Department of Mechanical Engineering
THE UNIVERSITY OF UTAH

Motor Control for Medical Infusion Pump

Team Members: Lauren Kochaver, Cole Paradis, Nikita Rabbitt, Sam Schmiett
Faculty Advisor: Dr. Mark Fehlberg
Sponsor Advisor: Dr. Ryan Stanfield

MOOG

Introduction

Enteral infusion pumps are medical devices that administer nutrients to a patient requiring tube feeding. Most pumps on the market are generally expensive and too large for true ambulatory use. This prototype uses an innovative pressure modeling method to replace complex pressure sensors, making it cheaper, smaller, and simpler than existing enteral pumps. This pump is a peristaltic pump, creating flow by rotating rollers across a flexible tube.

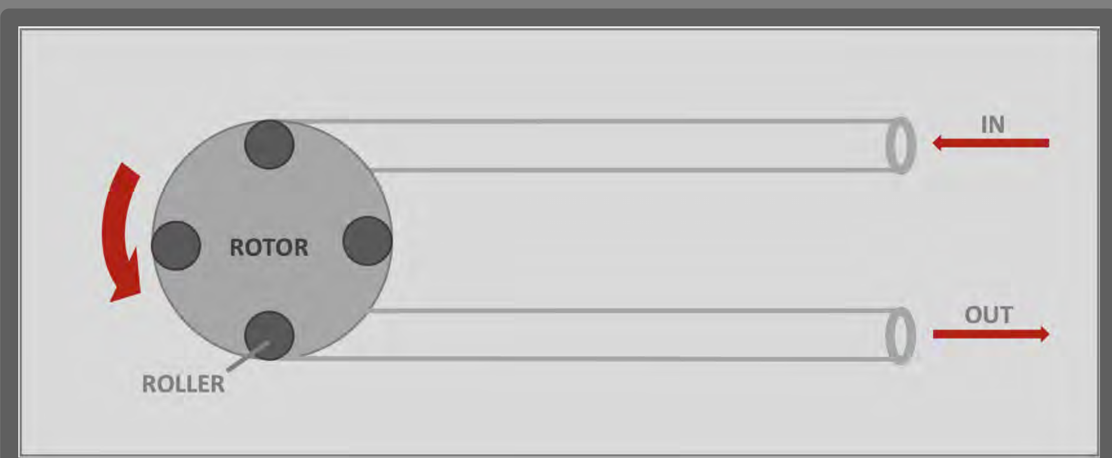

Figure 1. The basic operation of a peristaltic pump.

Problem

The current MOOG infusion pump uses Hall effect sensors to measure pressure in the feeding tube and alert the user if an occlusion is detected. Integrating these sensors requires a complex and expensive housing design.

Methods

As pressure in the feeding tube increases from an occlusion, the pump's motor must work harder to pump food. Therefore, by measuring the current drawn by the motor, the tube pressure can be estimated.

A testing apparatus was created to determine the relationship between the pressure in the tube and the current drawn by the motor. While the motor was running, a known back pressure was introduced to the feeding tube, and the motor's current was monitored. *Figure 2* shows the measured relationship between applied back pressure and average measured current.

