Proceedings of the 2021 Design of Medical Devices Conference
DMD2021
April 12-15 2021, Minneapolis, MN, USA

DMD2021-1021

SENSORIZATION OF MEDICAL TRAYS FOR TRAY-BASED SURGICAL PROCEDURE SIMULATION

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ABSTRACT

A concept for a sensorized medical tray in conjunction with real-time visual cues to aid medical residents in learning the steps of complicated tray-based medical procedures, such as central venous catheterization, was designed and tested as a first iteration. This paper outlines the selection of an LED screen to illuminate various medical devices and the testing of simple magnetic reed switches to use as sensors to track the movement of various medical tools from a tray. While this concept was designed around central venous catheterization, this work is translatable to any medical procedure using a pre-packaged plastic tray.

Keywords: Medical simulation, Sensorization

1. INTRODUCTION

Medical simulation is a powerful clinical tool used in many medical schools and hospitals to train residents in various procedures without having to put real patients at risk [1]. For many surgical procedures, a system that gives direct feedback to the trainee in real-time is beneficial as it provides relevant, targeted information that is critical to individualized learning in complicated medical procedures [2].

Visual cues and signals are useful and aid trainees in learning and memory [3-4]. One way to get these visual cues in real-time is through sensorization. Sensorization is the process of adding sensors to various devices in order to provide direct feedback to the user. This has many applications in a variety of fields, but a few examples of sensorization within the medical field include rehabilitation, surgical skill assessment, and medical device training [5-7].

When considering using sensorization of medical devices in combination with visual learning cues, it should be recognized that many complicated procedures in medicine that need to be taught to medical residents use pre-packaged surgical kits. The kits are often re-manufactured for price optimization and/or waste elimination [8]; this means that a sensor-based simulation designed for a medical tray-based procedure needs to be flexible to account for variations in the tray manufacturing. One example of a tray-based medical procedure where this is the case is central venous catheterization (CVC). CVC is conducted using a pre-packaged bundle kit specifically designed for the procedure.

The CVC procedure has a high infection rate, indicating a necessity for a robust tool to better train medical residents of the many CVC steps [9]. In order to create a simulation for this type of procedure, movement of the tools out of the tray needs to be tracked, the tray needs to be able to provide feedback to the user if tools are selected incorrectly, and the simulation needs to be translatable to multiple types of trays.

This paper outlines a proof of concept for a sensorized medical tray focusing on the testing of sensors to be used for tool tracking, and of an LED screen to be used for real-time visual feedback to the trainee based on the sensor information. An example for what this would look like on a CVC tray once implemented can be seen in Figure 1. The red arrows indicate the location of the sensors.

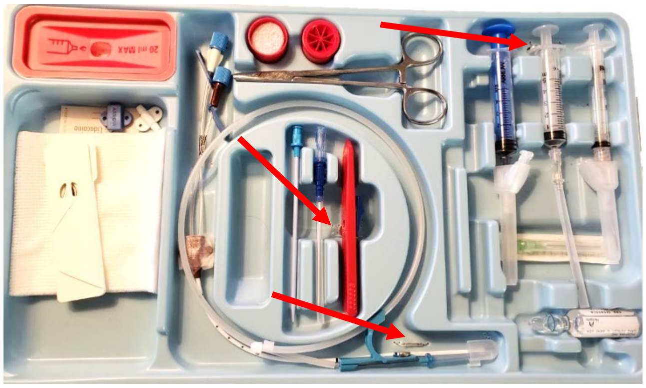


FIGURE 1: SENSORS EMBEDDED INTO A CVC MEDICAL TRAY FOR TOOL REMOVAL TRACKING

While this paper focuses on CVC, this type of trainer could be used for any tray-based medical procedure. The LED screen test results, sensor test results, and design decisions for future iterations of a sensorized medical tray are presented in this paper.

2. METHODS

2.1 LED Screen

One the biggest benefits of real-time feedback, is the ability for the trainee to receive direct “coaching” without actually having someone present to proctor the simulation [10]. One method of doing this for a tray-based procedure is through a light emitting diode (LED) screen underneath the medical tray that can light up different areas of the tray in different colors to indicate which tool needs to be removed at which time, or when a tool is removed incorrectly. Given the variation of light in hospital operating rooms, it is important that the LED screen be as bright as possible to be able to see the colors through the plastic of the medical tray in various light settings.

An experiment was conducted with four different screens to assess the visual brightness of each screen through a medical tray in two different light settings, half light and full light, as seen in Figure 2.

