2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

RiNeo MR: A mixed-reality tool for newborn life support training

Serena Ricci, Giulia Addiego Mobilio, Andrea Calandrino, Matteo Pescio, Ester Issa, Paolo Rossi
Manuela Chessa, Fabio Solari, Marco Chirico, and Maura Casadio

Abstract— **The first minute of life, the Golden Minute, has been defined as a critical window in which fundamental physiological processes occur for establishing spontaneous ventilation in a newborn. Resuscitation is more likely to succeed if it is performed properly and at the right time. In this scenario, simulation is an appropriate tool for training and evaluating the abilities of all staff working in the delivery room, as well as students. As simulations require a high degree of immersivity in order to be effective, the use of technologies like Virtual (VR) and mixed reality (MR) have garnered more interest in training. Currently, some VR and MR applications have been developed for adult life support training, but neonatal tools are still missing. To overcome this limitation, we present RiNeo MR, a prototype of a MR simulator for neonatal resuscitation training. The simulator consists of (i) a sensorized physical model of the newborn that allows monitoring chest compressions; (ii) a VR head mounted display that allows visualizing a virtual 3D model of the manikin and scenarios of the delivery and operating rooms. This enables students, and healthcare providers to be immersed in realistic hospital settings while performing life support procedures on the newborn manikin.**

Clinical Relevance— **The newborn life support training (NLS) in facilities reduces term intrapartum-related deaths by 30%.**

I. Introduction

Out of 136 millions of babies born yearly in the world, around 3,7 million dies during childbirth [1]. It is estimated that a non-negligible portion of deaths is due to the lack of expertise in performing neonatal resuscitation maneuvers by the medical personnel involved in delivery room care. The start of spontaneous breathing is a crucial moment of the physiological transition from intra-uterine to extra-uterine life. Five to ten percent of newborns need assistance in this phase to establish an effective spontaneous breathing [1], preventing birth asphyxia that causes around 25% of all neonatal deaths [1], [2]. Many studies have shown that an affective newborn life support (NLS) training reduces delivery room death rate by 30% [1].

It is natural to assume that all staff involved in perinatal medicine (pediatricians, gynecologists, anesthesiologists, midwives, nurses, and paramedics) need to train the best to face neonatal resuscitation. However, only a few specialists in the delivery room master NLS, typically neonatologists and anesthesiologists [3]. A possible way to increase the number of healthcare providers trained in NLS is through simulation, which plays an important role in the medical learning process, as it allows to build a background based on riskless and controlled experiences [4]. In this context, new technologies such as virtual and augmented reality (VR, AR) have been introduced in simulation with the aim to increase users' engagement, immersivity and sense of presence [5]. Nevertheless, one of the main limitations of VR for medical training is the lack of a realistic haptic feedback which may affect the learning outcome. Because of this, literature on VR for life support training is focused on MR systems, that combine physical elements with VR, such that users perceive haptic feedback and perform actions in a realistic way [6].

Currently, some VR and MR applications have been developed for adult first aid and emergency training: [7] realized VREM, which combines a half body manikin with Head Mounted Display (HMD), tracking devices, and data gloves; [8] has implemented VReanimateII, a VR tool for first aid and reanimation training. VReanimateII increased Cardiopulmonary Resuscitation (CPR) knowledge of people with limited experience by 20% [8]. Recently, some other research groups implemented MR prototypes [9]–[12], supporting the idea that MR is a promising approach for life support training. Still, tools for pediatric resuscitation training are limited to either non-immersive serious games [13] or AR applications [14]. Further, to the best of our knowledge, no MR tool for NLS training has been developed yet, despite research works highlight the need immersive simulators for NLS training [15].

