CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: A pneumatic nipple to improve infant feeding outcomes: control software	
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Project Overview:

Feeding problems in infants are prevalent and can impact over 25% of term infants and up to 80% of preterm infants. As such, the ability to safely and effectively feed is a primary criterion for discharge from a hospital, and the inability to do so is one of the major causes of prolonged infant hospitalization. Infants with feeding difficulties generally must be fed on bottles and are often prescribed one of two feeding interventions: slow-flow nipples, or thickened milk. While these interventions successfully limit the frequency of choking (aspiration) during feeding, they are purely compensatory and do not address or rehabilitate the underlying pathophysiology that generated the difficulty. These one-size fits all approaches to reduce flow rate are outcomes-based approaches that do not account for these different mechanisms of poor performance. Furthermore, there are no manufacturing standards regarding bottle-nipple construction, and the material properties, such as stiffness of a nipple can vary widely across, and even within manufacturers. This is critical, because nipple stiffness has known consequences on infant feeding performance. However, we have very little insight into how infants respond to these three metrics of variation (nipple stiffness, hole size, or milk thickness).

The Mayerl Lab at NAU is hoping to study how infants are able to respond to these three different metrics of variation. To accomplish this, we hope to develop and use a bottle-nipple system with modifiable properties (nipples stiffness, hole size, and milk viscosity, a 'pneumatic nipple') to measure performance and physiology during feeding in term and preterm infant pigs with high-speed x-ray video coupled with several other metrics of feeding physiology and performance (electromyography, pressure generation, respiratory patterns, Fig. 1). In doing so, we will evaluate both how infants respond to these metrics, but also what the downstream performance consequences are of these responses. This will allow us to develop protocols whereby we adjust nipple or milk properties to match an individual's specific physiology, thereby creating the first 'individualized medicine' for infant feeding problems, rather than the current one-size-fits-all approaches used. These interventions will thus be physiologically based, rather than purely compensatory, and also allow us to evaluate if we can entrain novel motor outputs via motor learning, which has never been evaluated in infant feeding, even though motor learning paradigms are incredibly successful at rehabilitating poor performance in adult locomotor tasks.

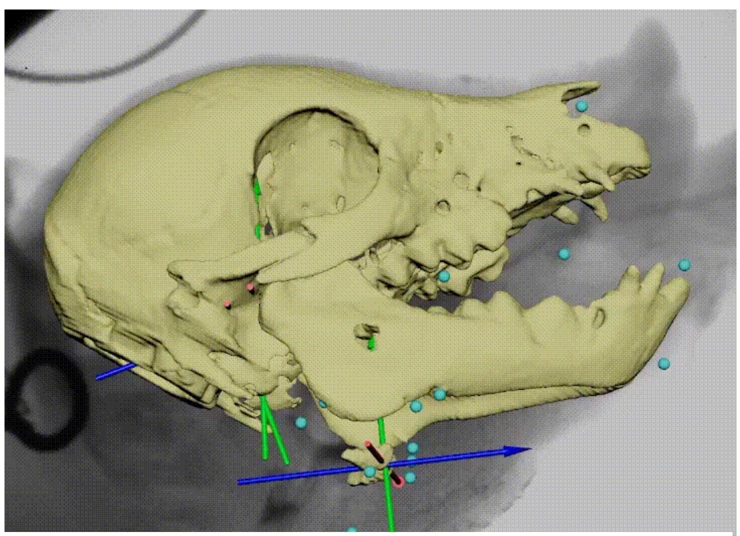

Figure 1. Example image taken from high-speed biplanar Xray video of an infant pig feeding. The yellow structure is the skull (top) and hyoid bone (bottom), and the small blue structures are radio-opaque markers in structures of interest.

The key goal of this project is to develop the interface to control the pneumatic nipple feeding system so that we can document the neurophysiologic changes that occur in infants when the nipple hole size, stiffness, or milk viscosity are adjusted. This interface will be run through a windows computer, and record changes in properties in synchrony with other metrics of performance.

The hardware for this project will be developed by students in a Mechanical Engineering capstone. These students will create the parts and electronic connections controlling them to adjust nipple stiffness, hole size, and milk type. They will interface with students from Computer Science, who will use the output from the electronic connections to develop a computer program that can be used to dynamically control those properties.

The computer science team specifications and goals:

The specific aims for the computer science team can be divided into several achievement level:

Level 1 – A simulated program used to modulate nipple and milk properties during feeding

- The team will create a computer program (Microsoft windows or web app) with a graphic user interface to control nipple hole size (2 – 3 discrete metrics), stiffness (2 – 3 stiffnesses), and milk viscosity (a continuous scale). The program should be able to be operated by keyboard shortcuts or mouse clicks. These digital controls will eventually be attached to the physical hardware developed by the ME students. Students will interface with ME students to understand input and output from the physical model for future integration.The input from the software should be to result in a change in nipple or milk properties through interfacing with the arduino/pi control.
- The user should also have the ability to synchronize output to an ADI powerlab Data Acquisition Center (DAC, Fig. 2). The DAC will store the outputs for future analysis when synchronizing data from the DAC with X-Ray video data. The DAC output is saved per pig, and the primary objective of the output from this project will be to know what output is connected to what nipple (or milk) parameters. One option to do this is to associate a voltage output with a specific setting that has been calibrated but other possibilities exist.

