

# Design and Fabrication of an Adaptive Feeding Aid Device to Assist Individuals with Disabilities

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**Annotation:** This project focuses on the development of an Adaptive Feeding Aid Device aimed at assisting individuals with neuromotor disorders in performing daily feeding tasks independently. These disorders often lead to tremors and reduced motor control, making self-feeding difficult. The device was built using an Arduino microcontroller, servo motors, and motion sensors to detect tremors and stabilize the spoon during use.

Practical testing and a user evaluation survey involving Biomedical Engineering students were conducted to assess usability, comfort, and effectiveness. The results showed that while the device meets its core objectives, limitations remain in motor responsiveness, device weight, and signal processing accuracy.

Future improvements will include upgrading to lighter hardware, implementing advanced filtering algorithms, enhancing real-time performance, and conducting clinical validation. This project highlights the potential of combining embedded systems with biomedical design to create affordable and accessible assistive technologies that improve daily life for individuals with motor impairments.

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## 1.1 Introduction

Motor functions in the human body are controlled by the neuromuscular system, which consists of muscles and nerves. In particular, neurodegenerative diseases cause loss of motor function

through the deterioration of the structure and therefore function of neurons. In this case, reflexively tremor movements occur in the body [[1]. Some diseases that cause tremor formation; Parkinson's disease (PD), dystonia and cerebellar ataxia, multiple sclerosis, stroke, traumatic brain injury and amyotrophic lateral sclerosis (ALS) or Lou Gehrig's disease [2]. According to a report of the World Health Organization, more than 10 million people in the world go to medical experts with tremor complaints [3].

Tremors are generally classified into two main categories based on the time of occurrence: resting tremors and action tremors. Resting tremor, which typically manifests when the affected body part is not engaged in any voluntary movement, is most commonly observed in individuals diagnosed with Parkinson's disease. This form of tremor is attributed to a reduction in dopamine production within brain regions involved in motor regulation, particularly the basal ganglia. It predominantly affects the hands and legs and typically occurs at a frequency ranging from 3 to 6 Hz. In contrast, action tremors, which emerge during voluntary muscle activity, are frequently associated with Essential Tremor (ET). This condition often involves the hands, head, and voice, and occurs at a higher frequency, generally between 5 and 12 Hz. Essential Tremor can significantly impair the performance of routine daily tasks such as eating, writing, drinking, and maintaining personal hygiene. Its etiology may include cerebrovascular incidents, traumatic brain injuries, adverse effects of certain medications, neurodegenerative disorders, cerebellar dysfunction, and hepatic or thyroid insufficiencies. It is important to note that physiological tremors in healthy individuals occur at a frequency of approximately 8 to 12 Hz and are characterized by very low amplitude, making them largely imperceptible and non-disruptive to daily function. Considering the functional limitations imposed by low-frequency resting tremors—particularly in neurodegenerative conditions—there is growing interest in developing supportive technologies aimed at mitigating their impact on fine motor activities. [4]

The use of drugs and surgical methods is common in the treatment of tremor. However, drug treatment may cause different side effects such as blurred vision, confusion, fatigue and muscle paralysis in some patients. Patients who do not respond to pharmacological treatment undergo surgical procedures such as deep brain stimulation, magnetic resonance guided focused ultrasound thalamotomy or gamma knife radiosurgery. However, it is available in individuals who both respond poorly to medication and for whom surgery is not possible. There is a need for equipment that facilitates the daily routines of individuals who cannot be treated.[5], [6]

The focus of the project is on action tremors that occur in the upper extremities during voluntary movement. These tremors negatively affect the patient's activities of daily routine, and patients have difficulty in eating, drinking, writing, holding glasses and keys. It is extremely important, especially since the difficulty in eating can lead to a decrease in the amount of eating [7]. In addition, mealtimes are the most important daily meeting times that people have with their family and friends in social life. For people who cannot provide their own nutrition with appropriate performance and satisfaction due to hand tremor, this situation becomes psychologically wearing out in the society and creates a compelling factor for them to establish relationships [2].

The designs on aids for eating (spoon, fork, etc.) are very limited. The first studies on devices that make it easier to eat are studies aiming to absorb the number of tremors by using heavier forks, spoons and plates. However, the use of heavy forks, spoons, etc. absorbs the tremor to a very limited extent and causes muscle fatigue / muscle pain. Today, with the development of technology, the orientation towards the design of vibration damping robotic eating apparatus (spoon, fork, etc.) with active controller, which is the focus of this research, has increased. Although the most successful products with active damping control are Liftware spoon and Gyro spoon[8], vibration damping rates are reported to be 76% in these products.

## 1.2 Literature review

### ➤ **Teixeira et al., 2013.** [9]

took a different approach by developing a dynamic vibration absorber (DVA) system for Parkinson's Disease (PD) patients that can adapt to changes in tremor frequency. They mathematically modelled, simulated, and experimentally verified the DVA system. To test its performance, they used both a sinusoidal disturbance signal and a wave jammer, which were collected by sensors from patients and reproduced by a vibration stimulator. The results of their tests were impressive, showing that the DVA system reduced vibrations by 90% and 50%, respectively, for these different scenarios. This adaptability to frequency changes makes the DVA system particularly effective in real-world applications, where tremor frequencies can vary.

### ➤ **Taheri et al., 2014.** [10]

developed a shock absorber orthosis designed to dampen tremors in patients with pathological tremors affecting their upper extremities. They derived an active control algorithm to estimate the tremor frequency, which involved designing a high-pass filter to isolate the tremor frequency. Then, using the backstepping method, they calculated the amount of torque required to absorb the predicted frequency. The proposed vibration suppression algorithm was tested on two types of disruptive vibration signals, and the results were outstanding. They demonstrated that their method could suppress vibrations by 97.5-99.2%. This high level of effectiveness highlights the potential of their approach for clinical use in managing tremors in patients with severe tremor disorders.

### ➤ **Abbasi et al., 2018.** [3]

designed a versatile device with active control mechanisms aimed at reducing hand tremors. This device is multifunctional, serving both as a spoon and as a stylus for tablets and smartphones. The device is built as an active-controlled, 2-degree-of-freedom robotic mechanism, which effectively reduces the impact of hand tremors during its use. Their design addresses the need for multifunctional devices that can assist with various daily tasks. Despite the high damping rates reported by these various exoskeleton robots, which range between 77% and 99.8%, the challenge remains in ensuring that vibration damping orthoses are ergonomic and comfortable for daily use. Furthermore, tremors can occur only during specific activities in some patients, while in others, tremors occur even at rest. Therefore, the design and use of action-specific robotic devices, tailored for particular tasks, offer a more effective solution than the continuous use of orthoses.

### ➤ **Fraiwani et al., 2018.** [1]

This work presents a self-stabilizing Parkinson's disease (PD) Tray (platform) that can help them to carry objects that they hold with their hand. The proposed design includes a mechanical platform and electronic system to control the tray and inhibits any vibrations of the base plate of the tray. An algorithm was developed that would take positional data from an Inertia movement sensors IMU, compute angles in degrees from its Euler angle raw data and then use those angles to control three servo motors in a direction counter to the changes in the IMU's position. The platform could stabilize the base of the tray such that objects placed in it would not be dropped. The tray was tested on simulating conditions and the result should that the mean absolute value of the acceleration values in X and Y directions were reduced from 2.23m/sec<sup>2</sup> to 0.26m/sec<sup>2</sup> in the X direction and from 1.41m/sec<sup>2</sup> to 0.34m/sec<sup>2</sup> in the Y direction.

