From the Eyes of the Patient – Real Time Gaze Control of Medical Training Mannequins

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Abstract
The eyes are a central point of interaction between humans in all sorts of situations – including clinical diagnosis. While modern medical training mannequins provide a high level of realism when it comes to e.g. Cardiopulmonary Resuscitation (CPR) procedures, the overall fidelity of the training is strongly limited by dead eyes and the subsequent lack of interaction with the simulated patients. While actuated robotic eyes are available on the market the question remains on how to make them behave in a natural way, especially in a diagnosis context. In this article we present a solution based on head mounted device that not only gives an operator the live-view of the mannequin, but also tracks their eye movement which is directly translated into a movement of the robotic eyes.

Author Keywords
Medical Mannequin; Eye Tracking; Diagnosis Training; Prototyping; AI Training.

ACM Classification Keywords
B.1.5. Hardware: Microcode Applications; H.5.1. Information Interfaces and Presentation: Multimedia Information Systems; H.5.2. Information Interfaces and Presentation: User Interfaces.

Training on Mannequins

Context: Modern hospitals have special training areas that are an essential tool for training new methods or refreshing memories of e.g. rare treatments or diagnosis protocols. Thorough training sessions are conducted in strictly controlled environments, under close observations from various experts, can include actors, and can be recorded to focus on specific details.

Mannequins: The central element of a training session is often a mannequin that can simulate certain actions and interactions, most prominently CPR. High-end versions offer a variety of programmable symptoms with respect to the electrocardiogram, breathing, or heart beat patterns. Furthermore, the different types of mannequins are always context specific, e.g. for training treatments on newborns. A high-end mannequin can be seen in Figure 2.

Introduction

Medical training mannequins are used as an essential tool for educating amateurs and professionals alike in various medical simulations, the most prominent being CPR training. Modern high-end mannequins include an array of sensors, actuators, and communication systems, enabling immersive training setups at various levels of stress for the trainees. Naturally, more complex procedures performed by professional medical personnel require a higher level of complexity and fidelity in the mannequins in order to create a realistic training environment. While a lot of these interactions can be sufficiently simulated by mechanical systems and appropriate material selections, some crucial elements are, simply put, too dead to create an immersive training atmosphere – a prime example being the eyes of the mannequin. Eyes do not only play an essential role in nonverbal communication [3], but also impact patient-centeredness and medical personnel's awareness about the patient's psychological distress and cognitive functioning [1]. Laerdal Medical, the world-leading producer of such mannequins, challenged the prototyping laboratory TrollLABS to come up with a way of creating realistic eyes that enable a natural and functional interaction with the medical personnel.

Eye Movement in Diagnosis

When encountering a new patient in an emergency setting, the doctors have to rapidly assess the overall health state on both, the visible - e.g. a limb in an unnatural angle - and the hidden level: A brain hemorrhage is invisible, yet highly dangerous. The diagnosis often relies on interacting with the patient's eyes: Voluntary (e.g. following a pen) and involuntary (e.g. oscillations of the eye) movements are indicators of neural damages, brain injuries, of the mental state, and more [5]. Currently available mannequins offer only very limited interactions with their eyes.

Exploring the Uncanny Valley

Presented here is a solution for the context of a training session: An instructor has the live view from the mannequin's perspective, all the while their eye movement is tracked and translated into movement of the robotic eyes itself. As the theory behind eye tracking and subsequent mapping is well established [2], the focus of this demo is on the physical implementation of this system, creating a more realistic experience for the trainee and allowing for training exercises that are otherwise impossible with real people. By adding a filter between the movement of the operator and the mannequin's movements, it could further allow to explore the uncanny valley [4] and investigate the degree of natural behavior required to overcome it.

Technical Description

In the use scenario, the operator wears the head-mount unit like a virtual-reality headset and does not require any additional equipment. The current prototype enables this by the means of two main components: A head-mount unit for the operator and a set of robotic eyes embedded in the mannequin. All data exchange between the two is wireless, using radio-frequency transceivers and regular WIFI connections. The head-mount unit, as well as the robotic eye-unit can be seen in Figure 1.