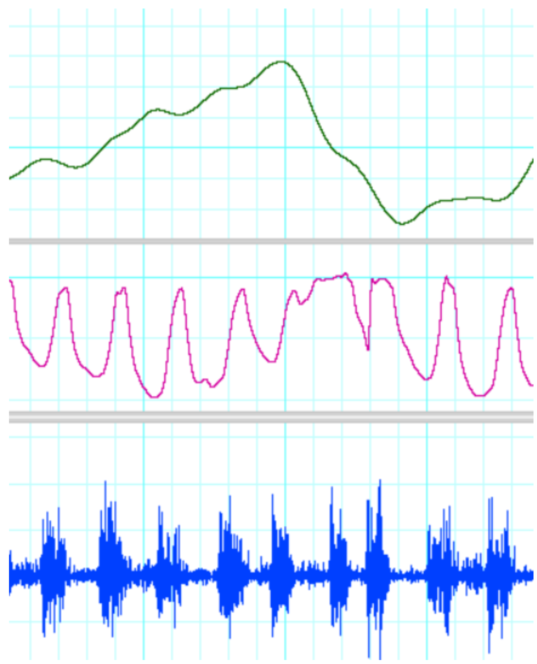

Figure 2. Example data that will be synchronized with changes in nipple properties. Green line: respiratory trace (slope up = inspiration); Pink line: intraoral pressure generation (each dip = one suck); Blue line: Muscle activity.

Level 2 – An integrated program that can be used to modulate one aspect of nipple or milk properties

- At this level, the computer program will be able to directly interface with a physical model developed by the ME students to control one aspect of nipple or milk properties. The output of this will be registered in real time by the ADI powerlab to be analyzed and synchronized with xray and other physiologic variables later.

Level 3 - – An integrated program that can be used to modulate two aspects of nipple or milk properties

- At this level, the computer program will be able to directly interface with a physical model developed by the ME students to control two aspects of nipple or milk properties. The output of this will be registered in real time by the ADI powerlab.

Level 4 – An integrated program that can be used to modulate all three aspects of nipple and milk properties

- If this final level is reached, we will have a functioning system in which all three metrics of variation can be physically controlled through the computer program, all of which can be registered in real time by the ADI powerlab.

The team will work with the client to refine and detail the goals based on requirements, analysis, and feasibility, as well as based on the ability of the ME team to produce a physical prototype. The eventual goal of this program will be to first be validated in an animal model in the Mayerl lab, with the eventual goal to be used in hospital settings to facilitate feeding performance in human infants. Furthermore, we hope to use data collected from this system to develop an understanding of the relationships between metrics of performance that are easily measured (such as intraoral pressure generation) and metrics of nipple and milk properties, so that a machine learning algorithm can be developed to modulate nipple properties dynamically and automatically to facilitate infant feeding performance.

This work is critical, as feeding difficulties are prevalent across all infants, especially those born prematurely or with other neurological conditions. The inability of these infants to safely and effectively feed not only impacts their growth and survival during infancy, but also is correlated with long term health consequences that can impact them throughout their entire lives. Developing interventions such as this, that are grounded in physiologic mechanisms and performance, is key to improving the quality of life, and the ability of these infants to survive and grow.

Knowledge, skills, and expertise required by the end of this project:

- Basic knowledge of programming in Arduino or Raspberry Pi, as well as programming techniques needed to develop a graphical user interface (GUI) as a stand alone windows program or a web app.
- Basic knowledge of wiring and hardware, enough to interface with mechanical engineering students
- Effective communication skills to interact with students and faculty who are not computer scientists to communicate needs for interfacing a physical model with the computer program.

Equipment requirements

- Equipment will be provided by the Mayerl lab, including computers to work with, the Arduino/Pi that is needed by the students, and the physical model provided by the ME students.
- Students are welcome to work on their own computers as well.

Software and other Deliverables

The deliverables are specifically aimed at making a GUI to control the physical properties of a bottle-feeding system for infants. Thus students will need to deliver:

- A computer program (windows or web) with a GUI that can control these properties in real time with a synchronized output to a DAC.
- A pdf manual sufficient to allow non-computer scientists to install and work with the program, as well as instructions on how to adjust the program to change pre-built levels.
- As-build documentation giving detailed technical description of how your product works, build specs, and anything else needed by future software teams taking up your project for further development.