ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #25511

Enhancing Simulated Environments for Nursing Education and Practices

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Enhancing Simulated Environments for Nursing Education and Practices

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September 2018

Abstract

The goal this summer was to research and investigate solutions to limitations in teaching nursing practices using a combination of audio, electrical, and mechanical engineering. The issues raised came from Notre Dame of Maryland University faculty who have practiced many years in the nursing field and nursing education and are now ensuring that nursing students receive the most realistic simulations. Students will have a more seamless transition from simulation to performing procedures on patients with enhanced simulations that allow them to practice as safely and realistically as possible.

The three projects we chose to focus on are not meant to be a new frontier in medicine, but they are steps to educating better nurses so that they are better prepared when they become our caregivers.

Introduction

The field of engineering encompasses a broad spectrum of practice, problem solving, and theory. Our project incorporated audio, electrical, and mechanical engineering. This summer I worked with my mentor and professor Dr Suzanne Keilson in collaboration with two faculty members in Notre Dame of Maryland University's School of Nursing. An Assistant Professor, Diane Aschenbrenner specializes in teaching unique pedagogy of high-fidelity simulations and Amanda Henson is the Director of the Center for Caring with Technology. As representatives of the nursing school, they approached us with a prioritized list of needs, objectives, and ideas. After visiting NDMU's nursing building, we spent some time brainstorming which projects we could take on and reasonably tackle with the time and resources available. This was an excellent model of the engineering design process steps of user-centered design. Identifying the user needs with sympathetic interviewing, clarifying a problem statement and brainstorming possible solutions.

Three rather distinct needs and projects emerged from the process. The foremost requirement was a series of new sounds that were missing from their simulations. This included environmental sounds, suction noises, and wet obstructed breathing sounds. The second requirement was to develop and adapt a sensor into the mannequins to assist in suctioning practices by allowing students to know when they have properly placed their suction tubes far enough down the trachea. And the third need that was exposed was the need for practical ways to improve sterile field training.

I

Background

The simulation labs are equipped with mannequins that range in functionality. The high-fidelity mannequin has anatomically correct air ways and landmarks, it also emits heart and lung sounds, and is capable of rapid eye movement and sporadic breathing. Every set up has a monitor that can indicate underlying physiological changes. All these functions can be monitored in the control room. The SimMan 3g* already has a very limited range of preprogrammed sounds. They were not made with any attention to authenticity. There is a lot of potential to provide additional sounds and interactive scenarios.

The client had asked us to focus on three types of recordings: 1. A rattled breathing from a patient whose breathing is strained indicates to a nurse a patient needs suctioning*. This teaches students to be aware of key symptoms without explicitly telling the student of the patient’s distress 2. The suctioning noise when the student is clearing mucus building in the tracheostomy tube. This sound can be notably alarming, so the student should know what to expect 3. A track of ambient ER noises that will play in the background of simulations, so students learn to ignore the sounds that may be distracting from their patient.

Methods

The primary software for auditory or 'foley' editing that was used for the project was Audacity. Audacity is freely available and had all of the functionality that was required. The SimMan 3G software would accept *.wav files for upload and playback and Audacity could output files in a number of common formats, including *.wav. Audacity also allowed for the layering of multiple tracks into a single sound output. This allowed for the art and engineering of creating the correct sounds that our users needed. The sounds were not simply available for download.

The suction sounds were created primarily in the nursing simulation lab. We tried to find these sounds online – free websites, YouTube – but they weren't out there or not the right quality. We took a day to meet in the simulation lab and recorded suctioning various liquid we brought in. Pudding and chick-fil-a sauce were too viscous, but egg whites turned out to have the perfect consistency to mimic the suction of an obstructed tube. The suctioning was done with the equipment that students would use. We used a Zoom H2 Handy Recorder which required some experimentation with the angle of the mic and amount of gain.

The rattled breathing is the most difficult and not perfected yet. Short of recording someone who is sick, it wasn't a sound we could replicate ourselves because the rattle is produced from deep in the throat or lungs. I tried to layer "dry" breathing with recordings we had from the egg whites but wasn't able to find the right "wetness" the client described.

For the ambient environmental sounds of a medical center or emergency room publicly available sound files were found and layered together so that the compilation of sounds was dynamic but not distinguishable. The base of this track surprisingly came from a call center which served as white noise. On top of the call center chatter, there were phones ringing, announcements, and monitor beeps. An interesting point in our crafting this loop was to make sure that it was long enough and so not too repetitive and also that there was nothing so startling or unique on the loop as to allow nursing students to become too familiar with the loop. This way, the loop will be a background that adds an important realistic layer to the simulation experience that students will learn to both be aware of, but not distracted by.

