OPERATION FEEDBACK

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UW BME Design

Abstract

Current models used to train veterinary students on IV placement do not provide feedback regarding whether the needle is in the right position, whether the student moved the needle around too much when placing the catheter, and whether the needle punctured through the bottom of the vein. The aforementioned feedback would allow for the process of IV placement to be precise, and minimize damage to tissue around the vein. The proposed design aims to mimic the operation of placing an IV catheter into the cephalic vein of a dog. The model alerts the user when they have entered the vein using an imitation vein filled with a conductive gel that can complete a circuit to turn on an LED. The design provides feedback of excessive or improper needle movement using pressure strips surrounding the vein that alert the user when they have exceeded a determined pressure threshold. The goal of the design is to revolutionize the way students train for placing IV catheters.

Motivation

- Veterinarians frequently give cephalic vein injections for the placement of IV Catheters
- Veterinary students often miss the lumen of the vein or apply excessive force while in the vein
- Improper procedure may cause complications including tissue and nerve damage
- Current training models provide feedback in the form of synthetic blood as shown in Figure 1
- Develop a training model providing more comprehensive feedback

Figure 1: This image displays an existing model that uses gravity and fake blood to provide feedback for veterinary students.

Background Research

- Catheters should be inserted at an angle between 15 and 30 degrees [1]
- Incorrectly inserting needle can result in tissue and nerve damage [2]
- Canines will often react to the needle prick, making it pertinent to have a person immobilizing bigger dogs [5]

Design Specifications

- Alerts the user when the needle is in the lumen of the vessel
- Provides feedback when the user applies excessive force while inside the vessel or attempts to insert the needle
- Should not use synthetic blood or dyed fluids
- Tube should last for 3 months of biweekly use
- Powered by USB or wall outlet

Acknowledgements

- Dr. Walter Block
- Prof. Kristen Cooley
- Dr. Chris Brace
- BME Department

Final Design

Structural Components

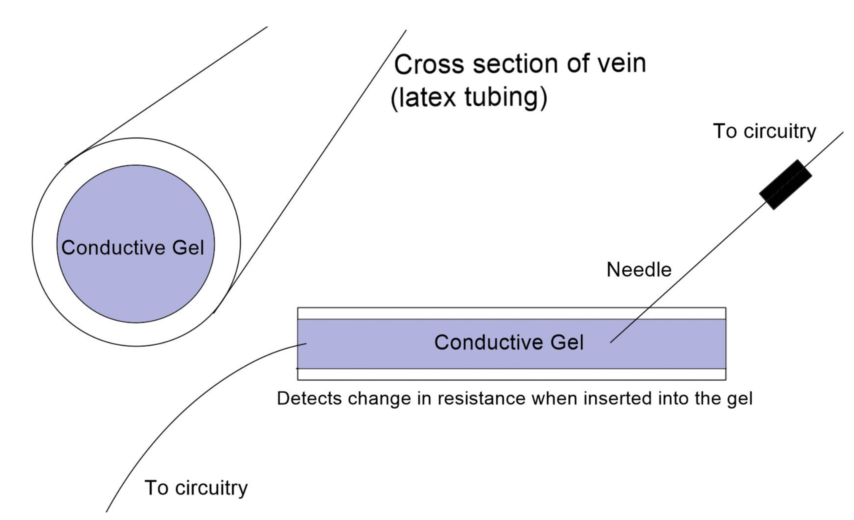

Figure 2: Diagram of Artificial Vein: The latex tube is filled with conductive gel which completes the circuit upon needle insertion

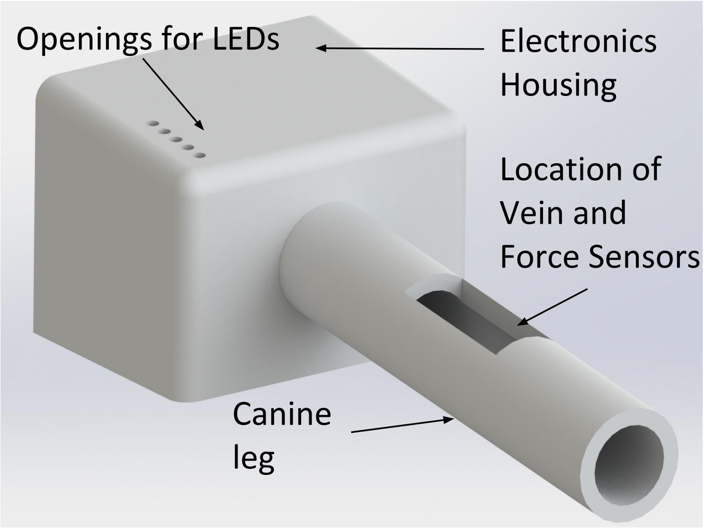

Figure 3: Isometric Render of 3D-printed Structure

Electronics Housing:
The Arduino/circuit board are in the housing unit. The box also functions as a support.