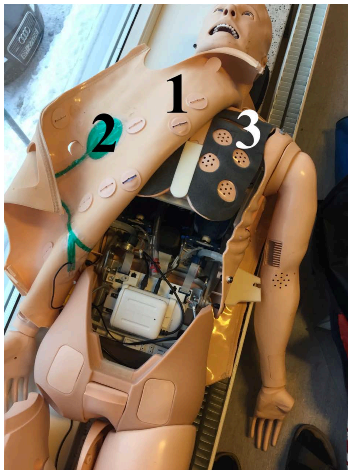

Figure 2: A high-end medical training mannequin, showing some of the interactive functionalities. 1) RFID chips in the skin enable location-specific, simulated ultrasound images. 2) The green patch is used for simulated defibrillation. 3) The rib cage contains speakers than provide simulated heart-beats or lung related sounds when listening with a stethoscope.

Figure 1: The operator (right) sees the live viewpoint of the mannequin (left) and directly controls the movement, incl. blinking, of the robotic eyes by the means of eye-tracking algorithms that are translated into according servo movements.

Head-mount unit

In this prototype, the computational core of the head-mount unit is a Raspberry Pi 3B (Raspberry Pi Foundation, Cambridge, UK) running Raspbian Jessie. It is sufficiently powerful to enable the two key functions: Displaying the view from the mannequin's perspective and tracking the movement of the operator's eyes. The live-feed from the mannequin is displayed on an LCD embedded in the casing, visible to the operator through a set of optical lenses. A Picam NoIR camera observes the pupil-movement, and subsequently the gaze of the operator. The according signal is then processed by the Raspberry Pi, resulting in x-y coordinates of the current eye-position. These coordinates are sent to an Arduino Uno ('master'), also included in the head-mount unit. It translates them into according servo-signals, which are then transmitted to the second Arduino Uno ('slave') in the mannequin via an ultra-low-power radio-frequency chip (nRF24, Nordic Semiconductors, Trondheim, NO).

Eye-Unit

The eye-unit serves as the interaction point between medical trainee and, indirectly, the operator. A Trek AI-ball WIFI camera uploads the video stream to the Raspberry Pi in the head-mount unit. The robotic eyes and eyelids itself are actuated by eight digital servos that operate in pairs. The pairs are controlled by four signals from the 'slave' Arduino Uno, and they control upper lids, lower lids, vertical and horizontal movement of the eyes. The mechanical eyes, as well as the aluminum frame with mounted servos were bought from Animatronic Parts (Pittsburgh, PA, USA). In order to make this eye-assembly fit into the head of mannequin, it was mounted in a frame made of laser-cut MDF.

A First Step to More Realistic Trainings

This prototype allows for controlled movement of the eyes of a mannequin, used within the context of a medical emergency response training. The limitations are mostly due to the resolution, meaning that very fine movements of the operator's eyes cannot yet be translated into movement of the robotic eyes. Nevertheless, this way of controlling the eyes is – by definition - more natural than any pre-programmed movement and opens a lot of interesting paths for training medical personnel and investigating the interactions between not only medical personnel and mannequins, but also on a more general human-robot level.

Experimental Validation

This prototype allows for first controlled experiments where one can assess the perceived level of realism during the interactions with the mannequin. Ideally, the natural behavior of the eyes helps bridging the uncanny valley and significantly increases the perceived level of realism during training sessions. Naturally, the operator is not in a state of emergency when conducting the training. Any live-tracked eye-movement is therefore the one of a healthy individual. While they could act in very limited way, one can imagine a software 'filter' that adjusts the movements of a health individual to that of a patient with e.g. a neural damage.

Train an AI

By recording the auditory and visual inputs to the mannequin, as well as the according natural eye-responses of the operator, one has an ideal training data set for machine learning algorithms. This AI can then not only be used for creating more autonomous mannequins, but one can imagine that such data-sets can improve human-robot interactions in general.

Eyes Do not Only Move

Left completely unaddressed by this prototype is the fact that eyes have many more levels of information that they can transmit, e.g. by pupil dilation. One way of enabling such additional functions is by switching to a completely digital eye model, omitting any mechanical actuations. Explorative work in this direction has already been started within our group.

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