Results

Overall, these new recordings for the simulations were successful. Although, some still require tweaking, they will hopefully give simulations a more realistic quality. We are going to arrange a time to meet and test the quality in the simulation labs in the fall of 2018 and spring of 2019. This testing will be including surveys of both the students and the instructors who use the simulations. If successful, they will also be made available to other nursing schools and interested parties. There is likely to be additional demand for other procedural or patient sounds.

II

Background

A tracheostomy is a standard procedure many patients receive when recovering from a surgery, have blocked airways, trauma, or are too weak to clear their airways themselves. It is an incision to open the airway. A plastic polymer tube is inserted into the trachea to help assist breathing; occasionally there is excess mucus build up. Nurses perform suction every few hours by placing a small tube into the patient’s airways. It is crucial that nurses reach deep enough into the airways to remove as much of the blockage as possible. The equipment of a tracheostomy generally consists of two key parts. There is an outer cannula with a neck plate. This is inserted into the incision to keep the airway open. The neck plate flange allows the outer cannula to be secured by tying it around the patient’s neck. The outer cannula allows the patient to breath while bypassing nose and mouth. This can also create challenges with eating and speaking. Sometimes there is a bypass to allow some air to pass through the mouth to all for speak. The inner cannula or small thin tube is inserted into the outer cannula. The inner cannula is much shorter, and it can be removed for cleaning. This allows for the quick and efficient gathering and removal of secretions without having to remove the outer cannula which supports keeping the airway open. That is not the only cleaning that is performed. A smaller, thinner flexible tube, a suction catheter can be inserted into the tracheostomy tube, while the inner cannula is in place. This allows for additional suctioning and removal of secretions deeper in the windpipe.

The objective was to come up with a device that alerts the student when they have successfully placed the tube deep enough. New nurses and doctors are often timid of going too far and hurting a patient or not deep enough. When a patient’s receives suctioning, the patient will likely be aware and experience some discomfort and react accordingly. Students need to practice developing the confidence to insert the tube far enough into the trachea, down to the point where the lungs branch.

Methods

Dr. Keilson and I came up with many approaches and started with piezo electric sensors. The most appealing aspect to these sensors is that they produce their own energy. Any mechanical pressure upon the piezo-electric ceramic material generates a voltage. This is because of the specific asymmetric crystal structure of the material. The sign of the voltage will change as the mechanical deformation changes or oscillates. The ceramic piezoelectric disk is small, about 25 mm in diameter, light, and does not require any additional power source. When the catheter presses upon it and then releases that pressure, it will generate a positive/negative voltage pulse. This way the mechanics are minimal and therefore do not take up much space in the already crowded mannequin. The sensor receives a little bit of mechanical energy from pressure and converts that energy into electrical voltage. The four diodes of the Wheatstone bridge rectify the voltage pulse so that there is a large single direction of current flow. This can then be used to light an LED and alert the nursing student that they have met and made contact where the sensor is located with sufficient force.

Results

In theory the sensors sounded ideal, but they had significant drawbacks. The first piezoelectric ceramic disk sensor we ordered required too much force to light the LED and get perceivable feedback. It was not likely typical students would press that hard when inserting the suctioning tube and encountering the disk in the trachea. There were other models to try. We then tried cantilevered weighted sensors; these sensors have a small metal weight that amplifies the mechanical energy so the LED responds to less force. This solution was not practical for the space the sensor was going into. In addition, the weighted sensors respond best to a quasi-continuous vibration with repeating frequency and not a single pulse, but a suction tube is more likely to rest against the sensor, therefore not producing enough mechanical energy to trigger the LED and is not likely to be vibrating.

Unfortunately, we ran out of time to order and test other theories, but we do know where we would go next. Taking what we learned about the sensor's limitations, we would go in a different direction. We needed a solution that has a broad enough surface area and requires minimal force to activate. A capacitive touch button, a lever switch or a keyboard or low force membrane switch are all likely commercially available products to explore. All these buttons and switches will require a power source, not an insurmountable problem. Small 3 -5-volt, button batteries should be able to power enough LEDs for signaling. Wiring would have to avoid the other electronics in the SimMan and also place the LED in an appropriate visible location for the students. A capacitive touch wouldn't require any pressure to trigger the light because it is activated by the touch or presence of a dielectric material entering the electric field. There are also some special low force requirement keyboard buttons available for those who need special ergonomic keyboards that minimize the force required to complete a keystroke. Two companies (Cherry MX and Gateron) also make tactile switches for gamers who need light tactile responses from switches. These switches respond to forces as low as 35 grams in commercial off the shelf design. This corresponds to the nursing student applying 0.3 Newtons of force to close the switch and light the indicator. Even if there are kinks and bending in the suction tube, there should be enough residual force when they attempt to place the tube properly to connect the switch and light the LED. Supplies will be purchased and tested over the coming 2018-2019 year.