### ➤ **Turgeon, Philippe et al., 2019.** [11]

In their work titled "Preliminary design of an active stabilization assistive eating device for people living with movement disorders," the authors propose a mounted damping mechanism that uses magnetic encoders, a gyroscope, and an accelerometer. The system is powered by the SAM E70 ARM Cortex-M7 microcontroller from Atmel, which is responsible for running the

device's complex Cartesian velocity-based damping algorithm. The motor assembly, gearbox, transmission, and encoders are all connected to an external handle that the user operates to stabilize movements during eating. Although the system offers a sophisticated approach to damping, the authors note a significant drawback: the device's lack of portability and simplicity, which are crucial for patients with neurodegenerative diseases like Parkinson's, where cognitive impairments such as dementia are common. Despite this limitation, the study provides valuable insights into the various tremors and movements experienced by patients during different activities, helping to inform future device designs.

➤ **Fromme et al., 2020.** [12]

A lightweight, wearable device was created to help reduce hand tremors in people with Parkinson's disease. The device is worn on the wrist and contains a structure filled with a constant volume of air. As the wrist bands, the air pressure increases, helping to stabilize the hand and counteract the tremors.

➤ **Kumar et al., 2022.** [13]

An algorithm was developed to record and suppress the physiological tremor present in the hands of surgeons doing robotic surgical procedures due to fatigue or otherwise. A prototype setup of master handle having six degrees of freedom with a vibration motor was designed and fabricated to record the hand tremor. The work involved recording the composite simulated motion consisting of both voluntary motion of surgeon's hand and associated involuntary motion of tremor in real time, determination of peak frequencies of both the motions and providing necessary information on the graphical user interface. The adaptive algorithm can cancel out the involuntary motion from the recorded raw signal in real time. After filtration, only voluntary motion remains for further processing. The developed algorithm promises potential to make robotic surgery more precise and error free.

➤ **Bhidayasiri et al., 2024.** [14]

An anti-choking mug specifically designed for people with Parkinson's disease (PD) was developed and tested. The mug is intended to help users maintain an optimal head position for drinking, thereby reducing the risk of choking. Key features included in the design are adjustable water flow and sip volume to control the amount of liquid dispensed, an inner slope to encourage a chin-down posture for safer swallowing, and a thickened handle and wide base to enhance grip and stability. The mug was tested by measuring neck flexion angles and comparing these to those achieved with a standard mug. Clinical assessments were also conducted to evaluate swallowing efficiency and safety. Significant improvements in swallowing and drinking safety were observed with the anti-choking mug compared to the standard mug.

**Table (1-1): Taxonomy table of Literature Review.**

WHO	WHY	HOW	WHAT
Name / Year	Aim	Methods	Results and Conclusion
Teixeira et al., 2013	To develop a self-tunable vibration absorber for Parkinson's disease tremor suppression.	A small-scale MRD was designed and tested for resistance forces and tremor suppression using mathematical models and dual-frequency motion experiments.	The MRD reduced tremors by up to 90%, showing promise for orthoses, with scope for improving coil design and fluid modeling.
Taheri et al., 2014	To design a robust controller for suppressing tremors at the	A robust tremor suppression algorithm was developed using a high-pass filter (3–12 Hz) and	The system achieved 97.5–99.2% tremor suppression (30–42 dB reduction) with minimal impact on

	musculoskeletal level.	backstepping control to apply suppressive torque via a pneumatic actuator. A joint simulator tested the system using Parkinson's and essential tremor data.	intentional motion, demonstrating potential as a non-invasive alternative for managing pathological tremors. Future work will involve patient trials.
Abbasi et al., 2018	To design a noninvasive, smart hand tremor attenuation system using active control.	<ul style="list-style-type: none"> <li>• Designed a handheld device with servomotors and active controllers (PID and computed torque) for tremor suppression.</li> <li>• Simulations used real patient data and low-pass filters to separate tremors from voluntary movements.</li> </ul>	<ul style="list-style-type: none"> <li>• Achieved up to 76% tremor suppression during tasks.</li> <li>• Lightweight, noninvasive design effectively controlled tremors without affecting voluntary movements.</li> </ul>
Fraiwan et al., 2018	To design a stabilization platform for Parkinson's disease patients.	A stabilizing platform with IMU sensors and servo motors counteracted tremors to balance a tray.	The platform reduced tremor-induced acceleration by over 85%, stabilizing loads up to 3 kg and enhancing independence for Parkinson's patients.
Turgeon, Philippe et al., 2019	To present advancements in rehabilitation robotics, including tremor suppression.	Compilation of studies and technologies presented at the conference.	Highlighted innovative tremor suppression techniques, emphasizing real-world rehabilitation applications.
Fromme et al., 2020	To design a lightweight, passive orthosis for hand tremor suppression.	A 33 g textile-based passive orthosis with an adjustable air-filled structure was designed to suppress wrist tremors and tested for torque, deflection, and tremor reduction during daily activities.	The orthosis reduced tremor power by 74–82% ( $p = 0.03$ ) with high comfort and wearability, showing potential for broader applications like spasticity management and exoskeleton integration.
Kumar et al., 2022	To estimate and suppress hand tremors in real-time for surgical robotic applications.	A six-DoF system with adaptive filters processed and canceled tremor signals (3–15 Hz) in real time, retaining only voluntary motion.	The system reliably canceled tremors, enabling precise motion transfer for robotic surgery and potential applications in tremor management.
Bhidayasiri et al., 2024	To develop and clinically test an anti-choking mug for Parkinson's disease patients.	A user-centered design approach developed an anti-choking mug for Parkinson's patients with dysphagia, tested on 15 participants.	The mug improved neck flexion ( $26.87^\circ$ vs. $11.93^\circ$ , $p < 0.001$ ), reduced aspiration risk, and enhanced safety, offering a practical solution for dysphagia management.

### 1.3 Background

For individuals with congenital amputation and manipulative and locomotive disabilities, some activities of daily living may prove to be a challenge, limiting independence and decreasing their quality of life. Feeding process is one of the most important activities in everyday life that influences many aspects of overall medical, physical, and social wellbeing.

### 1.4 Aim

This project aims to design and fabricate an adaptive aid device to assist people with decreased and uncoordinated movements to perform feeding activities independently.

### 1.5 Project Layout

This research was made up as the following chapters:

- **Chapter two:** covers how the device works and the components used to make it function.
- **Chapter three:** This chapter presents the experimental work, including system components and the creation of the Stable Spoon. It focuses on two main parts: the hardware design and the implementation of the system.
- **Chapter four:** This chapter shows the experimental results and their discussion.
- **Chapter five:** This chapter presents the conclusions with insights to future work expanding.

## THEORETICAL BACKGROUND

### 2.1 Introduction

An Adaptive Feeding Aid Device (Stabilizing spoon) is a device which maintains a horizontal position of its front regardless of the motion it receives from the user at the rear end of the spoon. For a theoretical demonstration of the spoon's movement, see Figure 1. It's have been developed foremost to help people with tremors and people who are functionally challenged with difficulties moving their hands. Its aim is to assist these people so they can eat independently. People with hand tremors could be persons with Parkinson's disease and people who are functionally challenged could be persons with Cerebral palsy.

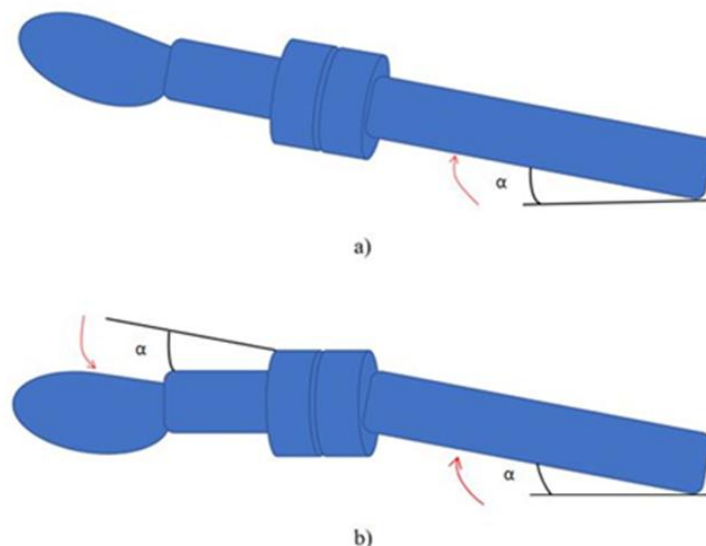


Figure (2-1) Spoon's movement illustrated (a) without compensation (b) with compensation.[15]

If the handle of the spoon is tilting an angle with  $\alpha$  degrees, see **Figure (2-1)**, actuators in the spoon's construction will compensate with the same angle  $\alpha$  and put the spoon bowl in its initial horizontal position.



