Robotic Arm

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Design Requirements

Customer Requirements

- Customer Requirement 1 (CR1): **Comfortable** for users to wear
  - The device will be worn by people and should be comfortable for the user to wear.
- Customer Requirement 2 (CR2): **Ability to Sit in Chairs**
  - Since the device would be worn in a day-to-day life capacity, it will need to be able to sit in chairs.
- Customer Requirement 3 (CR3): **Low Profile**
  - The device needs to be low profile for minimal obstruction for public use
- Customer Requirement 4 (CR4): **Accessibility** of the Design
  - The device should be able to be 3D printed so that it can be put on OpenExo.
- Customer Requirement 5 (CR5): **Durability**
  - The device should be able to be used repeatedly without mechanical fail as well as not be able to be easily damaged in what would be everyday life

Engineering Requirements

- Engineering Requirement 1 (ER1): **3 Degrees of freedom**
  - The device needs 3 degrees of freedom to be able to assist the arm of the user
- Engineering Requirement 2 (ER2): **Weight of Arm**
  - The arm before attached to the apparatus that the user will wear should be under 2 kg.
- Engineering Requirement 3 (ER3): **Speed of Arm**
  - The motors of the arm should be able to reach a minimum of 10 rpm.
- Engineering Requirement 4 (ER4): **Battery Life**
  - Through more research and deliberation, the battery is the biggest limitation of the device, so a goal of 30 minutes the desired time.
- Engineering Requirement 5 (ER5): **Manufacturing Cost**
  - The cost of material and manufacturing should be less than $2000 to keep the device affordable.

QFD

		Degrees of Freedom					
		Manufacturing Cost	neg				
		Speed of Arm		neg			
		Battery Life	neg	neg	pos		
		Weight	neg	pos	pos	pos	
			Engineering Requirements				
Relative Weight (%)	Customer Weights	Customer Requirments	Degrees of Freedom	Manufacturing Cost	Speed	Battery Life	Weight
11	4	Comfortable	3	1	3	3	9
22	5	Ability to Sit in a Chair	9	1	1	1	1
10	2	Accessibility	3	9	3	3	3
5	3	Durabiltiy	1	1	1	1	9
22	3	Low-Profile	3	3	3	9	9
Technical Requirement Units			N/A	$	rpm	Minutes	kg
Technical Requirement Targets			3	<2000	>10	>30	<2

Positive	pos
Negative	neg

Strong	9
Moderate	3
Weak	1

Top Level Testing Summary

Experiment/Test	Relevant DRs	Testing Equipment Needed	Other Requirements
Endurance Test	ER4-Battery Life	Device, Timer, A User, Camera, Battery	Battery is fully charged
Range Test	ER1-Degrees of Freedom	Device Camera A User	N/A
Weight Test	ER2-Weight of Arm	Scale Camera Device	The device will be disassembled so that the arm is being weighed by itself
Comfortability Test	CR1-Comfortability CR3-Low Profile ER2- Weight of Arm	Device Multiple Users Camera	N/A
Chair Test	CR1- Comfortability CR2-Ability to Sit CR3-Low Profile	Multiple Chairs Device Multiple Users Camera	N/A
Sensor Test	ER1-Degrees of Freedom	Device Camera Computer	Ability to read sensors
Speed Test	ER3- Speed of Arm	Device Camera User Timer	Average time it takes to lift an arm.
Bump Test	CR5-Durability CR3-Low Profile	Device Camera	N/A

