful for training purposes (cf. [1]).

Taken together, even with only part of its potential exploited, our manikin already showed to be a cheap, open source and preferred alternative to current state-of-the-art manikins. Our work continues with exploiting its adaptive characteristics via iterative development and evaluation cycles. As for now, our manikin showed to have the potential to overhaul medical simulation by providing a concept that is open and adaptive, allowing optimized training.

References

1. Doesburg, W., Heuvelink, A., van den Broek, E.L.: TACOP: A cognitive agent for a naval training simulation environment. In: Pechoucek, M., Steiner, D., Thompson, S. (eds.) Proceedings of the Industry Track of the Fourth International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS-05). pp. 34–41. New York, NY, USA: ACM, Utrecht, The Netherlands (2005)
2. Russell, S.J., Norvig, P.: Artificial Intelligence: A modern approach. Harlow, Essex, England: Pearson Education Limited, 3rd edn. (2014)
3. van den Broek, E.L.: Affective Signal Processing (ASP): Unraveling the mystery of emotions. Ph.D. thesis, Faculty of Electrical Engineering, Mathematics, and Computer Science, University of Twente, Enschede, The Netherlands (2011)
4. van der Sluis, F., van den Broek, E.L., van Drunen, A., Beerends, J.: Enhancing the quality of service of mobile video technology by increasing multimodal synergy. Behaviour & Information Technology **37**(9), 874–883 (2018)
5. Wheeler, D.S., Wong, H.R., Shanley, T.P.: Pediatric critical care medicine, Volume 1: Care of the critically ill or injured child. London, UK: Springer-Verlag, 2nd edn. (2014)