### 2.2.3 Microcontroller

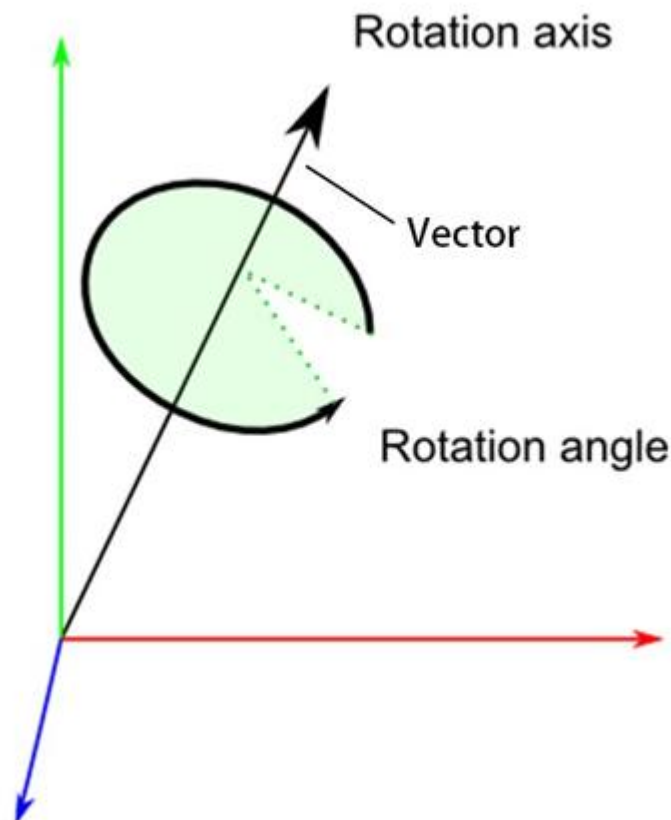
A microcontroller can be considered as a small computer that can be programmed to control electronics. It consists of one or more CPUs along with memory and programmable inputs/outputs. It has a broad area of use and can be found in automobile engine control systems, medical devices, toys and remote controls. The largest names within microcontrollers in hobby projects are Arduino and Raspberry Pi. In short, Raspberry Pi has a large processing power and is used for a wide range of applications, the Arduino comparatively, tends to be used for projects with less processing power.[17]

### 2.3 Quaternions

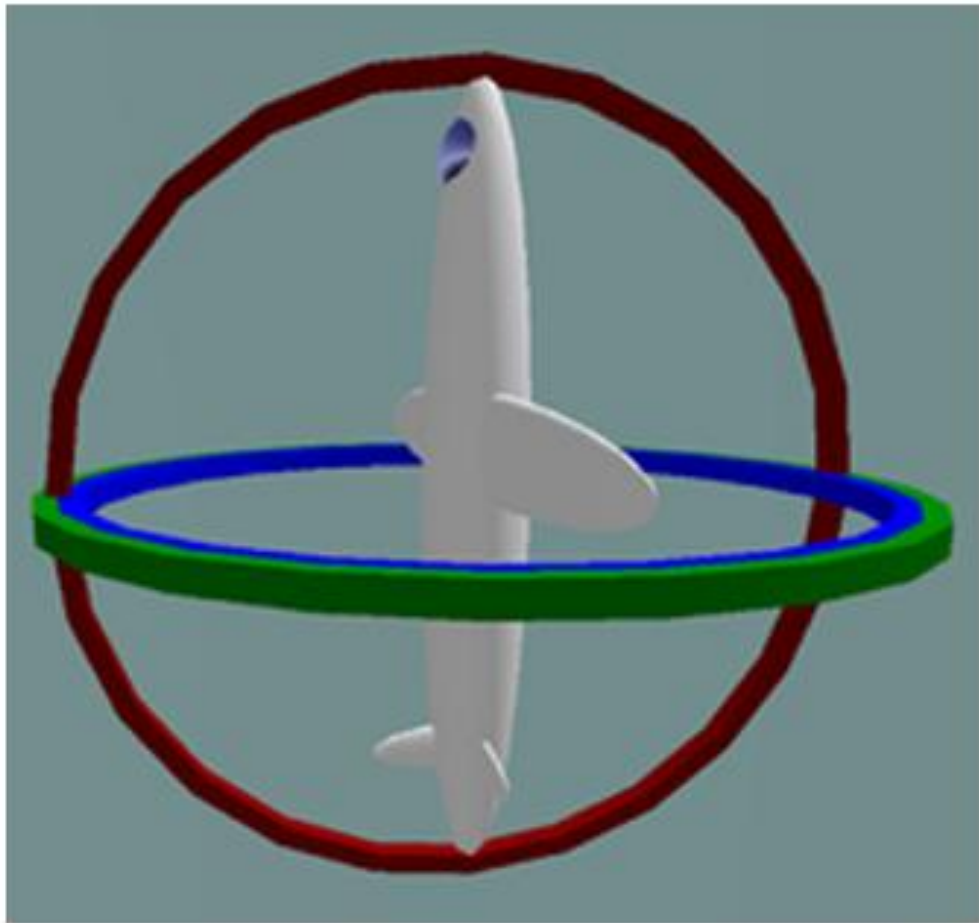
Quaternions is a mathematical method which is useful when describing motions in 3D. The theory is commonly used in computer graphics, for example when an object in the graphics makes a transition from a rotation to another. Unlike Euler angles, using quaternions will avoid the problem of a locking position and is therefore simpler to compose.

A quaternion can be seen as a vector in a 3-dimensional Cartesian coordinate system, the vector or quaternion can point in any direction in this coordinate system and rotate around its own axis, shown in **Figure 2.4**. This will allow the quaternion, or the object that is being manipulated, to rotate in any direction without being at risk for a locking position. A locking position, or "gimbal lock" as it is called, is a loss of one degree of freedom in a three dimensional, three gimbal mechanism. This phenomenon "locks" the system into rotating in a degenerate two-dimensional space and allows the object to rotate only in two directions instead of three.[18]

It occurs when the manipulated object is rotating making two or three gimbal axes align and become parallel to each other, shown in **Figure 2.5**.



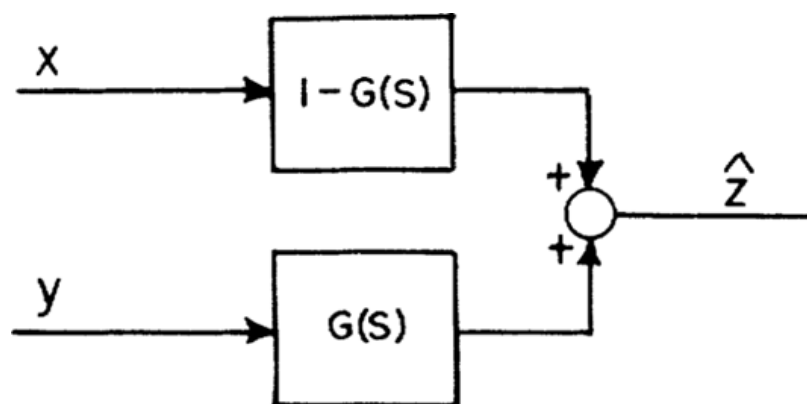
**Figure 2.4.** illustrates the direction of rotation around an axis using the right-hand rule, where the thumb indicates the axis and the curled fingers show the direction of rotation.[23]



**Figure 2.5.** Gimbal lock problem where the x- and y-gimbal axis are aligned making the object lose one degree of freedom.[24]

#### 2.4 Complementary Filter

An IMU presents occasionally values that are incoherent and vary unreasonably to one another. To get proper values, i.e. clear values, a filter is needed. A complementary filter consists of one low pass filter and one high pass filter. **Figure 2.6** shows a block diagram where  $y$  is a high frequency signal and  $x$  are a low frequency signal going through a low pass filter,  $G(s)$ , respectively a high pass filter,  $1-G(s)$ , which then results in a filtered signal,  $\hat{z}$  [19]



**Figure 2.6.** Complementary filter

The implementation of this setup of a complementary filter in software is shown in the equation:

$$\hat{z} = x(1 - G(S)) + yG(S) \quad (2.1)$$

$$yG(S) + x(1 - G(S)) = \hat{z}$$

where the fraction,  $G(S)$  is generally 0.98 and the parameters  $x$  and  $y$  represent values from the accelerometer respectively the gyroscope from the IMU.