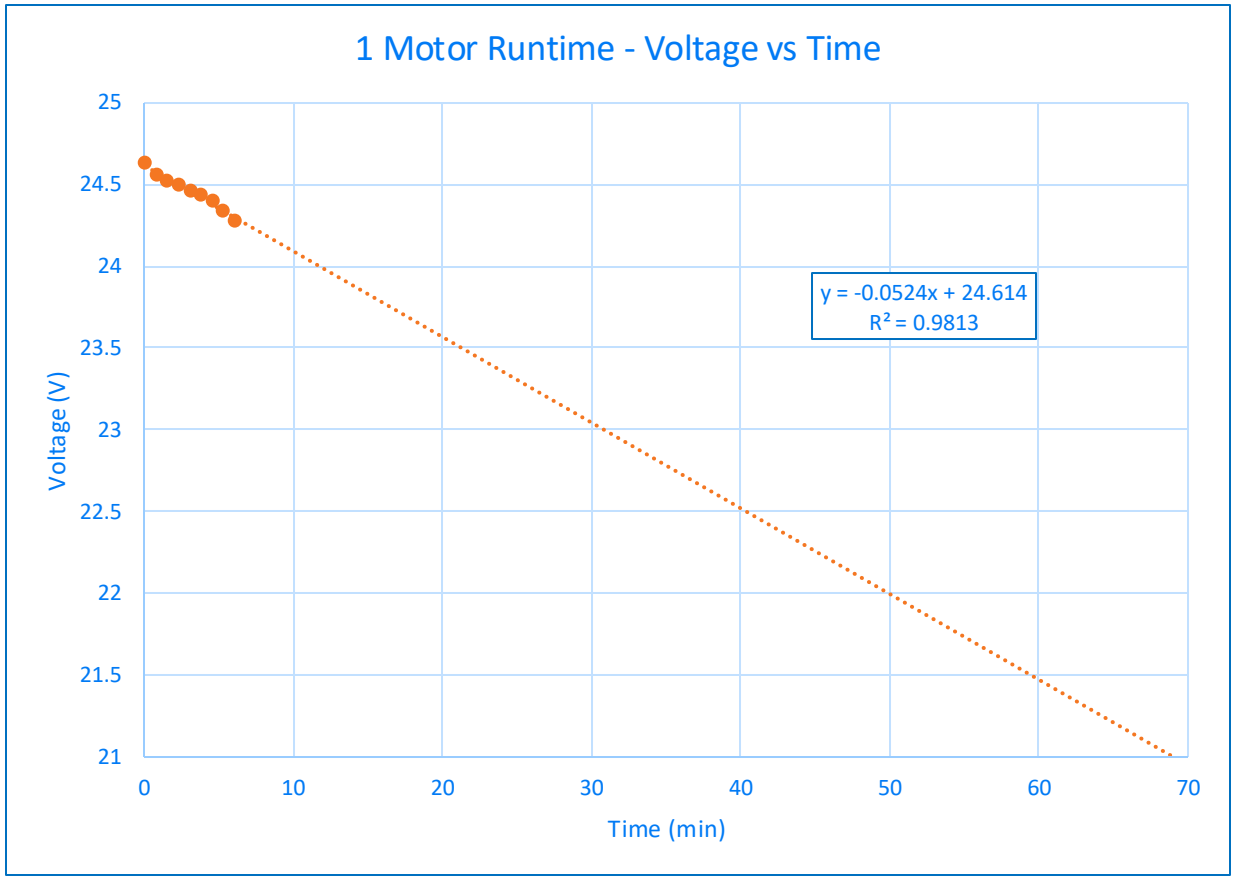
Endurance Test Plan

Summary: The test will answer the question of how long the battery will last in the device. The design requirement that this will be testing is ER4, which is battery life. The variable that will be tested is the battery itself to see how long it will last while powering one motor. The battery will consistently be at full charge to see how long a full battery can last in the device.

Procedure

1. Make sure Battery is fully charged
2. Have correct command on the motors so that it is constantly spinning at a safe speed.
3. Connect all components to the board to control the start time of the test.
4. Have motor run a total of 6 minutes recording data after 45 second intervals for a total of 9 data points
5. Using the data a projection was found through extrapolation to see how long it would take to reach lowest voltage.

Endurance Test Result



This graph is a projection of the battery life if only one motor was spinning. The minimum y value is 21 V and correlates to the minimum Voltage per Cell for the 6 cell battery.

1 motor = 68 minutes of runtime
2 motors = 34 minutes of runtime

Range Test Summary

Summary: The test will answer the question of how many degrees of freedom the device has. This will be testing ER1, the degrees of freedom, so that the entire range of motion desired for the device has been reached. There is not much equipment needed, so it will just be the device itself and a user to wear it and test it. The isolated variable would be the device itself as no changes would be made while the user tests it.