It should be noted that based on availability, an epidural tray was used for this experiment rather than a CVC tray. These two medical trays are both made out of the same plastic, polystyrene, with a thickness of roughly half a millimeter. This experiment is directly translatable to a CVC tray; the differences between them are negligible.

The images were then imported into photoshop where the histogram luminosity tool was used to measure the light shining through the tray in various areas, as well as the overall luminosity of each image.

For the half light condition, the overhead lights were turned off and only the residual room lights were left on. For the full light condition, all the lights in the room remained on. The screens used for this experiment were a Dell Inspiron 7000, a MacBook Pro, a Lenovo Yoga C900, and a Tru-Vu SRMH. An image of each screen in each light setting was captured using the camera on an original Google Pixel phone. The Google Pixel, similarly to most cell phones, has an auto-adjust feature in the camera. This is why in the figure the light exposure between images differs slightly even though the ambient light in the room had not changed.

2.2 Reed Switches

To provide accurate feedback and assessment it is necessary to track the movement of medical tools out of the tray during procedural simulation. Reed switches were chosen for this based on their simplicity and ease of use. A reed switch is a magnetic

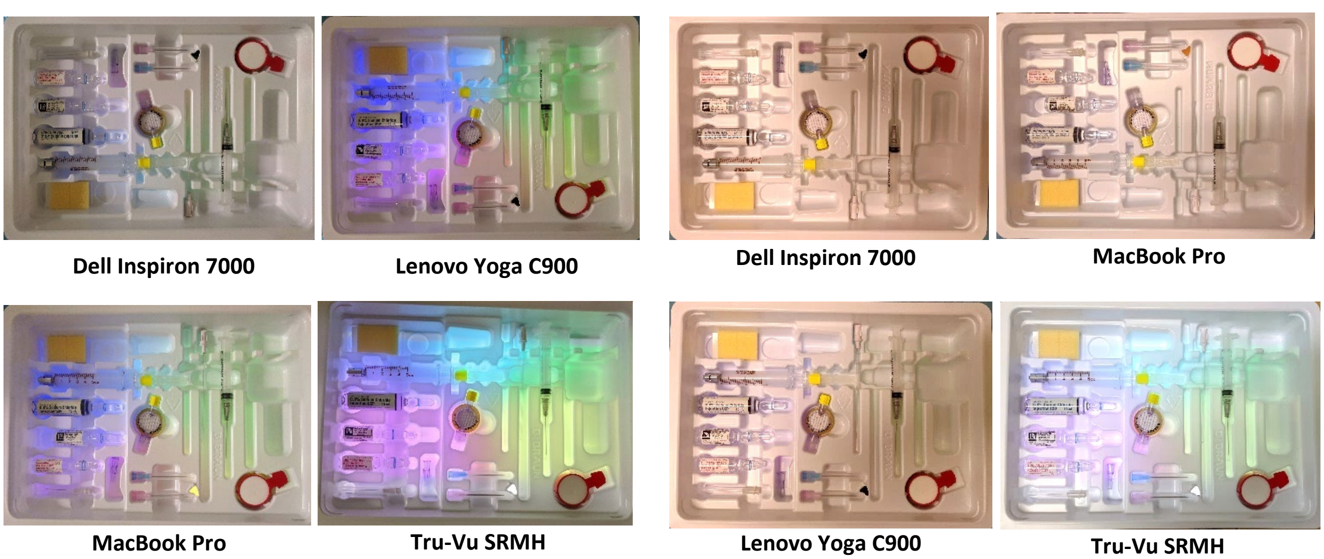
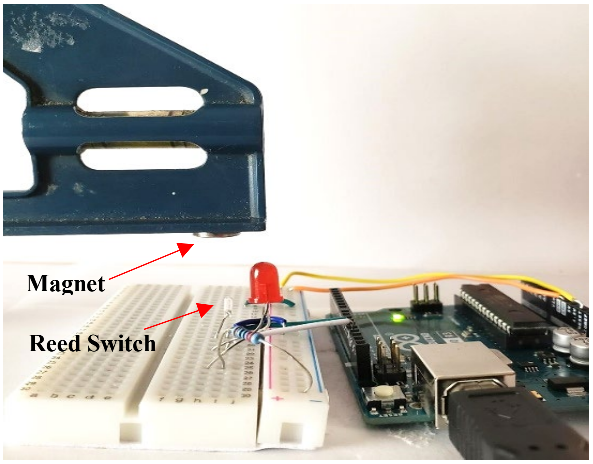


