Three-Way Syringe Mixing Team

In association with Aveuvas Technologies Inc.

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Design Review 4 Documentation

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Introduction:

George Aubrey

The mission of our team is to design a syringe mixing system for Dr. Tim Becker's Center of Bioengineering Lab which intends to perform research regarding an ideal methodology for treating brain aneurysms by testing the medication through mixing trials. The system which we have been tasked to design involves mixing three syringes with separate medication gels in which the energy imparted on the gels while mixing has a direct correlation on the efficacy of the drug's effects to treat brain aneurysms during human administration. This project is a continuation of last year's capstone team which failed to engineer the clinical device. Our team intends to improve on a majority of the aspects from last year's device including portability, ease of use, operability, and simplicity. We have improved several parameters of the previous year's device including weight, user-input simplicity, construction, mixing speed, and processing hardware drastically. Additionally, our device is very simple to take apart for a hospital setting with 3D printed components which are strong enough to handle the physical demands of the motors yet can be easily taken apart with no tools. This is ideal for cleaning and replacing components when needed.

Another key aspect of our project is to yield reproducible results time after time. Through our hypothesized Graphic User Interface (GUI) we guarantee this is achievable with our high quality motors and surge-protected motor driver system.

The bulk of our design stems from three key features we will convey within this document: The device's portability, the Graphic User Interface, and the motor and potentiometer hardware. Additionally, we will add upon our client's problem, the design process, project constraints, and our Work Breakdown Structure (WBS).

Main Device Features:

- Device Portability:
    - Collapsible platform
    - Lighter materials
    - Securely fastened motors
    - Easily removable 3D components
    - Attached panel for graphic user interface and system controls
    - Mounted microprocessor with standard wall power adapter
- Graphic User Interface:
    - Intuitive
    - Variety of Settings for User Input
    - On Board User Interface
    - User Friendly
- Motors and Linear Potentiometer:
    - Motor speed ranges from 2 - 9 inches/second
    - Motor speed and position controlled by physically attached Linear Potentiometers
    - Position control accuracy within 0.1 inch
    - Speed control accuracy within 0.1 inches/second
    - Current draw protection from MULTIMOTO Arduino Shield
    - Fast direction-switching capabilities

Client Problem:

George Aubrey

Our Client's, Dr. Becker's, problem is that the researchers in his Bioengineering Lab have no way to reproducibly and reliably mix the aneurysm medication component gels in their lab to derive the ideal mixing protocol for the most efficient way to treat aneurysms. These researchers in our client's lab are looking into the areas of mixing speed, measured in inches per second, and mixing duration. Both of these parameters play an important role in the efficacy of the medication after administration.

Our client has hired us to develop the system in its entirety including, the mission-capable motors, the Graphic User Interface, the various mounts which keep the components steady and attached. With these structures to develop and research, we were also tasked to build a collapsible platform to cut down on the space it takes up during periods of non-use.

Previously, the researchers within our client's lab had to mix these component gels by hand with exact amounts of strength but without any sort of checks and balances they had no capabilities of maintaining reproducible and reliable results as one person's strength to another's is not exact. Additionally the timing of these manual mixes was also variable as there existed differences in the reaction times and timings of the researchers. With a new computerized system in place, issues of keeping these variables constant throughout their research can be ignored.

Overall, the implementation of our device in this research setting will enable the lab researchers to perform reliable trials to test the medication and reproduce similar results compared to their original method of preparing samples by hand.

Design Process:

Austin Heller

Throughout the course of the project, the team has decided on various specific devices to implement in the final project design. The main components chosen for the final design are listed below. In this section we hope to portray our reasoning for choosing these various devices, and how they help us towards our project end-goal.

Tubular High-Speed Linear Actuators (PA-15):

The previous group to work on this project chose motors, the PA-14, that had a maximum speed of 2 inches per second. This was the the minimum speed capability requested by the client, Dr Tim Becker. Our group originally decided to use another version of this same motor, called the PA-14P which had a built-in linear potentiometer for position and speed control. However, initial tests suggested we needed to take another look at the motor spec sheets. What we learned from this is that the motors have a negative linear relationship between motor speed and push weight.

