ExoActuator

Preliminary Proposal

Abdulrahman Alshammari

Alex Frieden

Chancelor Cuddeback

Callum Fisher

Joshua Davidson

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Project Sponsor: Biomechatronics Lab at NAU

Faculty Advisor: Dr. Trevas

Sponsor Mentor: Dr.Lerner

Instructor: Dr. Trevas

DISCLAIMER

TABLE OF CONTENTS

Contents

1 BACKGROUND

1.1 Introduction

Team Exoskeleton was asked to test control modes, and design a motor controller for two types of actuators that may be used to retrofit a lower limb orthotic device, designed by the Biomechatronics lab at NAU. This orthotic device is used to research and/or validate rehabilitation techniques. The new actuators may provide more advanced control modes that could enable researchers to create more effective treatments. The team was asked to demonstrate effective control of a T-Motor AK80, the team was asked to do the same for a T-Motor R80 in addition to creating a motor controller PCB. These new motors offer a high torque to weight ratio and enable programmatic stiffness and damping. The researchers at the Biomechatronics lab plan to incorporate these new features into more advanced control schemes. These control schemes will be used to help persons with motor impairments walk more efficiently, thus enabling them to lead more active lives.

1.2 Project Description

Our team was tasked with the challenge of creating a testing bench to test the robot actuators. In order to test the actuators the team must learn how to communicate with the actuator and its CAN bus protocol. The actuator has an integrated MIT Mini Cheetah controller and the team's goal is to make it move. After that is achieved then the team will make a controller for the mini actuators that the client has in his lab. These mini actuators don’t have controllers built into them so the team will have to code a current controller into them themselves. If the team meets these requirements then additional tasks will be added on as per client requests.

2 REQUIREMENTS

The client wants the team to build a testing bench for his lab that will help him in testing his actuators and motors with ease. The team will have to make the testing bench and make the actuators and motors move with code designed by the team.

2.1 Customer Requirements (CRs)

Required CRs to add to all projects unless given permission by the instructor to omit:

1. Build a test stand for th actuator that will be able to withstand peak operating conditions
2. Provide a method of measuring torque and speed of the motor
3. Make a circuit controller for the mini actuators that don't have circuit controllers built into them
4. Some additional requirements include: programming/validating various control modes, and (if time permits) retrofitting the exoskeleton
5. Within $3,000 Budget

(Requirements may be added over time if tasks are completed to the clients specifications)

2.2 Engineering Requirements (ERs)

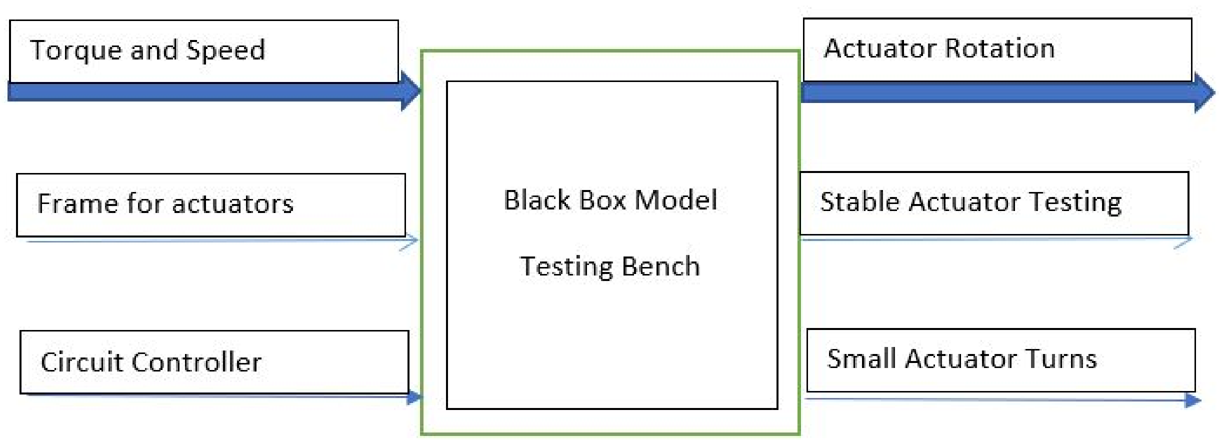
Engineering requirements:

1. Motor requires a maximum of 576 Watts
2. Controller should use CAN to provide current control to the actuator
3. Within $3,000

2.3 Functional Decomposition

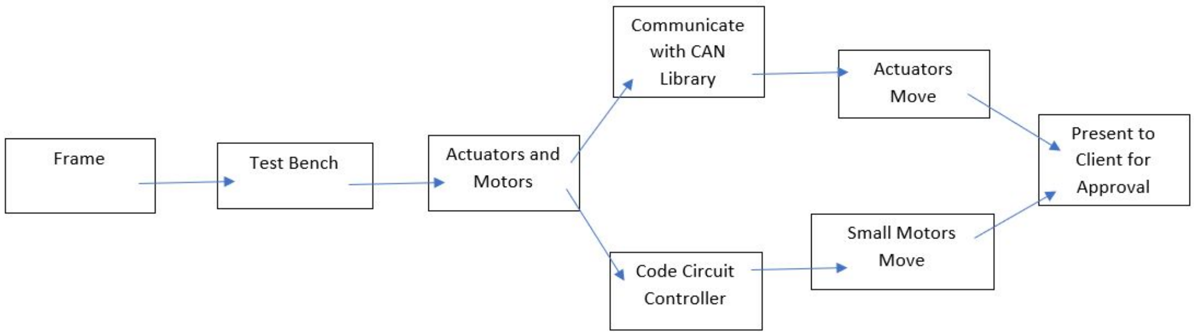
For the team, designing a test bench that will test multiple actuators is the first step, then the team is to make the actuators turn using the built in circuit controller in the motors that the team bought for the project. After those two criteria are done then the team will then move on to coding a circuit controller for the smaller motors that do not have a built in controller for the team to communicate with so the team will have to design their own. Once the team gets the motors moving and the client is happy with the results then the client will add more tasks to the team as time will dictate.

2.3.1 Black Box Model



Our inputs for this project are the following: a circuit controller for the smaller motors, a frame for the actuators to be tested on, and to measure the Torque and Speed of the motors. This will then produce the following outputs: the small actuator motors will move, the testing bench is stable and able to test multiple motors, and the final output will be getting the big motors to move. These inputs and outputs will be accomplished not in the following order but will be accomplished as soon as possible.

2.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis



The functional model shows the steps that the team will take to complete the set standards that the client has set for the project that he is sponsoring. The team will first get the frame, then build the test bench, afterwards the team will work on getting the actuators and small motors to move through either coding a circuit controller or communicating with the built in circuit controller via arduino. After these steps are completed then the team will go to the client and see if these components of the project are satisfactory to the clients criteria and if so then the client will add more tasks for the team.

3 DESIGN SPACE RESEARCH

This section contains the literature review, the tasks assigned to each team member, and concept generation, concept selection.

3.1 Literature Review

Each member of the team was designated a part of the project to study. Due to our project changing a few times over the past few weeks this study process has changed a few times. Also our client wants us to mainly focus more on the motors and actuators and getting them to move. Some members studied the frame and what it would be made of, one member studied sensors such as thermometers so when testing the actuators they don't overheat, another member studied coding to help another member who was learning how to communicate with with built in CAN library in the motors that the team bought, and the final member looked into brakes such as Prony brakes. These topics were found and researched through videos, articles, and online tutorials.

3.1.1 Student 1 (Abdulrahman Alshammari)

The task assigned to me during the project involved designing the components of the testing system for the motor. In order to design these testing components, the major task was to design a thermometer to test the temperature of the motor during its operation. For the purpose of temperature sensing, I have selected a TMP37 sensor. TMP37 is a precession cartridge sensor and it is suitable for temperature measurement of up to 125 C very accurately. The other choices of sensor that I had include DHT11, LM35, BMP150. The TMP37 is selected for its low cost, high precession, good support with arduino and good sensitivity after comparing all other choices. The temperature sensor will be attached to the body of the motor during testing and temperature values will be taken during the motor operation under various loading conditions. an interrupt based arduino code is prepared for the temperature to take measurements after precise intervals. The main heating of the motor occurs when the brakes are applied to the motor or when it is attached to a high load on the dynamometer. Hence the sensor is critical to take measurements under these conditions to accurately check and not the motor operation.