Procedures:

1. Have the user put on device and be fully strapped in.
2. Make sure the device is not turned on as electrical components are not being tested.
3. Have the user move arm to make sure the device can follow it to make sure the degrees of freedom are reached.

Range Test Results

Results:

The result is that all 3 degrees of freedom were reached with 2 being active degrees and 1 being a passive degree of freedom

Weight Test Summary

Summary: The test will answer the question of how heavy the device is. The design requirement that this will be testing is ER2, which is weight of arm. The variable that will be tested is the arm part of the device to see how heavy the arm is as that will be the biggest weight on the user. The arm will be separated from the rig that is worn by the user to get true weight of the arm.

Procedures:

1. Have the arm separated from the wearable rig.
2. Lay device on scale to record weight or hung from it to record weight

Weight Test Results

Results:
The results that was expected was to be under 2 kg. This was a critical design requirement as the device will be used by stroke survivors, so the device cannot be heavy to impede in their rehabilitation. This was achieved with the result of the arm weight being 1.3 kg

Comfortability Test Summary

Summary: The test will answer the question of whether the entire design is comfortable to wear. The design requirements that this will be testing are CR1, comfortability, CR3, low profile, and ER2, weight of the arm. The variable that will be tested is the device itself to see if a user would be comfortable wearing it. The device will not be changed through testing with different users.

Procedures:

1. Have users put the device on.
2. Have user give feedback on how they feel in device
3. Repeat with multiple different users.

Results: The consistent feedback about the device was that ut was comfortable to wear and go through range of motion from several people including our client, Dr Lerner

Chair test Summary

Summary: The test will answer the question of whether the user can sit in chairs while wearing the device. The design requirements that this will be testing are CR1, comfortability, CR2, ability to sit, and CR3, low profile. The variable that will be tested is the full device to meet the client's demand of ability to sit in chairs. The device will not be changed while different chairs are tested.

Procedures:

1.Have the user put device on

2.Have user sit in chair

3.Have user give feedback on if they are comfortable

4.Repeat with several types of chairs

Chair Test Results

Results: The results that we received was that it can sit in chairs but was unable to be comfortable in tight chairs with arms. This might vary from user to user, but we will be testing with one user. The device can be adjusted to the location of the arm that can decide how well they can sit in several types of chairs.

