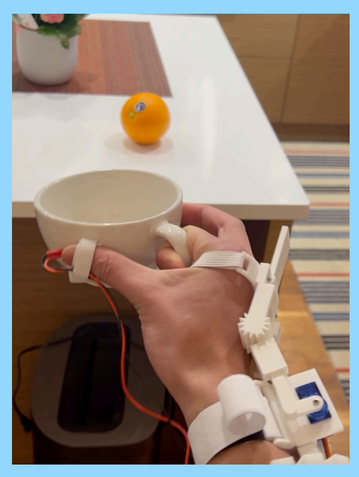
Inspiration

Since I was a young boy, I've noticed that I have shaky hands. As I grew older and my boxes of Legos turned into boxes of hex nuts and wires, I often found it difficult to align screwdrivers to their respective screws while doing precision work. Consequently, in the summer of 2022, I decided to self-diagnose myself on Google to see why my hands trembled and how to suppress it, only to be met with expensive technology and medicine far out of my budget. This led me to think of the millions living in developing countries, who are affected by debilitating hand tremors and have no access to technology to help them live their day in stability. And thus, the idea for the ExoTremor was born.



(Above) The ExoTremor allows movement disorder patients to pick up a cup of water without spilling everywhere.

Purpose

- Movement disorders like essential tremors and Parkinson's disease are found around the world, predominantly characterized by their debilitating tremoring of the fingers, hands, and arms.
- What aggravates this problem is that current assistive devices on the current market are either unaffordable due to prices ranging into the hundreds and thousands or limited in their adaptability to different physical circumstances.
- Hence, the purpose of this invention, the "ExoTremor", is to minimize the cost of production to increase accessibility to this assistive device for people around the world, while maximizing its functionality.
- Costing less than $50 to produce, the ExoTremor detects when the user is holding an item such as a toothbrush or a cup of water, and locks wrist-movement.

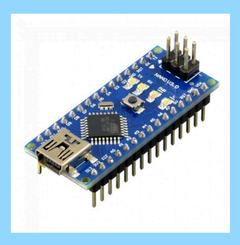
Materials

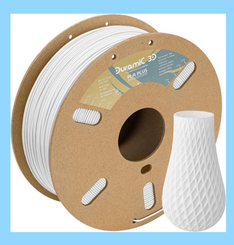
Materials:

- PLA Plastic (both hard and flexible versions) -> $3.25
- SG90 servo motors -> $5.56
- M3, M4 hex nuts and bolts -> $2.80
- Super glue -> $0.50
- Velcro -> $2.57
- Copper wires, solder, and heat shrink -> $2.00
- Arduino Nano -> $11.33
- RP-C flexible thin film pressure sensor -> $6.37
- 8mm x 2mm cylindrical magnet -> $2.16
- 9V Battery -> $ 1.54

Respective costs:

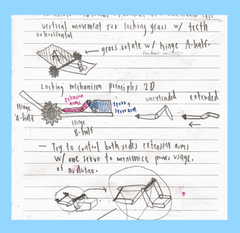
Total = $38.08



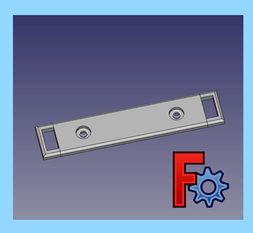


Construction

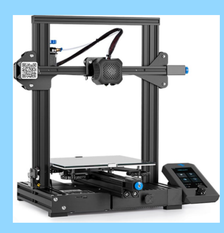
- Throughout the research phase of this project, I read and highlighted key details in existing scientific papers on movement disorders such as essential tremors and Parkinson's Disease.
- I emailed professionals in the industry (biomedical engineers at nearby hospitals and universities), and was able to gain insight on not only the technical elements of creating an exoskeleton like the biomechanics of tremors, but also what the current market lacks: a low-cost solution.
- Each of the 47 parts that make up the ExoTremor were first sketched on paper before being recreated digitally on CAD software, and finally printed via a 3D printer using plastic filament.