Because we wanted a system capable of mixing in ranges equal to or faster than 2 inches per second, we chose the next fastest motors of the smallest size, the PA-15 motors. These motors are capable of pushing our syringes in a range of 2-9 inches per second. The drawback to this decision is that these PA-15 motors are twice the size of the PA-14, making the system drastically bigger.

MultiMoto Arduino Shield:

One of the biggest mistakes made by the previous group is that they attempted to create their own motor driver. Flaws in their design caused the system to malfunction and fried the circuit.

Originally we attempted to do the same thing - create a motor driver capable of controlling the system without malfunctioning. Soon into the design, it was realized that it would be infeasible to create our own driver due to the complex needs of the system such as voltage limiting for speed control, reversible motor directionality, and current protection for the control system.

To solve this issue, we researched different types of motor drivers until we found the MultiMoto Arduino Shield. The MultiMoto Arduino Shield is a motor driver that acts as a shield for the Arduino, and made specifically to be compatible with the types of motors we are using. The MultiMoto Arduino Shield provides an H-bridge for direction control, a voltage limiter to control motor speed, and a current limiter for protecting an Arduino from current spikes, making it the perfect device to use for our project.

Arduino Mega 2560:

Because we found that the motors could be controlled from the MultiMoto Arduino Shield, we figured the best unit to use to control the motors would be an Arduino. Originally we used the Arduino Uno R3, as it contained enough pins to use the shield, and we thought we could run a GUI on the system by connecting its serial port to a computer. However, a PC-based GUI did not turn out to be feasible for reasons to be described in the next section.

Instead, the group decided to use an Arduino Mega 2560. This Arduino unit was chosen because the Mega contains more analog and digital pins than the Uno, allowing us to build an onboard GUI while still being compatible with the MultiMoto Shield.

On-Board Graphic User Interface:

By client specifications, the user must be able to control motor speed and mix duration. Therefore, we needed to build a user interface that allows the user to change these values.

Originally, we planned to create a PC-based GUI controlled by MATLAB, as matlab has the capability to interact with the Arduino through its serial port. Where this idea failed was that we could not export the GUI to a standalone application due to the MATLAB Arduino support packages being non-exportable. After other failed attempts to create a GUI from other services such as Device Druid, it was decided to instead build an on-board GUI.

To create this on-board GUI, we decided to use a LCD display, a number pad, and a rotary potentiometer.

T-Shaped Device Mount:

Two device mounts were considered for the final project. The first was an in-line mixer that had two motors on one end and the third motor at the other. This design was proposed to help consolidate space since the motors are relatively large. We would also have built a hinge system with this design so that the device could be folded up for storage. The issue with this design is that being able to connect the syringes in the center would require a syringe connector that had too much dead volume - the amount of liquid that would be stuck in the connecting tube after mixing. To minimize dead volume, a larger design was deemed acceptable.

The final mount design chosen for our project is a T-shaped design where each motor sits on a limb of the ‘T’. We also included hinges at each limb of the ‘T’ to fold the device and conserve space when the device is not in use.

12VDC 10A Power Supply:

This item was chosen in a trial and error fashion. We knew that we needed at least a 12 volt direct current (VDC) power supply. Originally we acquired a 12VDC 2 amp (A) power supply because we misread the MultiMoto Shield specifications and assumed we only need a 2A supply.

However, this proved incorrect after initial tests showed that the motors could not run full speed with that supply. After re-evaluating the specifications for the entire device, we decided that a 12VDC 10A power supply would be sufficient enough for the project, as the max current draw of any one motor at maximum weight is 9A, and the typical is 6A.

Project Constraints:

Lamar Callico

Throughout this project, the team has faced many constraints imposed by our client, availability of parts, and time. One of our clients constraints for this project is to have a motor that is capable of mixing at least two inches per second which later changed to at least a maximum rate of two inches per one fourth a second. This had impacted our design because it caused the team to order new motors capable of meeting these requirements which led to the purchase of Tubular High-Speed Linear Actuators (PA-15). These PA-15 actuators were significantly bigger than the previously used motors causing the team to redesign the positioning of these motors differently than the T-shape design. As the team had designed a new layout of the device with having two motors in parallel and the third one facing the two, the different elbows syringes caused constraints to the amount of dead volume present after the mixing. This had caused the team to convert back to the original design with the modification of the device being able to be folded upright.