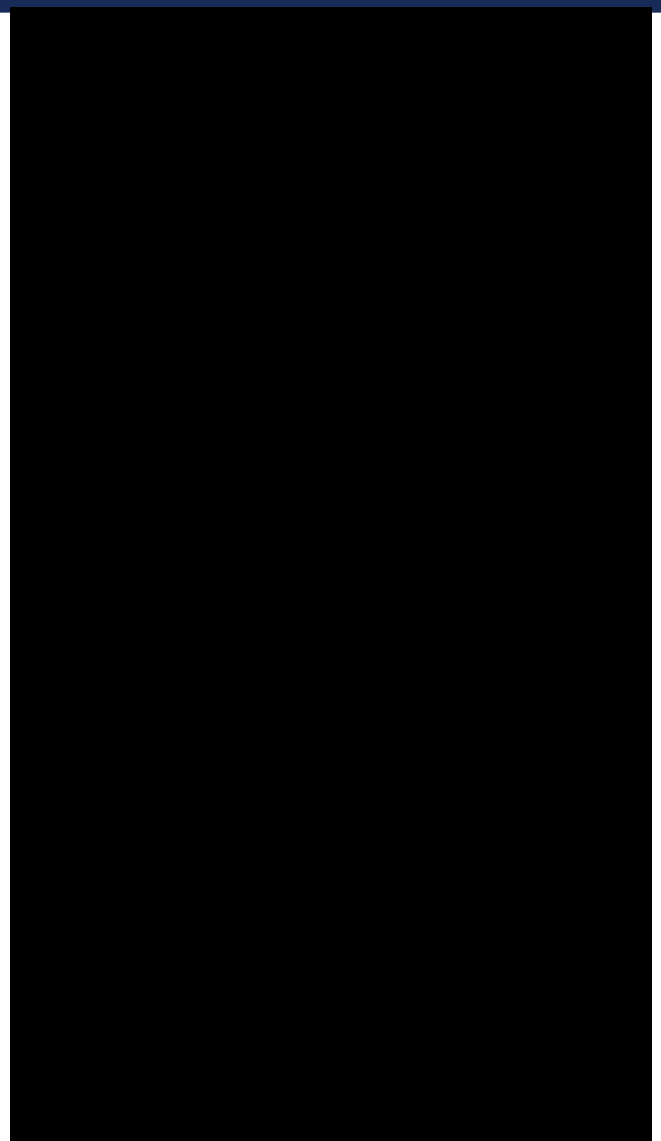
Sensor Test Summary

Summary: The test will test if the sensors can be read. The design requirement that this will be testing is ER1, the degrees of freedom. All things will be kept the same it is just a verification of the ability to read sensors.

Procedures:

1. Have all software uploaded to the board
2. Connect all components to the board
3. Have software running to be able see results
4. Add force to FSR to see if it can read.

Sensor Test Results



Results:

- The sensors read user input
- The sensors are able to detect force input through layers of foam padding
- In future work, the sensors will be implemented into the end effector and communicate with the motors for smooth operation

Speed Test Summary

Summary: The test will answer the question is the speed of the arm. The design requirement that this will be testing is ER3, which is the speed of the arm. The variable that will be tested is the motor to see if it is fast enough to raise the user's arm. The battery will consistently be at full charge to see how fast a motor is receiving full power. The variables that will need to be calculate is the speed using the time it took and the distance of the final

Procedures:

1.Make sure Battery is fully charged

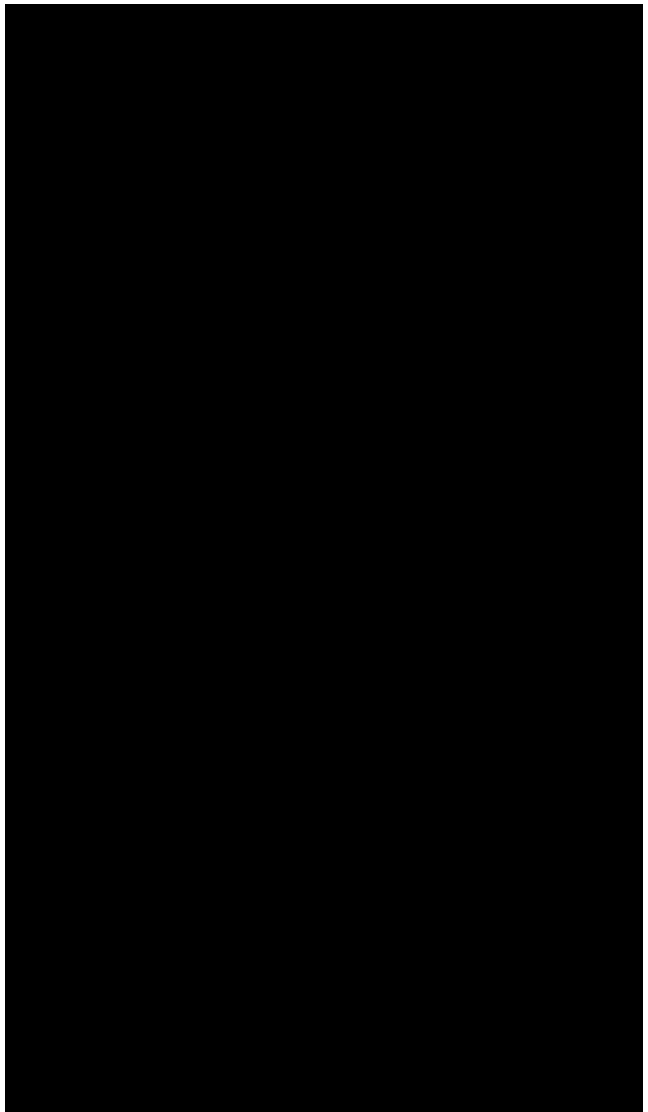
2.Have user put on device

3.Connect all components to the board to control the start time of the test.

4.Start timer to see how long it takes to lift their arm.

5.Repeat to be able to calculate the speed.