## EXPERIMENTAL WORK

### 3.1 Problem Formulation

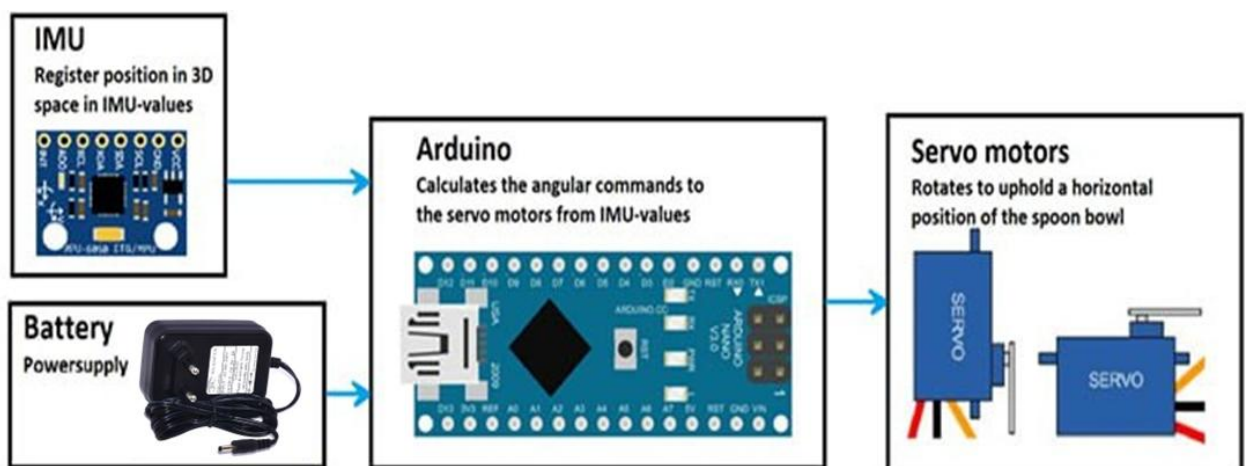
The Stable Spoon demonstrator was developed to enable testing and assess its effectiveness in assisting users with hand tremors. The primary challenges addressed during the experimental phase were:

1. Counteracting involuntary hand movements
2. Designing dimensions that are comfortable and practical for user grip

To achieve real-time stabilization, a single control algorithm was developed for counteracting motion. This algorithm processes real-time orientation data from an inertial measurement unit (IMU), the MPU-6050, which provides both gyroscope and accelerometer outputs.

The raw IMU values are processed and transformed into rotational commands sent to servo motors that actively correct the orientation of the spoon head. **Figure 3.1** illustrates a simplified overview of this system.

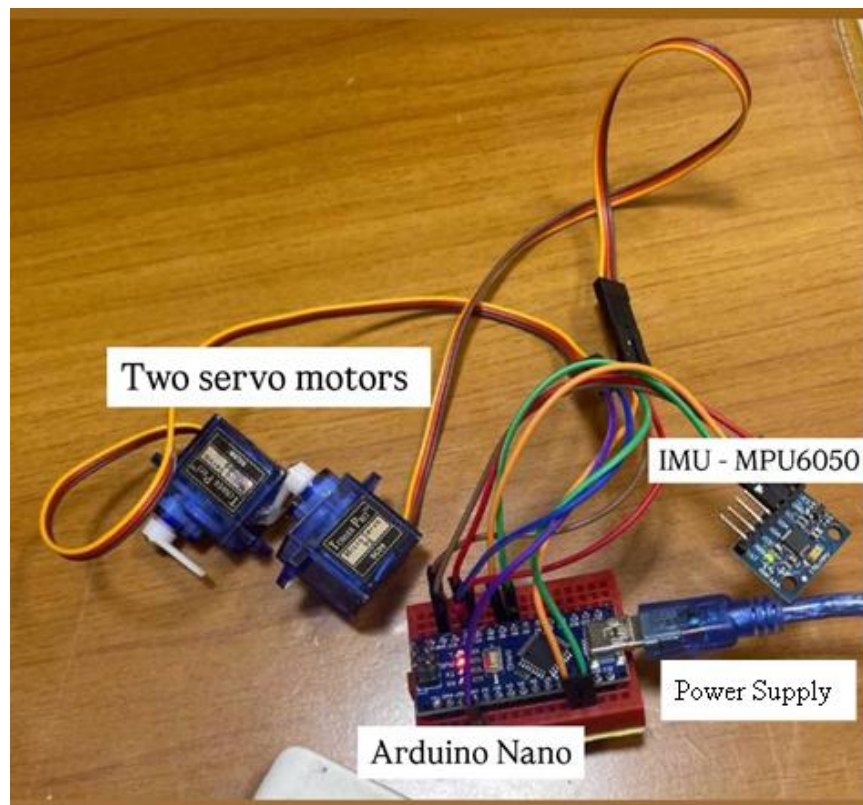
The custom-developed algorithm employs a complementary filter to smooth the angle calculations, reducing noise and drift. This ensures a stable, responsive correction of hand movements, offering a balanced trade-off between responsiveness and stability.



**Figure 3.1.** Overview of the involving components, created in Paint

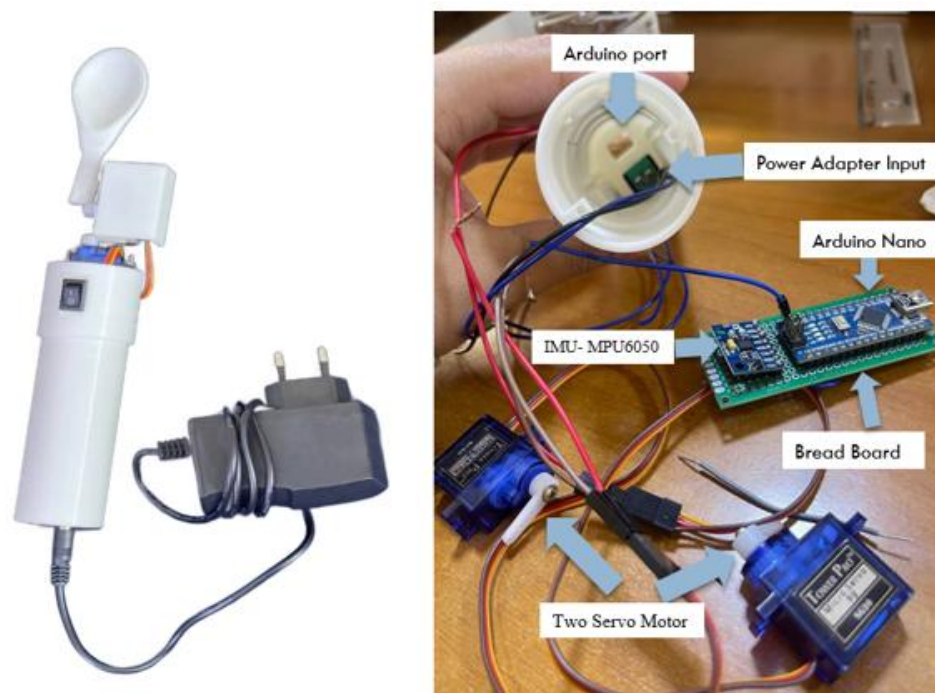
The size of the product had to be taken into consideration, as the device must fit comfortably into the user's hand. During the project, two key stages were developed: the first involving the circuit before the prototype was created, and the second featuring the prototype of the Mold with the sensors assembled inside it.