Canine leg:
Houses imitation vein filled with conductive gel. The leg is wrapped with synthetic fur, and the location of the vein is covered with synthetic skin to model the shaving of a canine leg to prepare for catheter insertion.

LEDs:
Provide real time feedback of a student's performance.
- Red and green LEDs: indicate if the needle is inserted
- Yellow, blue, orange LEDs: excessive pressure on left, bottom, right respectively

Circuitry and Code

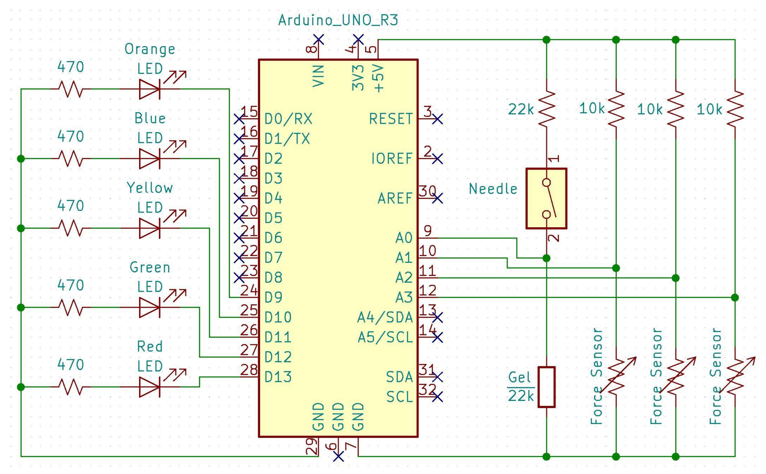

Figure 4: Circuit Schematic: The analog pins are used to measure the change in voltage across the resistors while the digital pins control the LEDs.

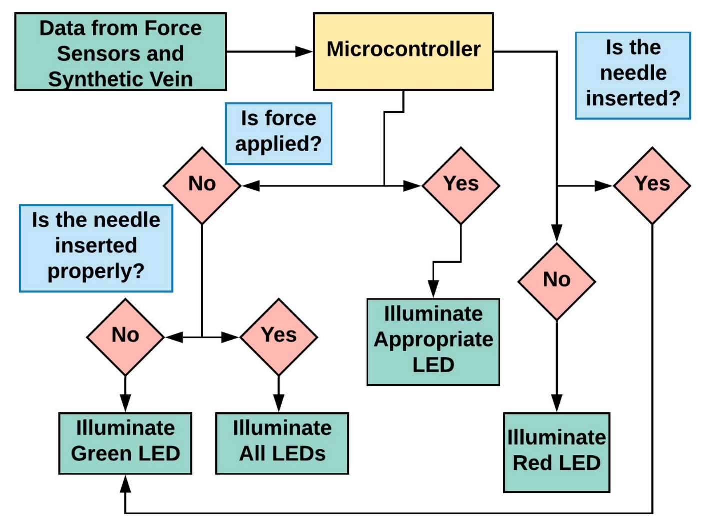

Figure 5: Code Block Diagram: The Microcontroller constantly takes in data from the device and checks if the pressure sensors are triggered or if the needle is inserted

Discussion & Future Work

Force Sensors
Three different force sensors were tested to determine their effectiveness in the design. The primary requirement for the variable resistors was that they must be sensitive to slight changes in force. The Velostat only experienced a change when touched in one particular place, not across the entire resistor. The Linear Soft sensors did not return to a constant baseline resistance which made it impractical to use. The final resistor had an almost infinite resistance when no pressure was applied and and drastically decreased with the slightest force making it a good candidate for the design.

Future Work
- Implementation of a scoring system to transform the educational model into a game
- Movement of the arm to simulate the movement of an animal during a real-life injection
- Display the results of a needle insertion on computer screen
- Make the vessel more easily replaceable

Testing

Pressure threshold
The set threshold is a change in voltage of 0.2 volts, which will turn on one of the pressure sensitive LEDs once reached. This 0.2 Volt change is equivalent to a change in resistance of 416.67 Ohms. The voltage drop for each pressure strip was recorded in response to one weight, as well as two, as shown in figure 6. Each of these weights were applied to each of the three resistors 20 times. The average voltage changes, from the application of one weight to the application of two, were calculated over the twenty trials. This value was used to determine the average change in resistance (Ohms) corresponding to the applied weight (Newtons). The equation shown below was then used to calculate the force, in Newtons, required to reach the threshold.

$$X = F / (RP1 - RP2) * 416.67$$

- X is the Force required to reach the pressure strip threshold in Newtons
- F is the known weight added of the additional screw in Newtons
- RP1 is the resistance measured within the resistive strip when only one weight is applied
- RP2 is the resistance measured within the resistive strip when both weights are applied
- The constant 416.67 is the value in Ohms required to reach threshold

Figure 6: The picture on the left shows how RP1 was recorded for each resistor. A 3.13 gram screw is placed in the center of the resistor. The picture on the right shows how RP2 was recorded, with the addition of a second screw weighing 3.18 grams.