To overcome this limitation, we designed *RiNeo MR,* a MR simulator for neonatal resuscitation training, that combines a real neonatal manikin with a VR scene. The goal of the projects was to design and implement an educational tool for the training, evaluation, and retention of NLS skills, especially for those professionals who are normally not involved in neonatal first aid. This work is the result of a multidisciplinary collaboration between physicians, computer scientists and bioengineers aimed at defining the most suitable technologies to enhance the emotional involvement of

*This work was partially supported by the operative program Por FSE Regione Liguria 2014-2020 RLOF18ASSRIC/17/1, by the Ministry of Science and Technology, Israel (Joint Israel-Italy Lab in Biorobotics Artificial Somatosensation for Humans and Humanoids) and by the program Erasmus+ KA201 Strategic Partnerships for School Education, First Aid Improve Survival.

S.R., G.A.M., and A.C. equally contributed to this work

S.R., M.Ch, F.S, M.Ca are with the Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genova, Italy and Simulation and Advanced Education Center - SimAv, University of Genova, Genova, Italy (serena.ricci@edu.unige.it, marco.chirico@unige.it, manuela.chessa@unige.it, fabio.solari@unige.it, maura.casadio@unige.it)

G.A.M, E.I, M.P are with the Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genova, Italy (s3906192@studenti.unige.it, s4395030@studenti.unige.it, s4522311@studenti.unige.it)

A.C is with Pediatric Emergency and Critical Care Department IRCCS Giannina Gaslini Children's Hospital, Genova, Italy and Simulation and Advanced Education Center - SimAv, University of Genova, Genova, Italy (s3509520@studenti.unige.it)

P.R. is with Simulation and Advanced Education Center - SimAv, University of Genova, Genova, Italy (paolo.rossi@unige.it)

traditional simulation carried out on manikins; this would ultimately increase the number of professionals able to perform successful NLS.

II. Materials and Methods

The system includes a sensorized neonatal manikin and a VR part consisting in 3D scenarios of the delivery and operating rooms, and a virtual representation of the manikin. The two parts communicate in real time via a communication system (Fig. 1).

A. Hardware

The physical model of *RiNeo MR* consists of a newborn manikin (M-1005745, 3b Scientific, Germany; Fig. 1) equipped with an infrared sensor (SHARP 0A41SK F71; Sharp Japan) to monitor in real-time chest compressions performed by the operator. The sensor, located on the manikin torso, is connected to the microcontroller Arduino nano 33 iot. The board receives chest compression data from the sensor and sends them in real-time via Wi-Fi to a computer which provides the virtual representation (Fig. 1). In addition, the hardware comprises an HTC Vive headset system (i.e., HMD, two Lighthouse units and two controllers) which is used to navigate the virtual environment.

1) Sensor's testing

In order to measure chest compression, several sensors are currently available (e.g., ultrasound, potentiometer, optical). However, our setup had strict space constraints, which required to use a small sensor that could be located on the manikin's back, without being detectable by the user. Indeed, we selected and tested an infrared sensor (see above). Prior to installing it in the manikin, we assessed whether the sensor could measure chest compressions performed by the trainee. Hence, we compared the readings of the infrared sensors, with those obtained by a linear slide potentiometer (BOURNS PTB0143-2010BPB103 100 mm), used as a reference sensor. Since the spatial constraints of the neonatal chest would not support simultaneous measures of the two systems, we built a setup specifically designed to test our system (Fig. 2). As soon as a compression is performed, both the potentiometer and the infrared sensor measure the compression depth. Both the sensors are connected to an Arduino Uno board.

As we wanted to ascertain whether the infrared sensors could measure chest compressions, we asked an experienced physician to complete 3 repetitions of 4 cycles of CPR (a cycle includes 30 compressions and a pause corresponding to 2 ventilations). For each compression, we computed compression depth and release by calculating the distance between consequent peaks. For each peak (i.e., both compressions and releases), the difference between the potentiometer and the infrared values has been computed. Finally, we computed the frequency of compression as the number of positive peaks in the cycle. This value was then converted into compressions per minute. All the analyses have been performed offline using Matlab (MathWorks, USA).