3.1.2 Student 2 (Alex Frieden)

The topic I chose was to research specifically what the frame of the test stand could be made out of. I first looked at prebuilt motor testers used in industrial applications. These devices were not exactly what this project asked for so I shifted to looking at materials to use. I looked into using MDF pressed wood boards. This material would have worked but would not have been easy to work with. The final selection to build the frame out of is 80/20 aluminum extrusion. This material has many advantages over MDF, including being more rigid, easier to connect pieces together, and more modular, with many different connectors readily available.

3.1.3 Student 3 (Joshua Davidson)

For this project I studied brakes and dynamometers. The purpose of this was to be able to create loads to test the motor, as well as validate the torque measurements. For this project, a prony brake seemed to be the most reasonable selection, as it is mechanically quite simple, and can double as a dynamometer. A disk brake was also an option, but it would be more difficult to measure the torque. The only other realistic choice was an ac motor running opposite to the motor being tested, but this would be more expensive, and not necessary for the level of testing that needed to be done. The prony brake functions by using a strap around a flywheel, which is attached to the motor. The strap is attached to two spring force gauges, which can be used in combination with rpm and friction measurements to calculate the torque. The gauges can also be tightened to increase the resistance, functioning as a brake.

3.1.4 Student 4 (Callum Fisher)

For this project I read up on how to program in arduino and C language. This was done so the team can get the laptop to communicate with the arduino and get the arduino to communicate with the actuators circuit controller so the team can get them to move. This will also be needed to help with the programming of a circuit controller for the other motors that the client wants the team to work with as well. Learning about function commands like (int), (float), and (return) will be useful in inputting the commands into the arduino so when the team finds a way to communicate with the Teensy CAN library and the actuators. Movement will then be achieved through those inputs. Now just to be clear I studied the normal C programming language and not C++ language.

3.1.5 Student 4 (Chancelor Cuddeback)

Chancelor Cuddeback researched the CAN protocol [1], and the motor controller that is embedded in the Ak-80 actuator [2]. The CAN protocol uses a sequence of bytes to determine the identity of the sender and receiver, the payload, and parity of the message. The CAN bus that is used to transmit the protocol, uses two lines, a CAN high and CAN low, with each end terminated with a 120 ohm resistor in a twisted pair. The actuator is based on the open source MIT Mini Cheetah Controller made by Ben Katz for his masters thesis. Ben Katz's thesis may be referenced for more information on the controller [2].