Sketches on paper



3D CAD design software



3D printer

Functionality

- The ExoTremor is meant to suppress hand tremors by locking two degrees of freedom of the wrist: flexion-extension (up-down) and supination-pronation (rotational).
- **Hinge Lock (HL)**: Locks the up-down movement of the wrist. Since the wrist behaves in a similar way as a hinge of a door, the pin controlled by the servo and the gear is able to lock the wrist "hinge" at specific angles, thus preventing the hand from trembling up and down while holding an object such as a spoon.
- **Rotation Lock (RL)**: Locks the rotational movement of the wrist. Rotating the wrist will also move the magnet belt that go around the middle of the forearm. When a user holds a cup of water, the mechanical electromagnet is activated, magnetically attracting to the magnet belt and locking the latter's movement.
- Both locking mechanisms are activated by a **pressure sensor** that the user wears on their thumb, to sense when they are holding an object.

User holds an object. Object triggers pressure sensor on the thumb. → Hinge Lock and Rotation Lock are activated. Two degrees of the wrist are consequently stabilized. → User can now hold the object in a much more stable position.

Acknowledgement

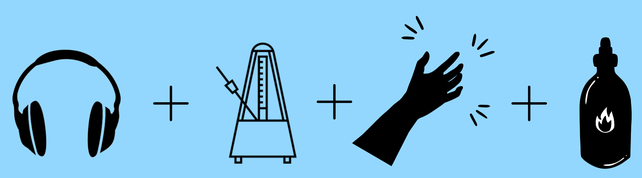
This project wouldn't have been possible without the support of Muhan Sun, my childhood friend based in Germany. His indispensable support in the coding aspect of this project proved to be much needed, helping the code of the Gyroscope Diagnostic tool to come to life and enabling me to effectively prove that the ExoTremor is effective. Other people I'd like to show my appreciation for include Mr. Owen Geigner from the Pacific Parkinson's Research Centre, for his answers to some of my questions regarding the biomechanics of hand tremors in the Research phase of the ExoTremor, and variables to consider while experimenting.

Pacific Parkinson's
RESEARCH INSTITUTE

Experimental Design

Phase 1
Isolated Flexion-Extension Test

1. Simulate 5Hz (300 bpm) **flexion-extension tremors** with headphones and metronome. Tremor hand accordingly.
2. Fix the forearm with the ExoTremor to a flat surface to isolate wrist tremors. This minimizes ulterior variables such as the forearm shaking that will skew wave form and amplitude results.
3. Record tremor wave form and amplitude using the **Gyroscope Diagnostic Tool** while holding onto one of three objects (pen, light hot sauce bottle, medium-sized jar). ExoTremor is not activated. Allow 15 seconds of tremor time.
4. Repeat above step 1-3 with ExoTremor activated.



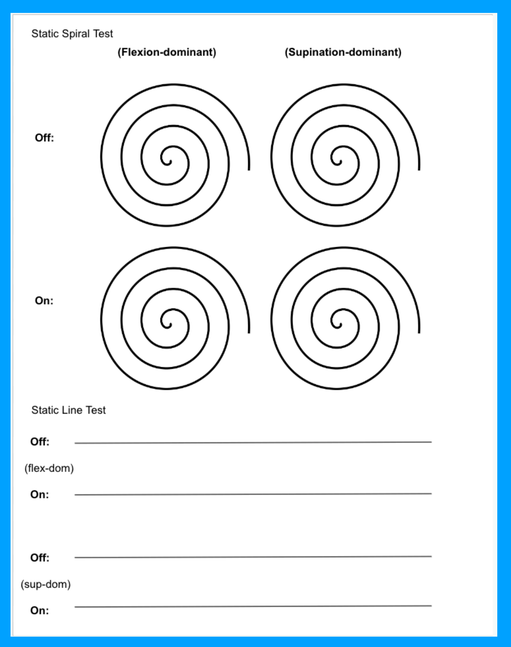
The Gyroscope Diagnostic Tool is capable of converting physical motion into graphical waveforms.

Phase 2
Isolated Supination-Pronation Test

Same as Phase 1, but simulate wrist **supination-pronation tremors** instead.