FIGURE 2: LED SCREENS IN HALF LIGHT CONDITION (LEFT) AND FULL LIGHT CONDITION (RIGHT)



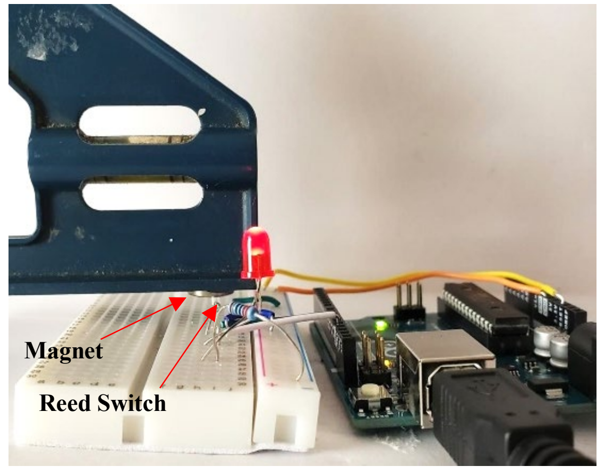


FIGURE 3: THE MAGNET IS ELEVATED AND THE LED IS OFF (LEFT); THE MAGNET IS LOWERED AND THE LED IS ON (RIGHT)

sensor that changes states based on the proximity of a magnet to the sensor. Reed switches only have two states, open or closed, which makes them ideal for reading whether or not a medical tool is still in the tray.

The reed switches used in these experiments were Cylewet Normally Open Magnetic Induction Switches for Arduino (CYT1004). To verify the reed switches a random sample of 3 was selected to assess the average distances that each would register the magnets. The magnets used were silver 10mm x 2mm disc magnets.

This test was conducted with an Arduino Uno (Somerville, MA), a reed switch, and an LED as shown in Figure 3. A simple circuit was constructed where an LED would be in the off state if the reed switch did not register a magnet, and in the on state if the reed switch did register a magnet. To do this, a single magnet was secured to the end of a slider directly above the reed switch. The slider was then moved downward toward the reed switch until the point where the magnet could be registered, which was observed by the LED turning on. The distance of the magnet to the reed switch was then measured using a pair of calipers. This experiment was conducted 15 times with each reed switch, and the distance at the time when the LED turned on was recorded.

3. RESULTS AND DISCUSSION

3.1 LED Screen

To illuminate the medical tools to use as feedback for the trainee, the luminosity of the LED screen through various sections of the tray is significant. For this experiment, 3 sections were chosen to be analyzed as circled in Figure 4. These sections were chosen because they allow the luminosity for three different colors, red, blue, and green, and three different sections of the screen to be observed. This allows a broad understanding of each screen and how well it can illuminate through the plastic of the tray. From left to right these sections are referred to as left purple, top blue, and right green respectively.

The luminosity values of the screen as well as the overall tray in both the half light and full light conditions are shown in in Figure 5. It can be seen from both graphs that for all three colors and sections of the tray, the Tru-Vu SRMH screen had the highest luminosity values. This means that out of each screen, the Tru-Vu SRMH could be seen the best through the plastic of the tray and is the most promising screen for illuminating tools during simulated medical procedures. The

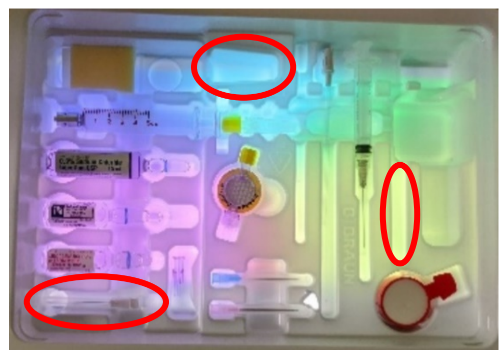


FIGURE 4: THE TRU-VU SRMH SCREEN WITH THE SECTIONS SELECTED FOR LUMINOSITY MEASUREMENT CIRCLED

only situation where the Tru-Vu SRMH was not the highest luminosity is for the whole tray measurement in the half light condition. Here, the MacBook pro showed the highest luminosity. This can be explained when taking into consideration the varying light exposure of the images. The light setting in each photograph of the tray is slightly different. This means that the higher sections of the tray where the LED is not shining through are reflecting varying levels of light back at the camera. This variation can be ignored because for the purpose of illuminating medical tools, it matters more how much light is coming through the tray in various colors, not how much light is reflected.