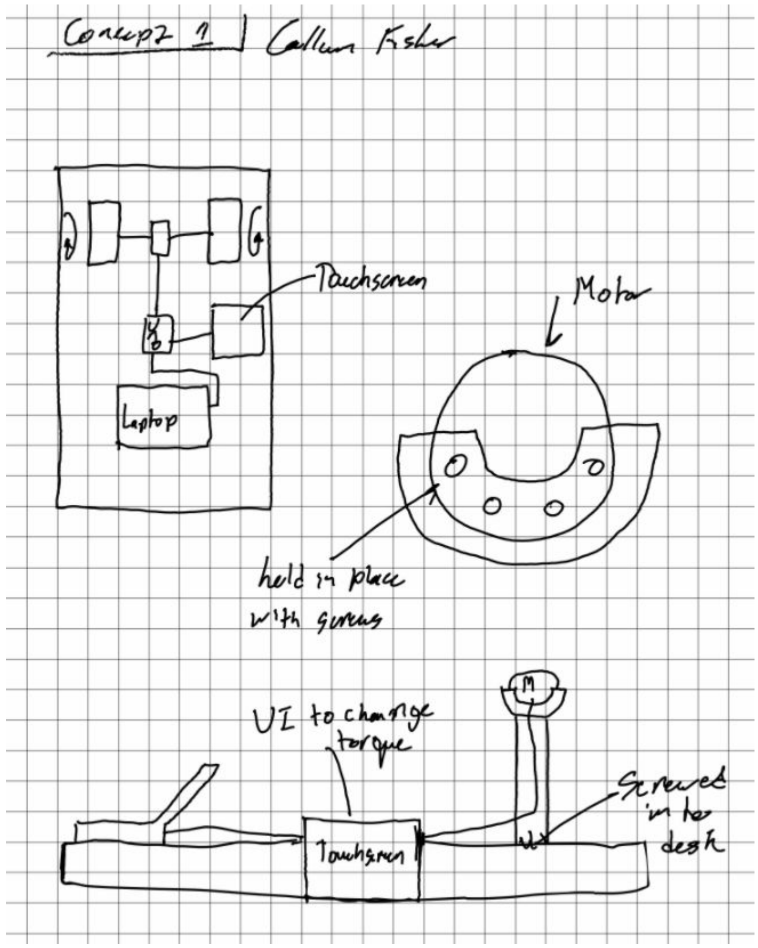
3.2 CONCEPT GENERATION

This section discusses the concepts that the team came up with so the team can get an idea for the final product that the team will bring to the client.

3.3 Full System Concepts

Each member of the group designed a full system concept of how the device might be designed or function. Out of those five concepts, the team narrowed it down to a list of three. Though each concept used similar materials in the concepts, the way each team member thought about the task was different.

3.3.1 Full System Design #1: Callum Fisher's Design Concept



The actuators are held in place by 3D designed holds that will hold the actuators with screws of the motors themselves. These molds will be placed on top of 8020.net 20-4040 aluminum extrusions that are bolted to the table.

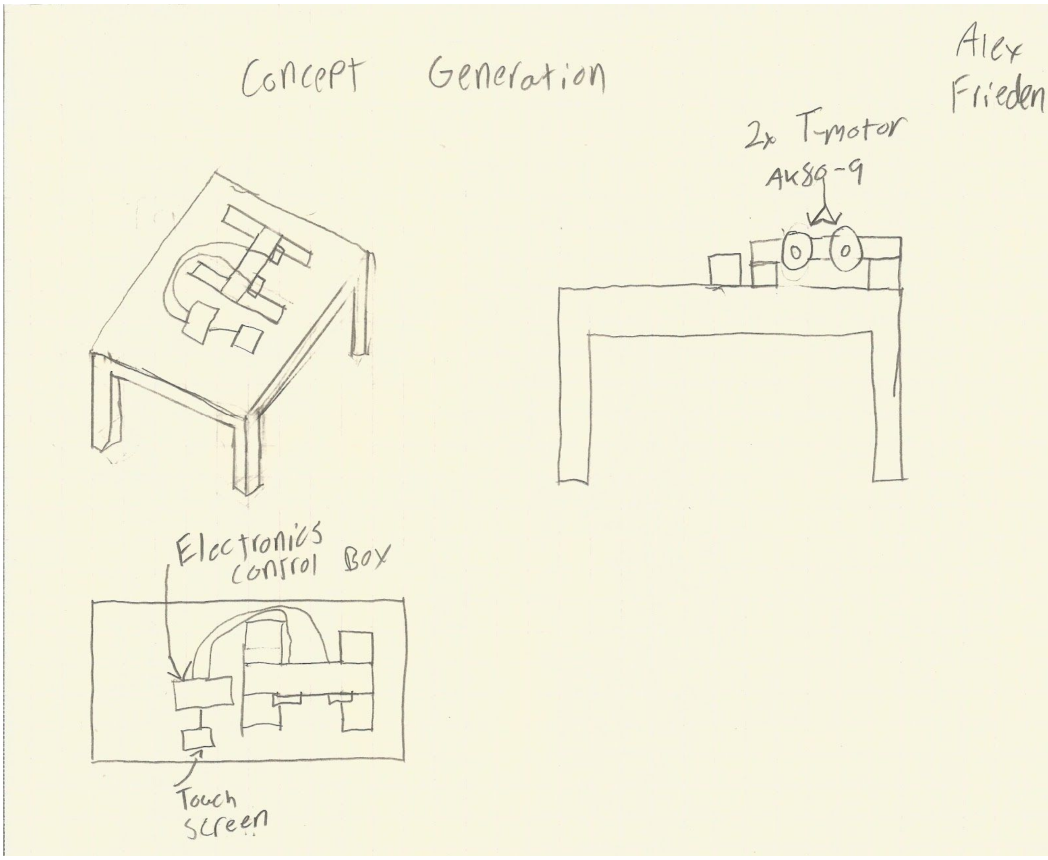
Pros:

- Plenty of space for electronics and sensors
- stable motor testing
- Less extrusions needed to be bought

Cons:

- Multiple molds needed for other motors
- Not much flexibility for future sensor placement

3.3.2 Full System Design #2: Alex Frieden's Design Concept



The frame is made using 80/20 aluminum extrusions bolted directly to the table to provide support. This design utilizes the built in T slots on the extrusions to connect the individual pieces to each other and to the table. The motors are attached with 3d printed brackets directly to the table. All electronics used to control the motors will be in a 3d printed control box.

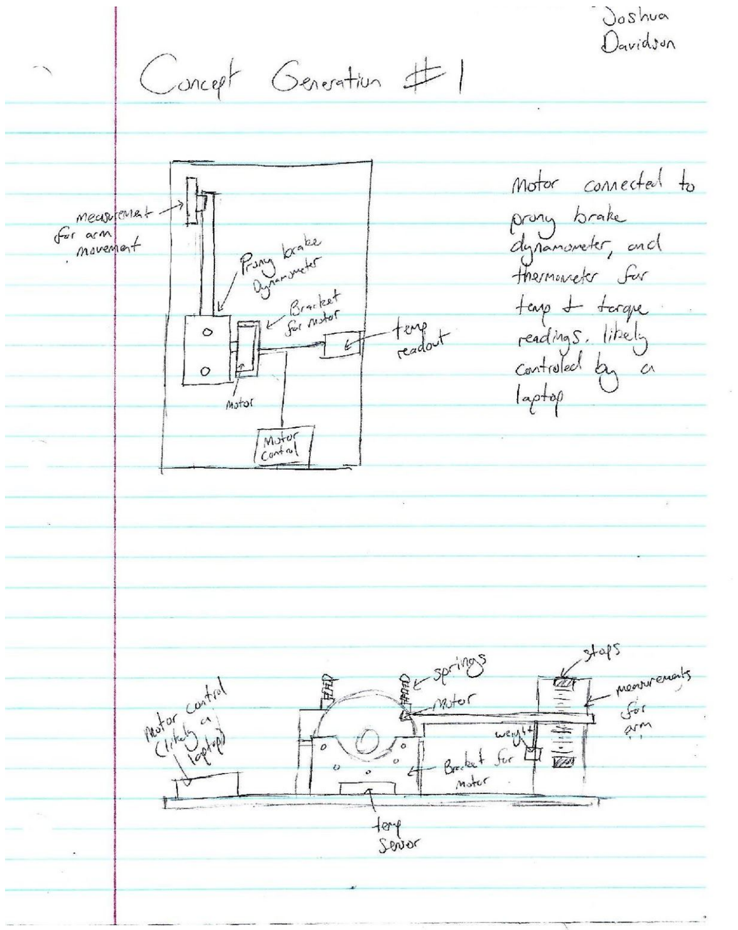
Pros:

- Plenty of space leftover on table to be use for workspace
- Ridgid construction being bolted to the table

Cons:

- Extrusions and hardware will need to be purchased
- Table to be used can be expensive

3.3.3 Full System Design #3: Joshua Davidson



This concept uses a prony brake dynamometer to take measurements of the motor's torque. The concept also has sensors for the temperature and motor speed.