Force required to turn on the pressure sensitive LEDs

Resistor	Pressure threshold (Newtons)
Resistor 1 (Left)	4.6×10^{-4}
Resistor 2 (Bottom)	1.9×10^{-4}
Resistor 3 (Right)	3.2×10^{-4}

Figure 7: Each pressure strips force threshold is shown here, as determined by the equation above.

Change in voltage during needle insertion
At first contact of the needle with the conductive gel, the distance between the tip of the needle and the wire at the end of the vessel is a maximum. This distance is shortened during the follow through of the insertion, and is at a relative minimum once the needle is inserted the full 3.5 cm. The resistance of the conductive gel decreases with a decrease in distance between the needle tip and wire, this drop in resistance corresponds to a drop in voltage. The decrease in voltage was recorded over 10 trials and the average was determined to be 0.402 Volts.

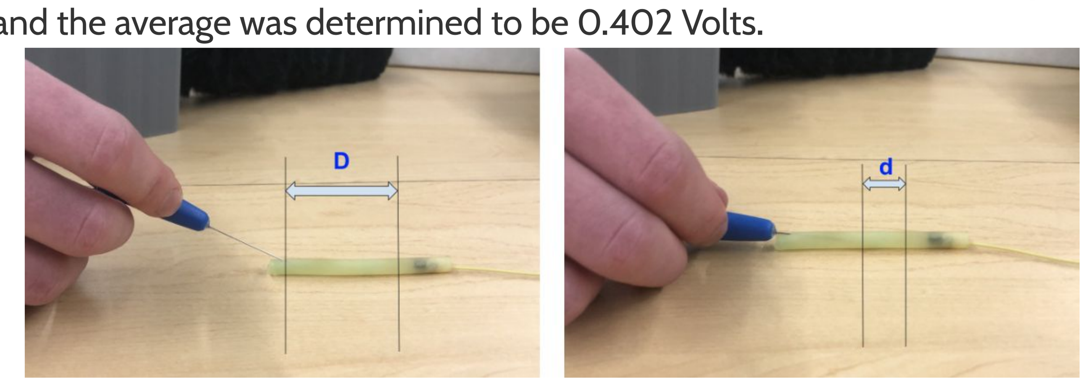

Figure 8: The left picture shows the initially large distance, and the right picture shows the decreased final distance.

Longevity of Conductive Gel
The viscosity of the conductive gel was tested to determine how long the imitation vein will last. A two and a half inch tube was filled with gel and left exposed to the air. The gel was checked on biweekly for 4 weeks. For as long as testing was able to be conducted, the gel remained in its viscous state. Therefore, the conductive gel will remain viable for at least 4 weeks inside of the model.

References

[1] "Seldinger Technique for Central Intravenous (IV) Line Placement," *Evidence Based Medicine Consult*. [Online]. Available: https://www.ebmconsult.com/articles/seldinger-technique-intravenous-iv-placement.

[2] E. M. Kagel and G. M. Rayan, "Intravenous catheter complications in the hand and forearm," The Journal of trauma, Jan-2004. [Online]. Available: https://www.ncbi.nlm.nih.gov/pubmed/14749578.

[3] H. Kalvøy, Needle Guidance in Clinical Applications based on Electrical Impedance . Department of Clinical and Biomedical Engineering Rikshospitalet, Oslo University Hospital Norway.

[4] "Life/form® Canine IV Leg," GTsimulators.com. [Online]. Available: https://www.gtsimulators.com/Nasco-Lifeform-Canine-IV-Leg-p/lf01016u.htm. [Accessed: 03-Dec-2019].

[5] E. Ades, "Restraint Techniques for Animals," *Johns Hopkins University*, 27-Aug-2010. [Online]. Available: http://web.jhu.edu/animalcare/procedures/restraint.html. [Accessed: 04-Dec-2019].

[6] "https://www.bristol.ac.uk/media-library/sites/vetscience/documents/clinical-skills/IV Catheter Placement.pdf," Bristol UK Vet Science Media Library, 2017. [Online]. Available: https://www.bristol.ac.uk/media-library/sites/vetscience/documents/clinical-skills/IV Catheter Placement.pdf.