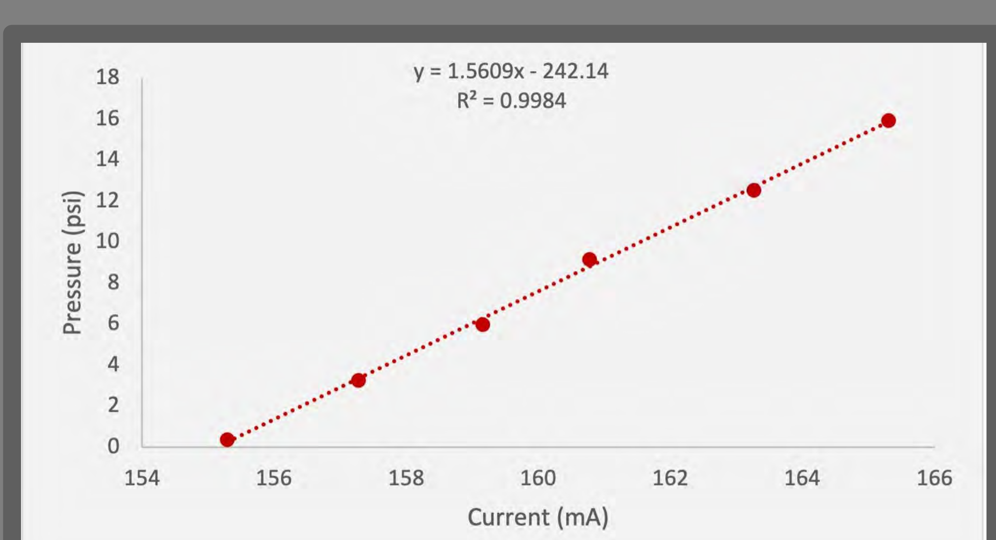

Figure 2. The measured relationship between applied back pressure and current drawn by the motor.