The availability of parts also played a major role in the design constraints. Our mixing device had constraints for the parts the team used in constructing this device. To meet the criteria of the device being portable, the team had use a metal that was strong and durable enough as well as light enough for portability. This caused the team to use different metal than the previous year that was less thick but durable with 3D components instead of metal. Another constraint the team faced was the lack of certifications of the machinery. Our device required metal to be trimmed, as well as having puncture holes throughout the base, and 3D printed components to build the base of the device. This constraint had little impact due to a team member working closely together with an Mechanical Engineer peer who had the certifications needed, but it did cause us to change some of the designs for the components intended to hold the actuators and syringes.

The constraint of time is playing a role in constructing this device. Due to the teams lack of certification in the machinery department, it causes the team to depend to other personnel to complete our 3D printed and metal request causing a waiting period. This prevented the team from fully constructing the device as one, and allowing to further testing on motors and syringes.

Work Breakdown Structure:

ID	Activity/Task	Description	Deliverable(s)	People
1.0	*Code Development*			
1.1	Coding for Linear Potentiometer **COMPLETE**	Build Code to Test and Calibrate Linear Potentiometer measurements to motor size and stroke.	1. Ability to control motor position accurately through code 2. Ability to control motor speed accurately through code 3. Ability to move on to motor tests	Austin Heller

1.2	Coding for Motor Position Control **COMPLETE**	Use Linear Potentiometer to code position control tests and calibrations for Motors.	1. Ability to code motor position controls 2. Ability to calibrate motor extension lengths 3. Ability to test mixing capabilities	Austin Heller
1.3	Coding for Motor Speed Control **COMPLETE**	Use Linear Potentiometers to code speed control tests and calibrations for Motors.	1. Ability to code motor speed controls 2. Ability to calibrate motor speed 3. Ability to test mixing capabilities	Austin Heller
1.4	Coding for Time and Synchronization **COMPLETE**	Test code to control mix time durations and synchronize motor movements	1. Ability to control mix time durations 2. Ability to synchronize motor movements 3. Ability to track speed for ensured reproducible results	Austin Heller
1.5	Bare Minimum Code Compilation **COMPLETE**	Compile all tested code into arduino code to act as worst-case-scenario (not as user friendly) User Interface.	1. Bare minimum code for user 2. Reference for control logic should the client look to improve the code or develope a better GUI 3. 90% Completed Project	Austin Heller
1.6	Coding for GUI Compatibility **COMPLETE**	Alter tested code to make compatible with GUI (to be developed).	1. User-friendly control interface for user 2. Compatibility as standalone application on any computer 3. 100% Completed Project	Austin Heller and Lamar Callico
2.0	*Graphic User Interface Development*			
2.1	Research Possible GUI’s **COMPLETE**	Research different possible GUI implementations for on-board GUIs and/ or PC-based GUIs.	1. Gain multiple sources to test 2. Find easiest GUIs to begin testing with 3. Determine compatibility of Arduino Code	Lamar Callico
2.2	Simple GUI Testing **COMPLETE**	Test best GUIs from research for ease of use, simple compatibility, and learning curve.	1. Find easiest GUIs to continue testing with 2. Determine GUI functionality	Lamar Callico
2.3	GUI Code Compatibility Testing **COMPLETE**	Test remaining GUIs for compatibility with Arduino-coded functions and libraries.	1. Find best GUI for our device 2. Ability to move on to GUI completion.	Lamar Callico and Austin Heller
2.4	GUI Completion **COMPLETE**	Complete Coding of GUI.	1. Completed GUI 2. Device will have user-controlled inputs. 3. GUI will be on board or PC-based	Lamar Callico and Austin Heller
3.0	*Mounting Hardware Construction*			
3.1	Conceptualization **COMPLETE**	Determine what arrangement of hardware provides the most compact area while still being able to function.	1. Ideas to bring to a consultation 2. Determination of what all must be constructed	George Aubrey and Austin Heller
3.2	Consultation **COMPLETE**	Consult with a Mechanical Engineer familiar with CAD programs to design the mount	1. Aide from a mechanical engineer familiar with how to create what we need. 2. Ability to begin mounting components construction.	George Aubrey, Austin Heller, and Travis Byakeddy