In the initial stage, Shown in **Figure 3.2.**, the circuit was assembled and included two servo motors, Imu- Mpu6050, an Arduino Nano, and a battery. The components were arranged in a compact layout to ensure they could be efficiently integrated into the prototype. The circuit provided the necessary control and feedback for real-time stabilization, ensuring that the device could respond effectively to the user's hand movements.



**Figure 3.2. Hardware components for the proposed system**

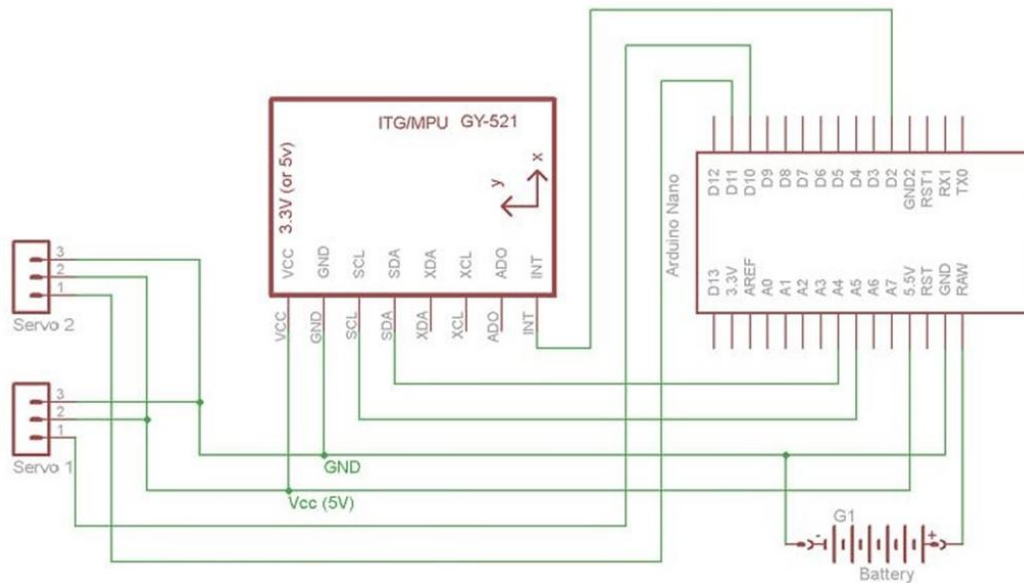
Once the circuit was finalized, Shown in **Figure 3.3.**, the prototype of the Mold was created, and the sensors were assembled inside it. This stage allowed for an early evaluation of the device's physical structure, including how the circuit and components would fit within the Mold. The assembly design ensured that the servo motors, gyroscope, Arduino Nano, and battery were placed efficiently to maintain the functionality of the device. The prototype also focused on the ergonomic aspects of the design, ensuring the device could be comfortably held and operated by the user.



**Figure 3.3. Integration of Components into Prototype Mold.**

### 3.2 Electronics

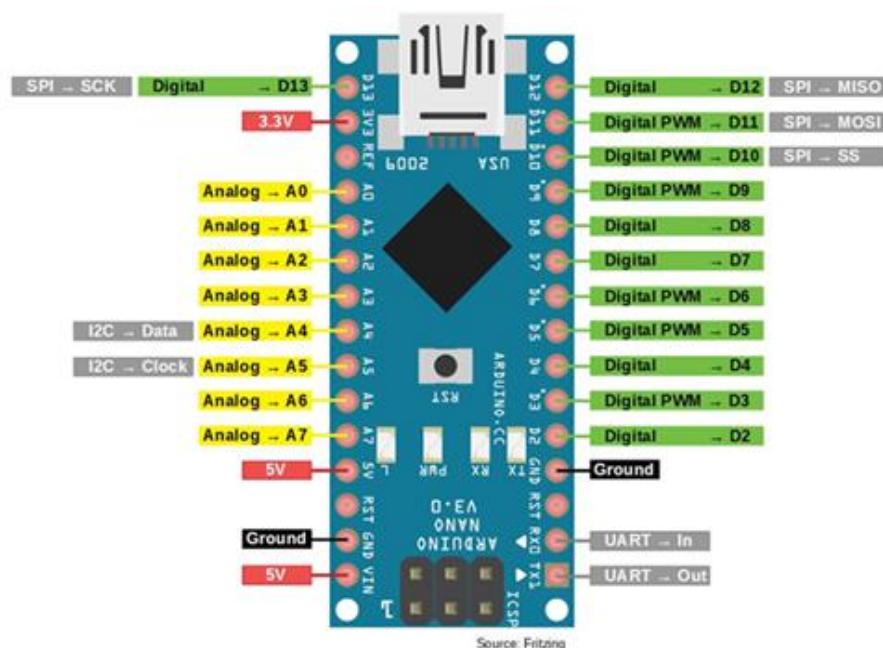
The electrical components used in this project were connected with the Arduino Nano as demonstrated in the following electronic schematic, **Figure 3.4**



#### 3.2.1 Microcontroller-Arduino Nano

The Arduino Nano was chosen for the Stability Spoon due to its compact size (45 mm × 17 mm × 10 mm) and light weight (around 7 grams), making it ideal for handheld, battery-powered devices. It uses the ATmega328 microcontroller, offering a good balance of performance and low power consumption. With 14 digital I/O pins (6 supporting PWM) and 8 analog inputs, it can connect to sensors and actuators needed for real-time stabilization.

Motion sensors like the MPU-6050 (accelerometer and gyroscope) connect via I2C using pins A4 (SDA) and A5 (SCL), allowing the Nano to detect tremors and activate components such as servo motors for correction. Its mini-USB port enables both programming and power supply, and its open-source platform allows easy development using C/C++ for motion filtering and control. Overall, the Nano's small size, functionality, and ease of integration make it ideal for smart assistive technologies.

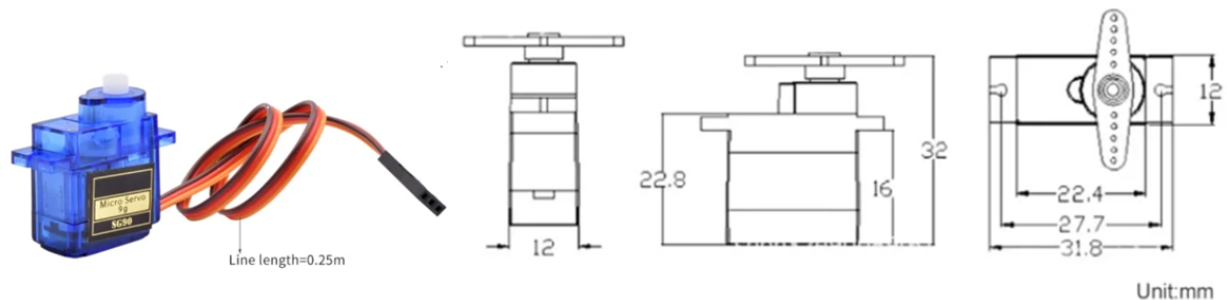


**Figure 3.5.** Arduino Nano board pinout [20]

### 3.2.2 Servo motor- Micro 9g servo FS90

The FS90 Micro 9g servo motor is used for its lightweight design, compact size (23.2 x 12.5 x 22.0 mm), and sufficient torque output of approximately 0.127 Nm, making it ideal for a handheld assistive device. Weighing only 9 grams, it fits easily into the spoon handle without adding bulk, while still providing the power needed to make fine adjustments that counteract hand tremors.