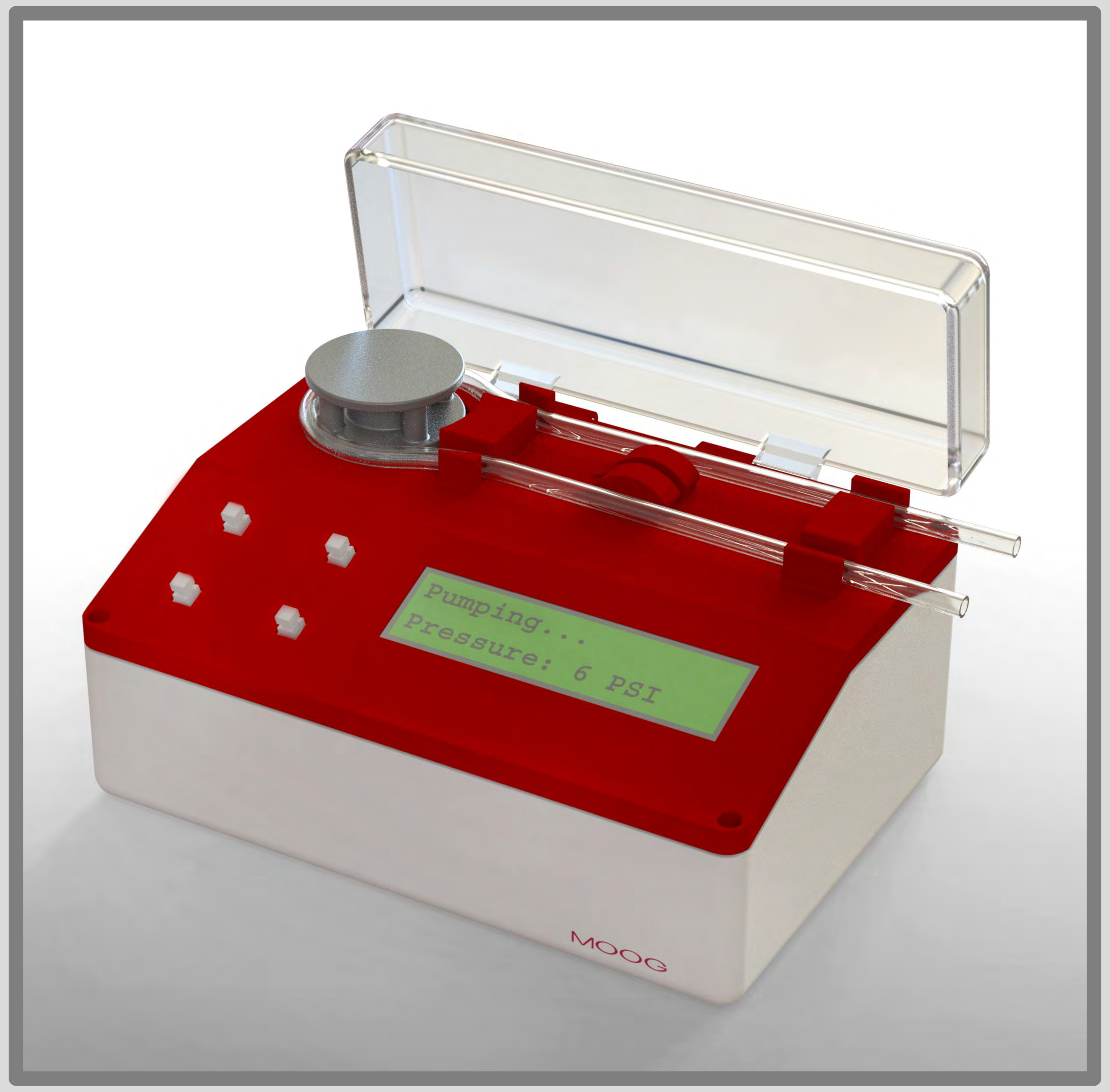

Figure 3. CAD Model of Pump Housing

Current Filtering

The current drawn by the motor proved to be inherently noisy and unpredictable, making pressure estimation based off current data difficult. A Fast Fourier Transform was used to reduce the oscillatory nature of the noise, and a moving average filter was layered on top to flatten the data. Filtered but responsive current data was required to make the pressure estimation effective.

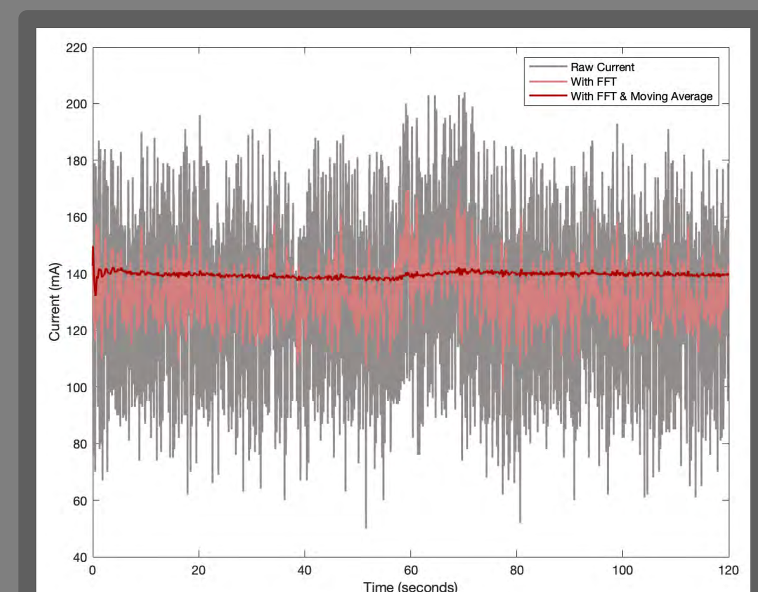

Figure 4. The effect of filters on motor current.

Housing Design & User Interface

After evaluating user needs, a simple and minimalistic housing and user interface was designed. The housing features four buttons and an LCD screen. This screen can display the dose, the pump run time, the volume flow rate, and the pressure in the tube. The buttons allow the user to turn the pump on and off, toggle between menus, and clear errors. The housing design allows space for the development board containing the same microcontroller that MOOG uses in their medical infusion pumps. The housing also contains a motor driver, a motor, a battery, a speaker, and other electronics.

Results

Using the linear relationship from *Figure 2* and the filtering methods shown in *Figure 3*, the average pressure was successfully estimated within +/- 3 psi of the true value and with less than +/- 3 psi of noise. After running tests where a full occlusion (fully blocked tube) was introduced, our model correctly identified the occlusion and alerted the user 98% of the time. Over the course of 50 trials, the singular failure was due to inconsistencies in the motor current.