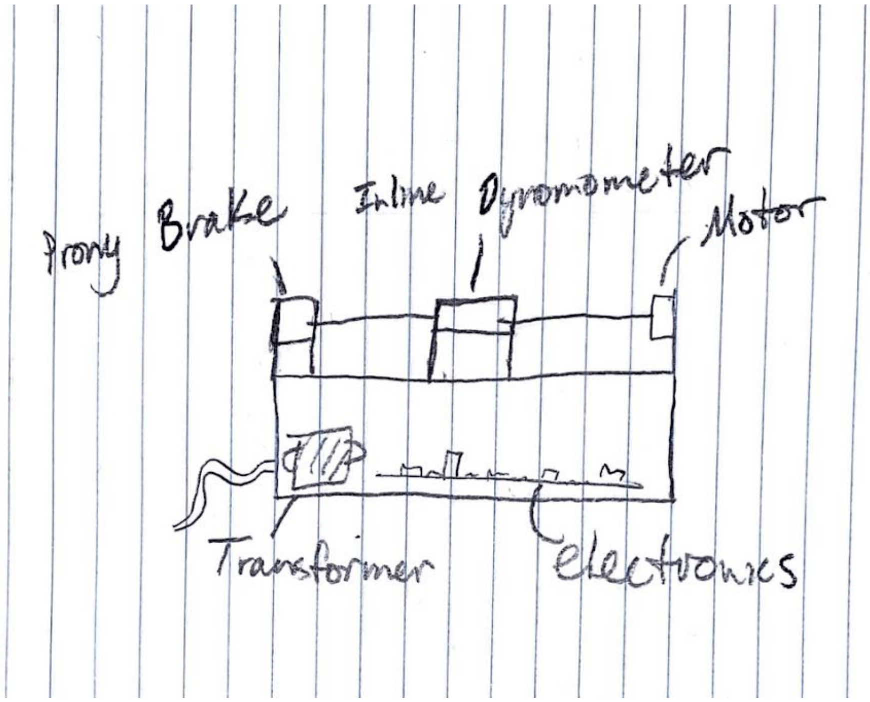
Pros:

- Several different sensors are being used to measure different aspects of the motors.
- Brake for safety

Cons:

- Complicated to assemble
- Not quite what the client requested

3.3.4 Full System Design #4: Chancelor Cuddeback



This concept uses an inline dynamometer, a prony brake, a simple motor mount, and houses the electronics beneath the motor-shaft assembly.

Pros:

- Electronics are nicely placed
- Inline dynamometer and redundant prony brake

Cons:

- Redundant torque measurements are expensive
- Motor may be mounted too high to work on easily
- Assembly may be too arduous

3.4 DESIGNS SELECTED – First Semester

Alex's design was chosen because of the simple design and the minimalist approach to the testing bench. The design gives plenty of space for the team to work on the electrical components and the actuators and motors while testing them at the same time. A 3D model of the design can be found in the Appendix A.

3.5 Technical Selection Criteria

Each person's concepts were evaluated on several different criteria including things like the safety and the cost of the device. Each criteria was then compared to a datum, which in our case was a bar drilled into the table.

Criteria\Concept	Chance	Callum	Josh	Alex
Safety	1	1	1	1
Cost	0	0	0	0
Min Deflection	S	0	1	1
Ease of Assembly	0	0	0	0
Sum of 1	1	1	2	2
Sum of 0	2	3	2	2
Sum of S	1	0	0	0
Note: The datum is a bar drilled into a table.				

3.6 Rationale for Design Selection

The reason the design was chosen was because of the simple design and the fact that it seems easier to add more features to this design than the other designs. The client just wants us to test the motors and the actuators on the testing bench. Adding brakes and sensors aren't the priority at the moment so the team chose this design due to it just focusing on testing the motors with the ability of upgrades down the line.

REFERENCES

[1] S. Corrigan, Texas Instruments, rep., May 2016.

[2] B. G. Katz, “Low cost, high performance actuators for dynamic robots,” thesis, Massachusetts Institute of Technology, 2016.

4 APPENDICES

4.1 Appendix A: 3D model of Design