Phase 3
Hand-Writing Tremor Test

1. Use a ballpoint pen and complete the **Hand-Writing Tremor Test** as shown below with three different frequencies (4Hz, 6Hz, 8Hz):
2. Trace the spiral to the best of one's ability without activation of the ExoTremor. Repeat this step with the ExoTremor activated.
3. Trace the lines labeled "off" to the best of one's ability without activation of the ExoTremor. Repeat this step with the ExoTremor activated.



Results

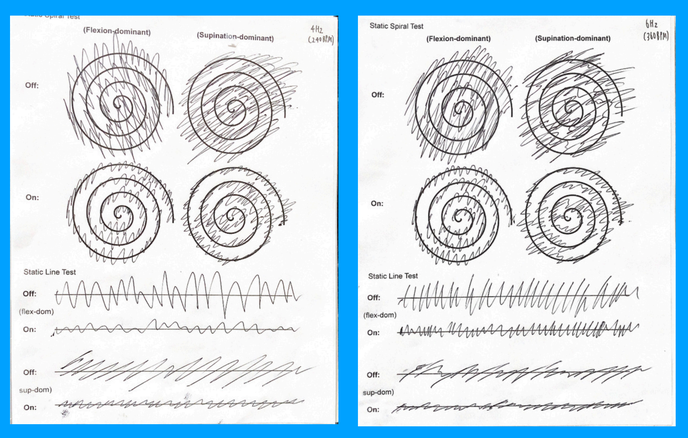
Flex-Ext	Pen	Sauce bottle	Medium Jar
Off-Amplitude	55.23	56.67	51.71
On-Amplitude	14.78	16.18	10.73
% Suppression	73.24	71.45	79.25

Definitions: "Off-Amplitude" is the amplitude of the tremoring when the ExoTremor is not in "locked" status. "On-Amplitude" is the amplitude of the tremoring when the ExoTremor is in "locked" status. % Suppression is the % change.

The **Isolated Flexion-Extension Test** resulted in consistent findings. With an average % suppression of approximately 74.6%, the amplitude of wrist tremors is significantly reduced. The "typical" wave form collected from the various repeated tests conducted also showcases a noticeable decrease in amplitude, signifying successful suppression.

Sup-Pro	Pen	Sauce bottle	Medium Jar
Off-Amplitude	62.50	42.51	35.23
On-Amplitude	19.32	25.42	16.01
% Suppression	69.09	40.20	54.56

The **Isolated Supination-Pronation Test** resulted in mixed findings. Due to the difficulty in simulating supination-pronation wrist tremors at heavier objects (sauce bottle, medium jar) effectively, the off-amplitudes exist on a wider range than that of the flexion-extension test. Due to both noticeable flaws in the design of the ExoTremor and the inability to simulate accurately, a reliable conclusion cannot be formed. However, from the wave form, it can be extrapolated that a noticeable level of suppression does exist. To what extent is debatable.



(Above) Typical examples of hand-writing tremor tests conducted. Notice the difference between the tests conducted with and without the ExoTremor activated.

Through careful visual analysis of the multiple **Hand-Writing Tremor Tests** conducted, it can be concluded that the ExoTremor does suppress an enough range of hand tremors movement so that writing is cleaner. The wavy lines on both the spirals and horizontal lines showcase evidently smaller amplitudes, hence being neater. However, as the Hz increases from 6Hz to 8Hz, the level of suppression appears to decrease, with a less noticeable difference distinguishing "on" and "off" spirals and lines.

Discussion And Future

From the design of the ExoTremor to the experimental data collected, one conclusion stands: the ExoTremor successfully suppresses hand tremors. The waveforms and numeric values of amplitudes generally confirm that tremors are suppressed to a significant degree, with the majority amplitudes being suppressed by more than 50%. Considering that most daily activities that involve hands are either solely flexion-extension, supination-pronation, or both, the ExoTremor meets the requirements for being able to help patients with debilitating wrist tremors. In the future, the following design changes will be made: (1) improve electromagnet design; (2) improve ergonomics of the entire exoskeleton; (3) include phalanges and MCP joint support.