These results show that using an LED screen to illuminate tools through a plastic medical tray is a viable way to provide real-time feedback, as the light and colors are visible through the plastic. The Tru-Vu SRMH is the most superior of the screens tested, and will be used for the future design of this simulation tool.

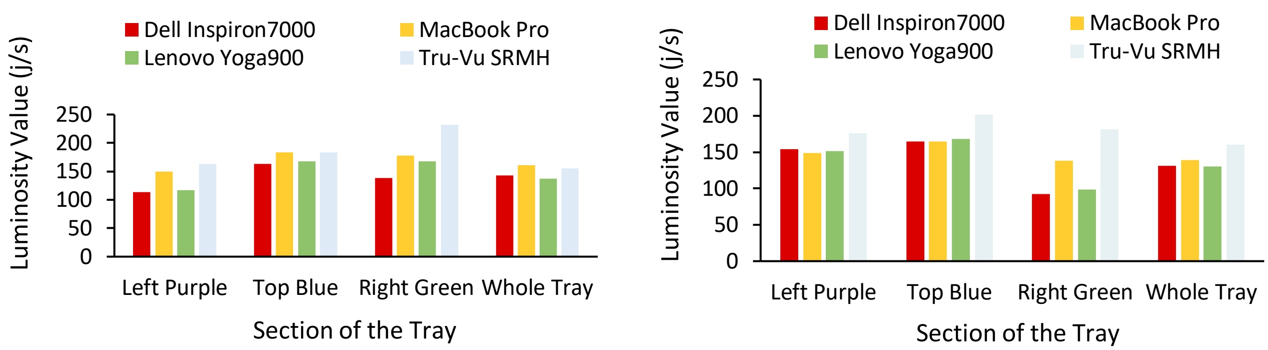


FIGURE 5: LUMINOSITY VALUES FOR SECTIONS OF THE TRAY IN THE HALF LIGHT CONDITION (LEFT) AND IN THE FULL LIGHT CONDITION (RIGHT)

3.2 Reed Switches

The experiment with the reed switches was conducted to determine the maximum distance that reed switches in the tray can be mounted from the magnets on the medical tools. The results of 15 trials to determine the average distances are shown in Figure 6. The average distances recorded for each reed switch over the 15 trials were 4 mm, 5 mm, and 7 mm. The average of these averages seen on the graph in orange is 5.5 mm.

Based on these results, future experiments can be done to ensure which distance gives the highest repeatability. Once that is determined, the sensors in the CVC medical tray can be mounted at that distance from magnets adhered to the medical tools, and testing can be conducted to further prove the feasibility of this method.

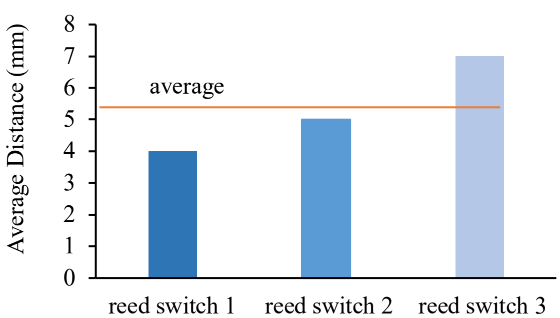


FIGURE 6: AVERAGE DISTANCE FOR EACH REED SWITCH

4. CONCLUSION

The proof of concept design and first step testing for a sensorized medical tray simulation that uses sensors to track the movement of various medical tools and an LED screen to provide real-time visual feedback was presented. Based on these results:

- A simple sensor approach to track the removal of medical tools from a tray is plausible
- An LED screen can be used to illuminate medical devices through a tray
- A sensorized medical simulation tool to train residents on the steps of CVC using a real CVC tray and tools can be created

The main objective of this study was to show that reed sensors are viable options for tool tracking, as well as to show that using light-based feedback through plastic is possible. These results have applications in any field where a simple tracking method is required; a combination of reed switches and an LED screen has potential to be a plausible method for providing feedback to trainees.

For future work of the specific application for CVC training, a higher fidelity model will be designed and fabricated, and a usability study will be conducted.

ACKNOWLEDGEMENTS

Research reported in this publication was supported by the National Heart, Lung, and Blood Institute of the National Institutes of Health under Award Number R01HL127316. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. Coauthors Dr. Moore and Miller own equity in Medulate, which may have a future interest in this project. Company ownership has been reviewed by the University's Individual Conflict of Interest Committee and is currently being managed by the University.

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