B. Software

The VR application is developed in the game engine Unity 3D (v. 2020.2.0b5), integrated with the immersive HTC Vive system, which is used to navigate the virtual environment. In addition, Blender software (https://www.blender.org/) is used to model the 3D manikin, as to make it look as the physical one [12]. The VR application includes two scenarios in which the neonatal reanimation takes place: the delivery room and the operating theater. Once we chose the settings to be implemented, we carefully defined the instruments that each room should contain. In particular, we selected and imported 3D models of room furniture and appliances from dedicated websites (e.g., free3d.com and 3dwarehouse.sketchup.com). All the models have then been customized to fit the scenarios we wanted to implement. Inside the VR there is also a virtual replica of the manikin. Starting from an existing 3D model [16], we edited it, so that its dimensions and appearance replicated the real one. In this way, we guarantee correspondence between what the user sees and what he touches, obtaining a coherent environment.

As mentioned above, data from the real manikin (i.e., chest compressions' parameters) are sent via Wi-Fi to Unity3D, to provide real time feedback.

III. Results

A. Hardware

As a first step, we wanted to assess whether the measurements obtained by the infrared sensor were comparable with those obtained by the reference sensor (i.e., linear potentiometer). Visual inspection of the data during chest compressions showed that both sensors detect values between 0.3 and 6.6 cm, that are compatible with a properly performed chest compression (Fig. 3). We then analyzed compression and release (Fig. 4). The average depth measured by the infrared and potentiometer sensors were (mean ± std) 5.0 ± 0.7 cm and 5.2 ± 0.6 cm, respectively. Average release was 3.6 ± 0.5 cm when measured with the infrared sensor and 4.0 ± 0.3 cm according to the

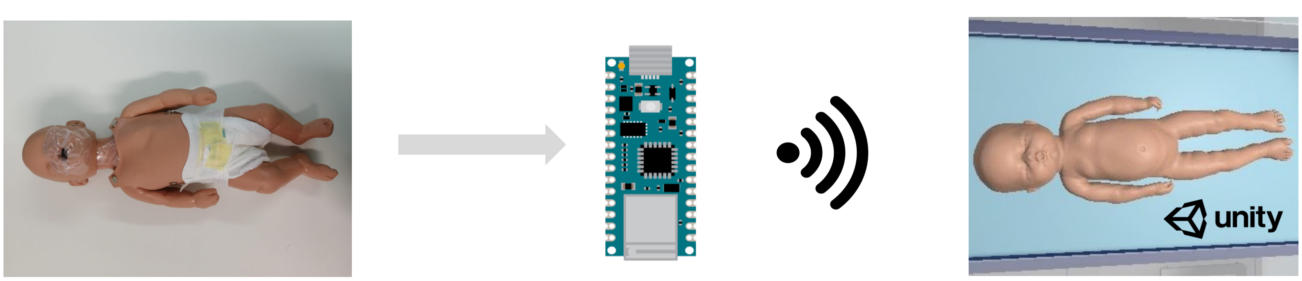

Figure 1: The communication system of Rineo MR . the physical manikin (left) is equipped with an infrared sensor connected to an Arduino nano 33 iot (center), which sends data via Wifi to the VR (right)

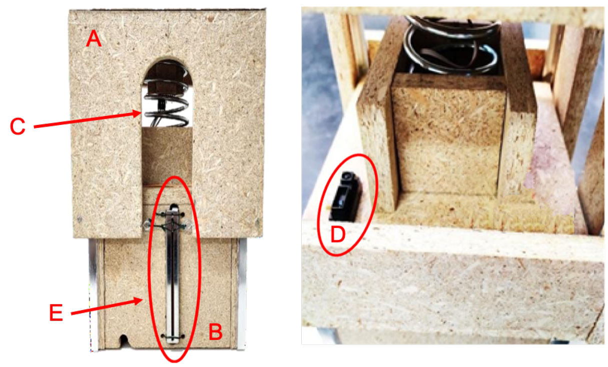

Figure 2. Experimental setup. The upper plywood element (A) slides on the lower one which remains still (B). A spring simulates chest stiffness (C). The infrared sensor is located at the top of the lower element (D), in correspondence of the spring. The potentiometer is parallel to one of the four lower outer faces, with the slider fixed to the upper part (E).

potentiometer. The difference between the potentiometer and the infrared measures at peak was 0.3 ± 0.4 cm (compression 0.2 ± 0.3 cm; release 0.4 ± 0.5 cm).