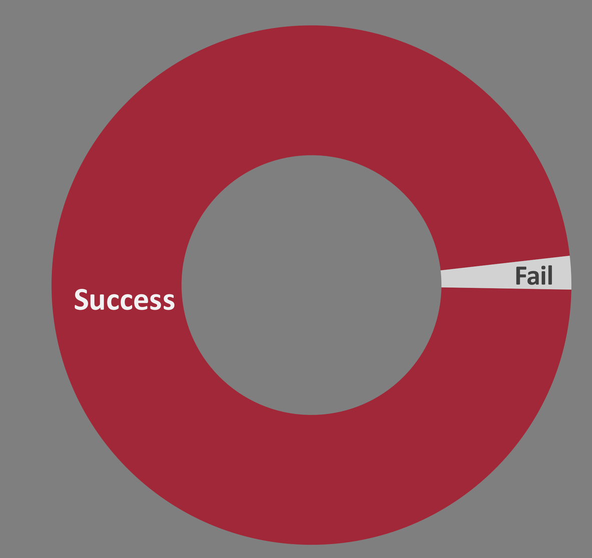

Figure 5. The success rate of occlusion detection.

The average time to recognize the occlusion was 6.2 seconds (SD = 3.6). The total cost of the prototype was less than $130 and had a total size of 45 in^3. Due to noise and variability of the current, the pump was less successful in recognizing minor, sustained occlusions. The prototype recognized partial, sustained occlusions only half the time in testing.

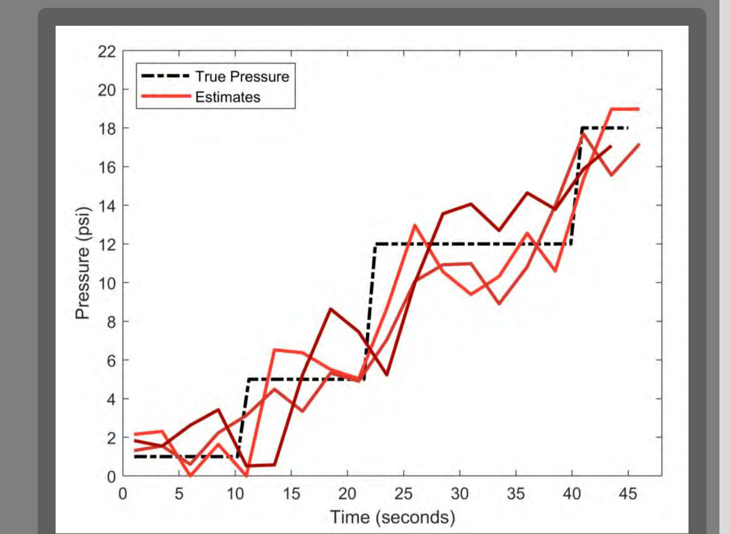

Figure 6. The accuracy of our pressure estimation for three repeated tests.

Table 1 . The desired metrics versus what our prototype achieved.

Metric	Desired	Achieved
Occlusion alarm sensitivity	±3 PSI	±3 PSI
Time to sense full occlusion	< 20 sec	6.2 sec
Physical volume of pump	< 30 in^3	45 in^3
Pump weight	< 1.10 lbs	1.02 lbs
Cost	< $500	$127.50

Conclusion & Future Work

The project determined that a medical infusion pump can operate without Hall effect pressure sensors to detect occlusions. The prototype successfully used motor feedback to estimate pressure in the feeding set and detect occlusions but has room for improvement in terms of estimation sensitivity. While this prototype was efficient in detecting full occlusions, it was less reliable in recognizing smaller, sustained occlusions. More intricate current filtering methods and more precise hardware could benefit the estimation sensitivity. Additionally, the overall size of the pump could be reduced by using custom circuitry and smaller components.

We believe the technology developed for this prototype could be a viable replacement with further development, and makes the goal of smaller, simpler, and cheaper enteral pumps achievable.