3.3	Metal Plate Mount Construction **COMPLETE**	Create a metal plate to mount the motors and other mounting devices to.	1. Metal plate for motors and rest of device to sit on 2. Ability to attach hardware to stable mount.	George Aubrey and Travis Byakeddy
3.4	Syringe-to-Motor Mount Construction **COMPLETE**	Create a device capable of attaching the end of a syringe to the arm of our motor.	1. Connector for Syringe and Motor 2. Ability to attach motor to syringe for better testing and calibration	George Aubrey and Travis Byakeddy
3.5	Syringe-to-Plate Mount Construction **COMPLETE**	Create a device capable of attaching the hull of a syringe to the mounting plate.	1. Connector for Syringe and Plate 2. Ability to attach syringe to mounting plate for better testing and calibration	George Aubrey and Travis Byakeddy
3.6	Vibration Dampening **COMPLETE**	Acquire materials to pad metal-contact areas on the device from other metal-contact areas to reduce vibrational movement.	1. Quiet device 2. Longer lifespan of hardware 3. Device nuts and bolts will not loosen	George Aubrey and Travis Byakeddy
4.0	*Device Finalization*			
4.1	Mount Device **COMPLETE**	Physically attach all hardware to the device mount.	1. Completed physical device 2. Ability to optimize calibrations. 3. As compact of a device as possible	George Aubrey, Austin Heller, and Lamar Callico
4.2	Solder All Connections **COMPLETE**	Solder all wired connections to create permanent connections and disable tampering.	1. Permanent wire connections 2. No device tampering or malfunction from disconnected wired. 3. Completed wiring of device.	Austin Heller
4.3	Optimization **COMPLETE**	Optimize calibrations, synchronization, and functionality of code until project end of semester.	1. Better motor synchronization 2. Smoother function flow and speed 3. More precise test reproductions	George Aubrey, Austin Heller, and Lamar Callico

Status of Planned Features (WBS):

Lamar Callico

Team member, Austin is tasked with Code Development of the Device responsibility. As you may see above, the code development process is almost completed.. Team member, Austin was able to build a functional integrated linear potentiometer and linear actuator device. Testing with the syringes and water liquid has been made, controlling the speed, duration, position manually through the code. The required work to finish the code development for the device requires the base of the device to be fully constructed because without a stable base for the device it causes errors and lack precision.

Team member, Lamar is tasked with the Graphical User Interface responsibilities. Lamar done the basic coding for the Graphical User Interface (GUI) using an keypad and LCD display. The team had changed the design of the GUI from using an online MATLAB version to onboard user interface limiting the use of different programs. Currently, the present GUI is able to ask for user input and store the value. Problems that are being faced is having the GUI being able to store multiple inputs storing, and being able to transfer the stored values to the motors parameters. To overcome this challenge, research is being done as well as promising develop is being made to accomplish this task.

Team member, George is tasked with the Mounting Hardware Construction responsibility. Working with a Mechanical Engineering peer, George was able to develop each 3D component and the metal base for the device. Each of the components have been printed and the process of the mounting of the device is in process. Challenges faced during the process of developing the base was the length of the motors, and lack of knowledge of the mechanical aspect from the team. The team was able to overcome this by teaming with an peer who specializes in this particular area, lending advice. Additionally due to changes in the platform's design the platform was remade twice.

After the completion of the mounting device and the finishing of the user interface, the team will optimize the device testing all aspects to meet our clients criteria. We intend and are confident that the team will be able to complete the project before UGrads.

Conclusion:

In summary, our project is for the purposes of allowing our client's lab researchers to perform reproducible and reliable results when mixing component medication gels to yield an ideal administrable sample to treat brain aneurysms efficiently. This project has been proposed to this team by our client Dr. Tim Becker of the Bioengineering Lab on campus. This project is a continuation from last year's capstone project who failed to build an acceptable design. Our team intends to improve numerous aspects of the project to make it the ideal system that's easy to use reliable and reproducible use after use. The team has a few modifications and testing left with coding of the device and GUI as well as the mounting the device as a whole, but is still confident that this project will be completed before UGrads.