We then analyzed the frequency of compression. The potentiometer and infrared sensor had equivalent compression frequency (first set 129 ± 1, second set 123 ± 3, third set 130 ± 1 compressions/minute). Altogether, these results support the idea that the infrared sensor can be used to monitor CPR performance, also considering its reduced dimensions which allows it to easily be installed inside the manikin.

B. Software

As labor can either occur spontaneously in the delivery room or as a result of a caesarian section in the operating room, we implemented both scenarios to immerse user in a realistic setting (Fig. 5). In particular, the two rooms are fully equipped with realistic appliances. Briefly, they are furnished with tables, surgery carts, a tray with surgical instruments, surgical lights, a sterilizer, an anesthesia machine and a defibrillator. Furthermore, they have dedicated equipment. The delivery room includes an infusion stand, an ultrasound, a

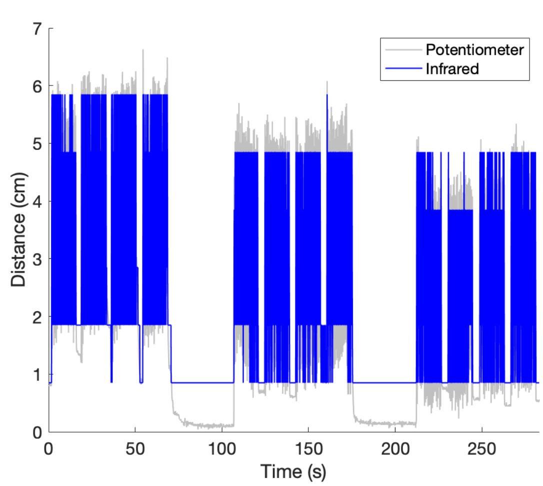

Figure 3: Potentiometer and infrared sensor data during the test consisting in 3 repetitions of 4 cycles (a cycle includes 30 compression and a pause) of chest compression.

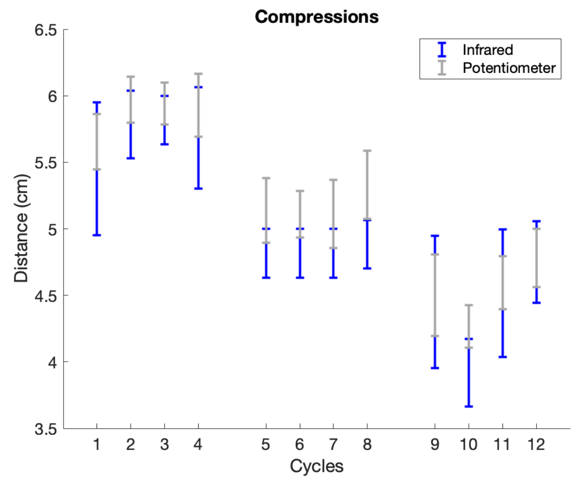

Figure 4. Chest compression measured by the infrared sensor (blue) and the potentiometer (gray) in each cycle. Bars indicate standard deviations

gynecological chair, a baby warmer, a suction machine and a bassinet. The operating room contains a surgical table and a monitor. As visible in Fig. 5, the delivery room is connected to the operating room by a door; the operating room has an additional emergency door and a window. The size of each room is 7.5x7x3 m and the equipment has accurate dimensions. As the virtual space is bigger than the physical room in which the simulation takes place, the user can change room by using the VR controller.

IV. Conclusion

RiNeo MR is a VR-based system aimed at improving clinical training practices by increasing the user's sense of immersion during the simulation. The goal of the project was to realize an educational tool to spread NLS knowledge among all staff involved in perinatal medicine. In addition, we wanted to combine the benefits of VR with those of using manikins to learn manual skills, by integrating hardware and software into a single application, which was the most challenging part of the project Indeed, the dimensions of the newborn manikin are small, thus requiring a careful choice of the electronics to be installed.