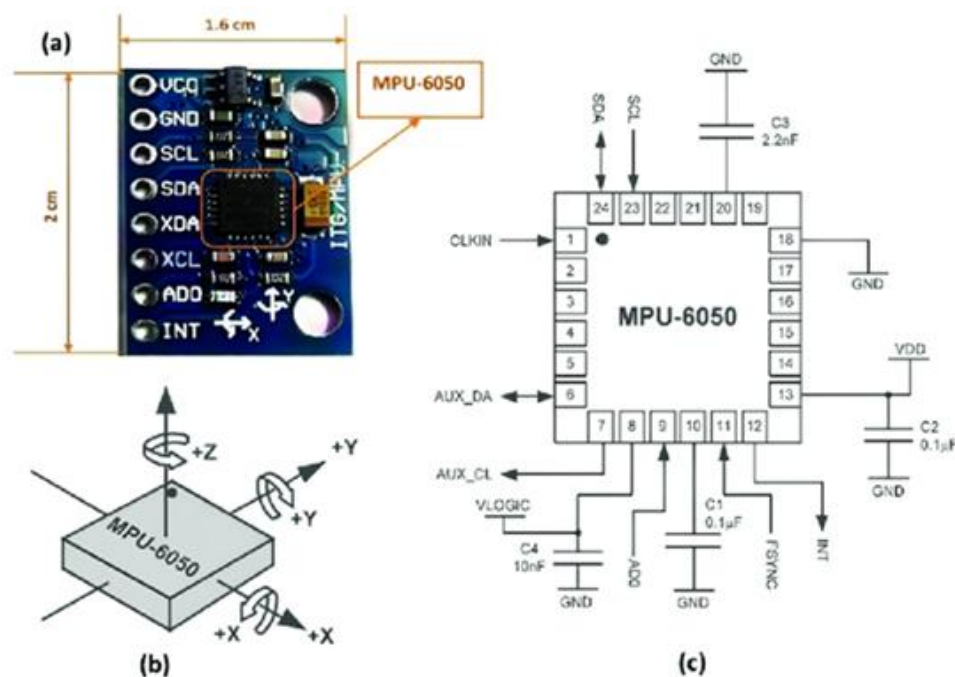
With a rotation range of about 180 degrees, the FS90 allows for smooth, responsive motion, helping maintain the spoon's stability in real time. It operates on a standard 3-pin interface—PWM signal, Vcc (4.8 V to 6 V), and GND—making it easy to integrate with the Arduino Nano. Its compatibility, low power requirements, and reliable movement make it an excellent option for enabling real-time stabilization in the Stability Spoon. **Figure 3.6**



**Figure 3.6. Tower Pro SG90 Mini Micro Digital Servo 9g and its dimensions.[25]**

### 3.2.2 IMU- MPU6050

The MPU6050 is a small, lightweight sensor used to detect motion and orientation. It combines a 3-axis gyroscope and a 3-axis accelerometer, providing real-time data on angular velocity and linear acceleration to detect hand movements and stabilize the spoon. Its onboard Digital Motion Processor (DMP) reduces the computational load, enhancing responsiveness and efficiency. At around 2 grams, it's perfect for compact devices like the Stability Spoon, and its compatibility with open-source libraries and I2C communication ensures easy integration with the Arduino Nano, making it an effective solution for users with tremors or motor control issues. **Figure 3.7**



**Figure 3.7. MPU6050 module (a) sensor module, (b) working axis details, and (c) circuit diagram.[26]**

### 3.3 Power Source for the System

A 5V 3A EU plug adapter is used as a high-quality power supply. the key details of the adapter:

- **Input:** 100V-240V, 50-60Hz, compatible with standard EU power outlets, suitable for global use.
- **Output:** Provides a stable DC 5V, with options for 2A or 3A output, ensuring adequate power for the Arduino Nano and connected components.
- **Outer Diameter:** 3.5mm and Inner Diameter: 1.35mm for compatibility with the adapter's connector.
- **Cable Length:** 100cm  $\pm$  1cm, providing flexibility for placement and integration within the system.
- **Plug Specifications:** Available in both EU and US plug versions for versatile usage.
- **Power Supply with LED Indicator:** Equipped with an LED indicator to show the power status.
- **Connector Polarity:** The adapter has inside positive (+) and outside negative (-) polarity, ensuring correct power delivery to the system.

This 5V 3A EU plug adapter is a reliable and safe power solution, providing stable voltage and sufficient current for powering the Arduino Nano and ensuring smooth operation.



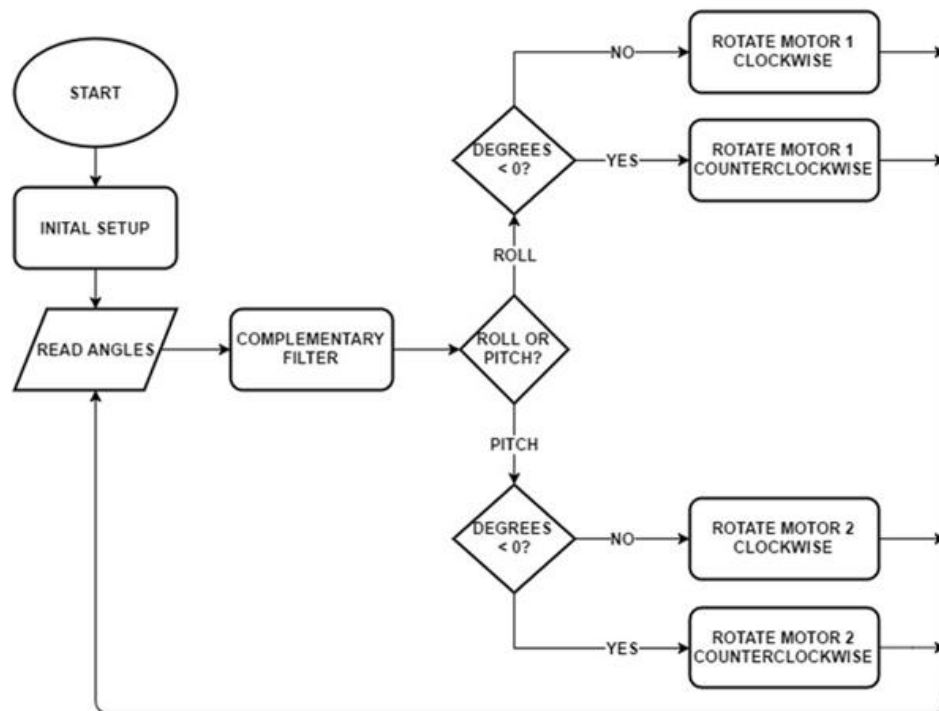
**Figure 3.8.** 5V 3A EU plug adapter [21]

### 3.4 Software-The project's code

The code interfaces with an MPU-6050 accelerometer and gyroscope sensor to control two servo motors based on the sensor data. Initially, the code wakes up the MPU-6050 sensor using the I2C protocol and reads both the accelerometer and gyroscope data, which represent the device's movement along the X, Y, and Z axes. A complementary filter is applied to combine accelerometer and gyroscope data to calculate pitch (tilt forward/backward) and roll (tilt left/right), with the gyroscope helping track short-term rotations and the accelerometer providing long-term stability. The calculated pitch and roll values are then adjusted using specific limits to prevent extreme movements and mapped to control two servos. One servo controls the roll movement, and the other controls the pitch movement. These servo commands adjust in real-

time based on the device's orientation, with pitch values constrained to stay within set limits for specific ranges, ensuring stable movement.

**Figure 3.9** demonstrates the work flow through a flowchart, from the start of the code to the rotational commands of the motors.