Ultimately, instead of a light, the goal is to have audible feedback such as a cough because that is how patients would respond when suctioning has been done properly. Rather than lighting the LED, when the switch closes it would have to create a signal for a microcontroller to play the correct sound file or else integrate with the larger SimMan Gen 3 software system.

III

Background

The third project requirement was to brainstorm ways in which students could be made more aware of the invisible sterile field. When a nurse opens a sterile pack in order to perform a procedure, they need to be careful to not contaminate the contents. Infections from mishandling instruments are a common and troubling hospital problem. The rules are tedious and easily forgotten when in high stress situations. The brainstorming connection here was with creating an electromagnetic (EM) field shape that mimics that of the sterile field, but in such a way that if the student were to cross the field there would be some signal to indicate that.

Methods

The signal could be auditory or visual. An auditory signal is reminiscent of the Theremin instrument, which creates sounds, notes, music, as the player passes their hands through the invisible EM field. The theory of operation relies upon a simple vertical antenna to create the field and the heterodyne circuitry to create the interference or beat of the hand breaking the field. There are many challenging design aspects to this problem. The first is to create an antenna which generates the appropriately shaped electro-magnetic field. That field might change dependent upon the situation, procedure or skill the nurse was practicing. This would only be intended to work in a simulated environment to increase student's sensitivity to the nature of the sterile field but is likely to not be practical to implement in an actual surgical situation where space is very tight, the sterile field is relatively complex and warning sounds or lights would be distracting rather than helpful to surgeons and their staff.

There are some basic fields generated by classic antenna shapes. An antenna is designed to radiate electromagnetic energy. An AC voltage source is necessary to drive the production of a radiating EM field because it is an accelerating electric charge that generates that field. A charge at rest or constant velocity only generates a static field. One can inductively link to such fields, creating something like a transformer, but the Theremin type designs depends upon the energy in radiating fields. A loop antenna can generate a radiating field whose wavelength is equal to twice the loop circumference. Similarly, a dipole or straight-line antenna can generate a field whose wavelength is equal to twice the antenna length. Such a standard dipole antenna radiates a toroidal field. General ways to characterize the fields generated by an antenna are to first understand that the 'near field' physically closest to the antenna stores energy in standing waves (static), whereas the far field which is furthest away radiates that energy with propagating waves. The shape of the field can be directional and have field patterns with main and side lobes of radiation or can be omnidirectional where the field is the same, isotropic, in all directions in a plane. Designing specialty antennas and investigating their field patterns would require sophisticated software that can solve the full spatial temporal partial differential equations of Maxwell for a given generation and boundary conditions. This is something that would require significantly more work, enough to become an independent project of its own. Before that is undertaken, additional feedback from the clients from the nursing school would be necessary to see how much of a priority the sterile field indicator remains.

Results

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Discussion

This project really helped me learn about technology I didn't know existed, how to adapt an object intended for one thing into a solution for another, and the process of trying, failing, learning. I'm able to take away research skills and what I learned about myself and what I want to do. Clearly there is still much work to be done. We expect to continue on projects I and II during the 2018-

2019 academic year as our priority and priorities for the Notre Dame of Maryland University School of Nursing.

Appendices

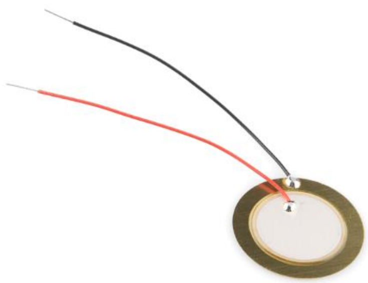

Figure: Piezo-electric ceramic disk force sensor

Figure: Commercially available mechanical switches with different required activation forces and tactile and auditory feedback

Figure: Key elements of a tracheostomy tube

Figure: Tracheostomy catheter, which is inserted into the inner cannula of the tube to actively clear secretions.