With *RiNeo MR*, the user wears the HTC Vive Headset being immersed in two VR two hospital-like settings (Fig. 5) where there is a virtual neonatal manikin (Fig. 1). Such virtual representation communicates in real time with a real manikin, which is sensorized to monitor chest compression.

A. Future Developments

With this study, we assessed whether the combination of VR with a real manikin could be successful for NLS training. In fact, some points still need to be addressed to improve the usability of the simulator, making it an immersive and optimized tool usable by different professionals.

1) To increase the immersivity of the VR applications

This includes mapping the virtual mannequin exactly onto the physical one through the HTC Vive tracking system, such that users can touch and move the real mannequin and all their actions are replicated into VR [12]. In addition, the system will be equipped with Leap Motion (Leap Motion, USA) to

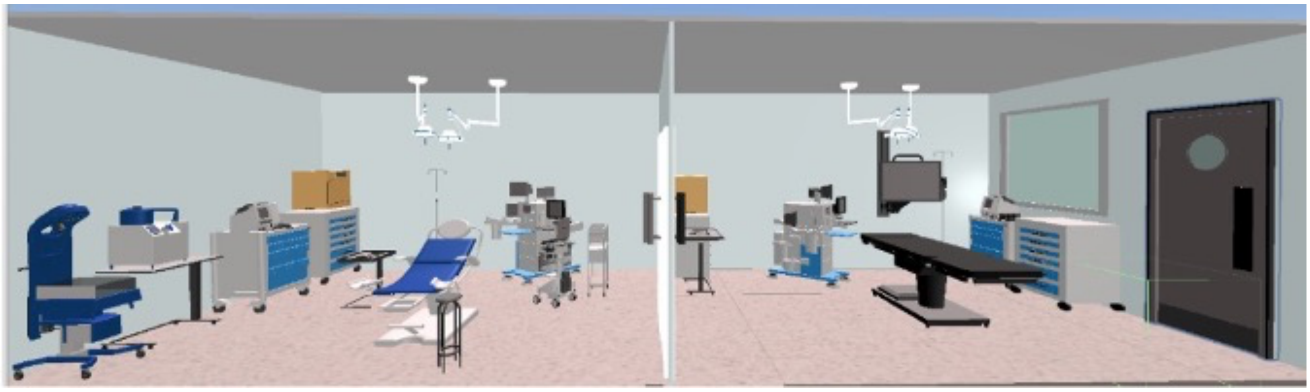

Figure 5. Virtual Reality Scenario: Delivery Room (left); Operating Room (right).

track the user's hands and develop additional interactions with the environment [17]. Other developments regard the inclusion of different virtual environments (e.g., ambulance, house setting) and improvements of the virtual manikin by adding animations.

2) To monitor additional NLS skills

One of the goals we have is to monitor NLS skills other than chest compression (i.e., manual stimulation, head positioning, bag-mask ventilation, CPR and drugs administration). To do so, we will install additional sensors on both the mannequin and on first aid tools (e.g., face mask, or laryngoscope).

3) To validate the system

This part will include quantitative and qualitative measures. The former evaluates the accuracy of the matching between real and virtual world, and the accuracy of the measurements obtained from the sensors. The latter determines the level of acceptance of *RiNeo MR*. At the end of these stages, we will perform learning outcome of our system with traditional tools such as high-fidelity manikins or serious games.

In summary, *RiNeo MR* is the proof of concept of a VR-based simulator for neonatal life support training. Its implementation highlighted points to address in order to create an immersive and optimized simulator usable by different professionals. Indeed, the possibility to being immerse in a real hospital setting and to perform manual skill in an accurate way on a manikin, make the system a tool suitable to increase the number of healthcare providers trained to perform successful neonatal life support.

ACKNOWLEDGMENT

The authors thank Andrea Canessa, Simone Marcutti and Giorgio Carlini for technical support.

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