**Figure 3.9.** Flowchart over the project's own developed code, drawn in the free software program Draw.io

### 3.5 Hardware

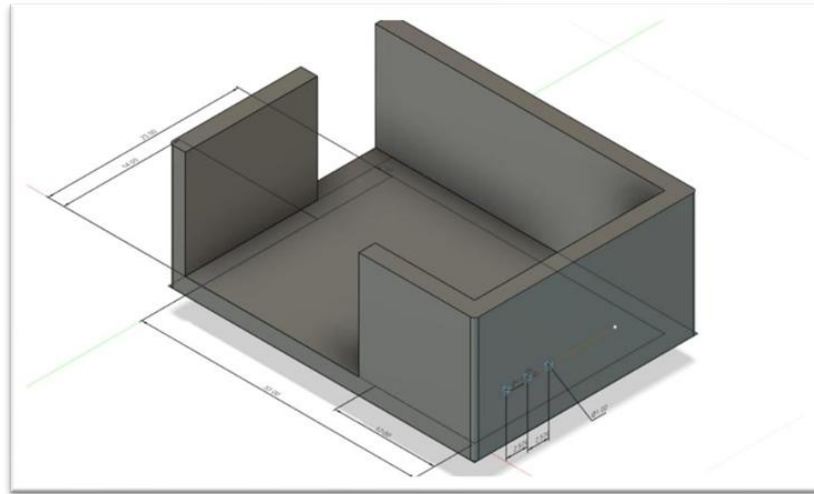
All of the mounting parts and the casing were made out of PLA (Polylactic Acid) constructed by an ender 3 v2 3D printer.

The casing of Prototype 3 is shown below in **Figure 3.10**, which is a hollow cylinder with details for mounting. One servo motor was mounted with screws in the holes shown in the figure, while the circuit board was placed on a shelf inside the cylinder for stabilization. The casing weights 34 grams and took 5 hours and 21 minutes to print.



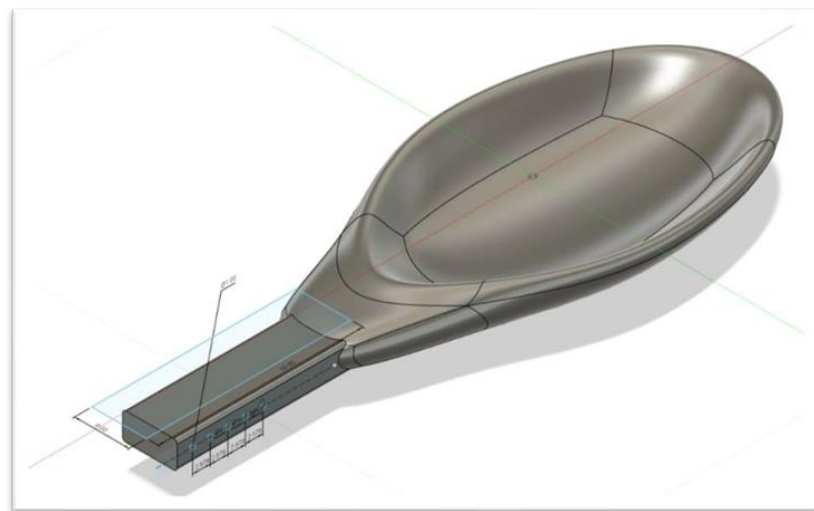
**Figure 3.10.** CAD-model of the Casing

The other servo motor was mounted to the first mentioned servo motor using a standard servo rotor connected with screws to a simple container, as shown in **Figure 3.11**, which was securely held in place. The container weights 4 grams, with 15% infill, and required 36 minutes to print.



**Figure 3.11.** CAD-model of the Container

The last hardware component is the spoon bowl, **Figure 3.12**, which was screwed directly onto the outermost servo motor's rotor. The spoon bowl weights 5 grams and took 1 hour to print.



**Figure 3.12.** CAD-model of the spoon shaft

Additional details were added, **Figure 3.13 (a,b)**, such as a USB port for the Arduino, a battery compartment, and a switch to turn the circuit on and off.



**Figure 3.13 (a, b).** Additional details of Prototype.

## RESULTS AND DISCUSSION

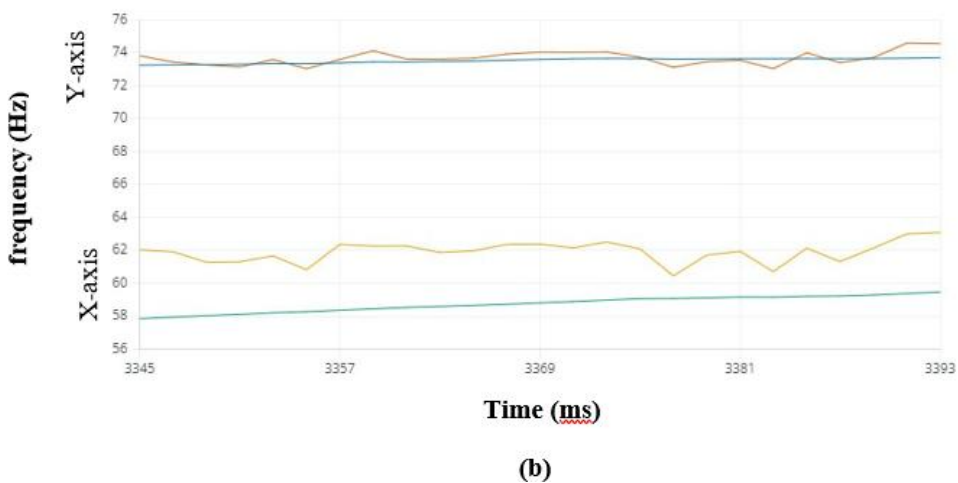
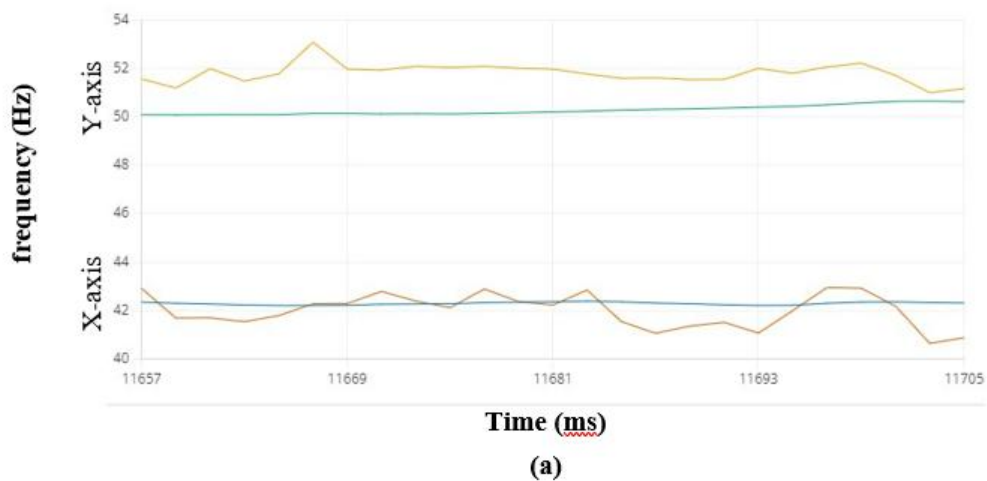
### 4.1 Introduction

This chapter presents the outcomes of the prototype testing, user feedback, and the challenges encountered during the development of the feeding aid spoon. Feedback from users indicated a high level of satisfaction, particularly with the spoon's ability to reduce food spillage caused by hand tremors. Several challenges were faced, including optimizing stability, usability, and responsiveness to tremor movements. Despite these difficulties, the final prototype proved to be effective and demonstrated significant potential in assisting patients with tremors during mealtimes.

### 4.2 Results Obtained

The project resulted in the successful development of a functional feeding aid spoon designed for patients with hand tremors. Real-time testing showed that the device effectively reduced the impact of involuntary movements, leading to more stable and controlled feeding. The system consistently minimized food spillage and improved overall hand coordination during use. Data collected from user trials confirmed that the prototype operated reliably, with performance metrics indicating a clear reduction in motion variability. User feedback forms also recorded high satisfaction rates regarding the spoon's comfort, grip, and responsiveness.