Speed Test Results



Results: The average time that it took 1.006 seconds. Moving 90 degrees results in 0.2485 rev/s which is 14.91 RPM. This is also at a low torque output as rated speed is 40 RPM with higher torque output

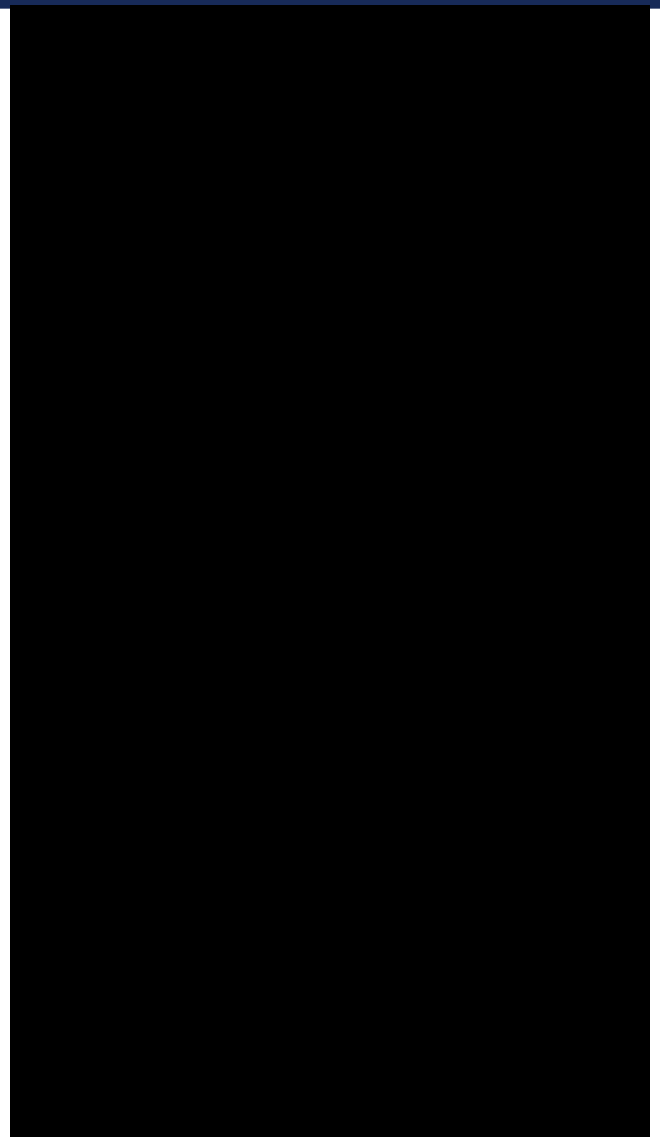
Bump Test Summary

Summary: The test will answer the question of how strong the device is. The design requirements that this will be testing are CR5, which is durability, and CR3, which is low profile. The variable that will be tested is the arm itself on the full device. The arm will be consistently on the same side as well as the being strapped to the user the entire time.

Procedures:

1. Have the user put the full device on.
2. Have user bump into tables, walls, and other objects to mimic real life possibility of running into things
3. Observe if there are any cracks or defects from the test
4. Run motors to see if those were affected at all

Bump Test Results



Results:

- The device is not affected by bumping into walls
- The device does not break upon impact
- The device is low profile to where the users arm would impact an object before the motors or more sensitive components

Specification Sheet

Customer Requirement	CR Met?	Client Acceptable?
CR1-Comforbility	✓	✓
CR2- Ability to sit in chairs	✓* Tight armchairs should be avoided	✓
CR3-Low profile	✓	✓
CR4-Accessibility of Design	✓	✓
CR5- Durability	✓	✓

Specification Sheet

Engineering Requirement	Target	Tolerance	Measured/ Calculated Value	ER Met?	Client Acceptable?
ER1-Degrees of Freedom	3	±0	3	✓	✓
ER2-Weight of Arm	<2 kg	+ 0.25 kg	1.3 kg	✓	✓
ER3-Speed of Arm	≥10 RPM	- 2 RPM	14.91 RPM	✓	✓
ER4-Battery Life	30 min	± 5 min	34 minutes	✓	✓
ER5-Manufacturing Cost	<$2000	+ $250	$1038.34	✓	✓

Thank you
And
Any Questions?

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