As shown in **Figure (4-1)(a,b)**, these are the results that concluded from the experience of the users, which are taken from the Arduino IDE, showing the tremored motion that are unfiltered, and the after-filtration motion to keep food on the spoon as much as possible without spillage.



**Figure (4-2)** Results Obtained from Arduino IDE  
(a) Unfiltered tremor motion (b) After-filtration motion

### 4.3 Discussion

The charts in **Figure (4-1)(a,b)**, illustrates comparative data trends over a specific range, likely representing sensor readings or stability metrics related to the prototype's performance. The lines suggest that the feeding aid spoon was effective in maintaining consistency in its key performance indicators. The uppermost line (yellow) appears to show data from uncontrolled tremor movements, fluctuating between approximately 50 and 53 units. In contrast, the lower line (orange) likely represents the spoon's response or compensation mechanism, showing a significantly dampened and more stable pattern, ranging between 41 and 43 units. This clear reduction in variability indicates the prototype's effectiveness in minimizing the amplitude of tremor-induced motion. The more stable middle lines (green and blue) may represent baseline or filtered values for comparison, showing minimal deviation over time. Overall, the results support the conclusion that the feeding aid spoon successfully reduced the impact of tremors, contributing to more controlled and independent feeding experiences for users.

### 4.4 Feedback from the Users

As part of the project to develop an assistive feeding device for individuals with neuromotor disorders, a survey was conducted to evaluate the proposed design from the perspective of potential users. The survey was distributed among Biomedical Engineering students, as their relevant knowledge was considered valuable for providing technical and practical feedback.

The survey focused on key aspects such as usability, comfort, effectiveness, and the suitability of the device for patients' needs. This step was intended to gather valuable insights that would help improve the prototype and ensure it was both effective and user-friendly.

#### 4.4.1 Data Analysis and Results

To evaluate the project comprehensively, five key points have been established for the survey. These points aim to obtain an accurate evaluation from all project participants and assess each aspect of performance.

##### Evaluation Scale:

1 = Not satisfied at all

2 = Not very satisfied

3 = Somewhat satisfied

4 = Quite satisfied

5 = Very satisfied

Based on these points, the questions directed to the users will be presented, along with a clear presentation of the analysis results, in addition to analyzing the collected evaluations to determine the project's success in meeting the users' needs.

The questions will be divided into two sections:

##### Section 1: The Assistive Device

Covers questions 1 to 8 related to the evaluation of the assistive device.

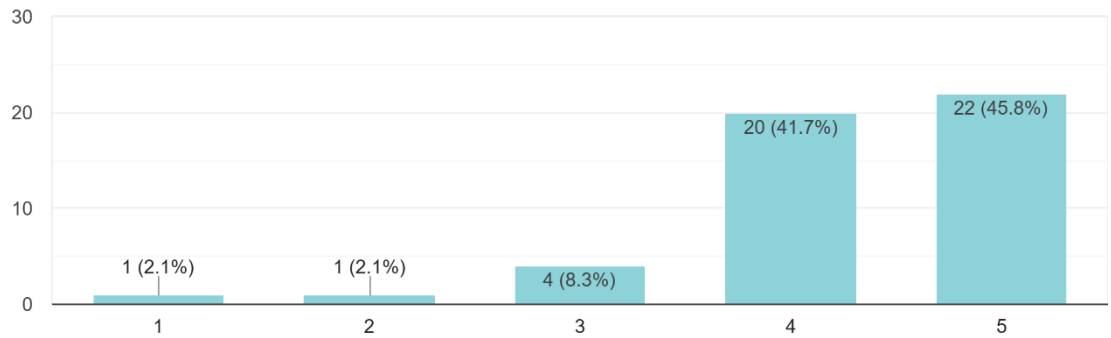
##### Section 2: Services

Covers questions 9 to 12 related to the evaluation of the provided services.

**1. How satisfied are you with the dimensions of your assistive device (size, length, width, height)?**

Section 1: The Assistive Device

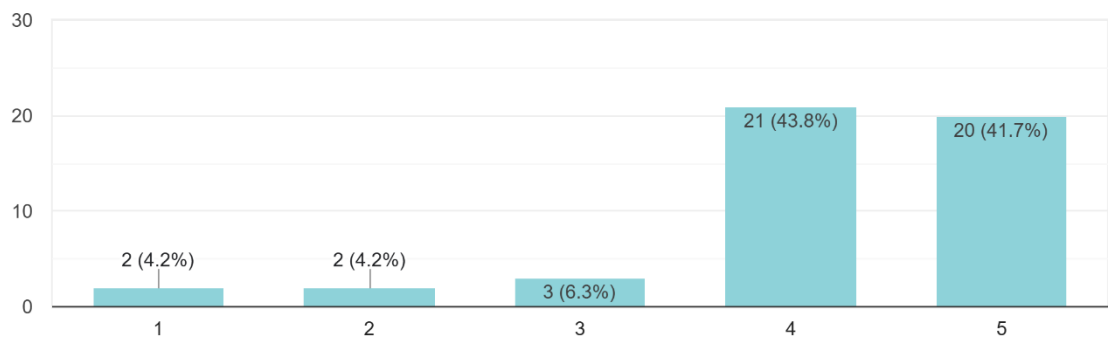
48 responses



**2. How satisfied are you with the weight of your assistive device?**

Section 1: The Assistive Device

48 responses

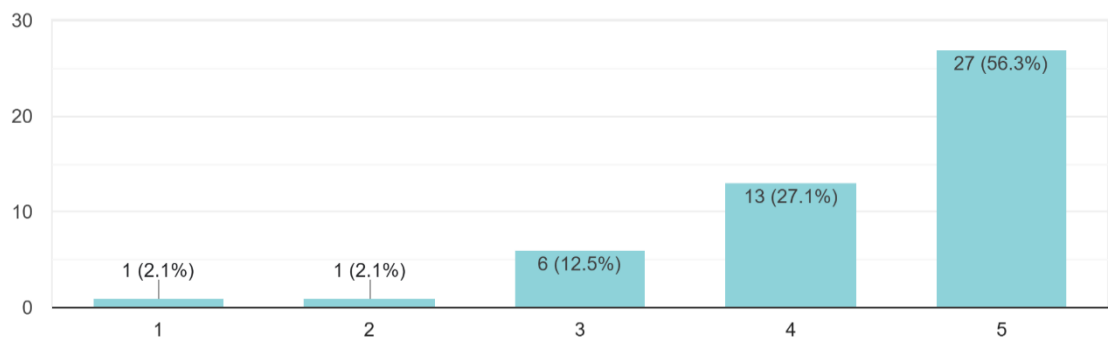


**Figure (4-2)** Average rating (4.15)

**3. How satisfied are you with the ease of adjusting or assembling the parts of your assistive device?**

Section 1: The Assistive Device

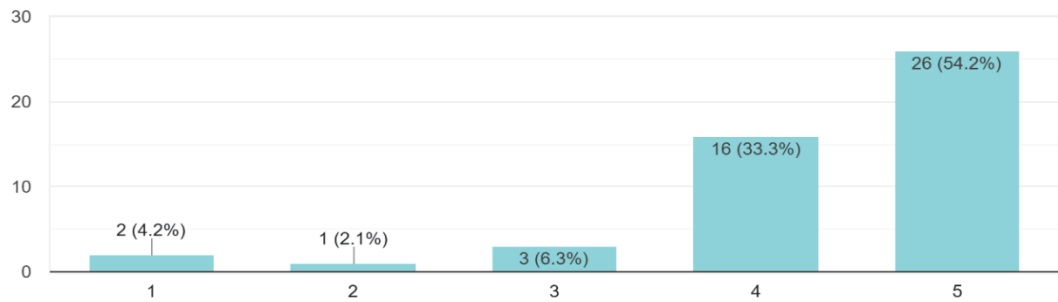
48 responses



**Figure (4-3)** Average rating (4.33)

#### 4. How satisfied are you with the safety and security of your assistive device?

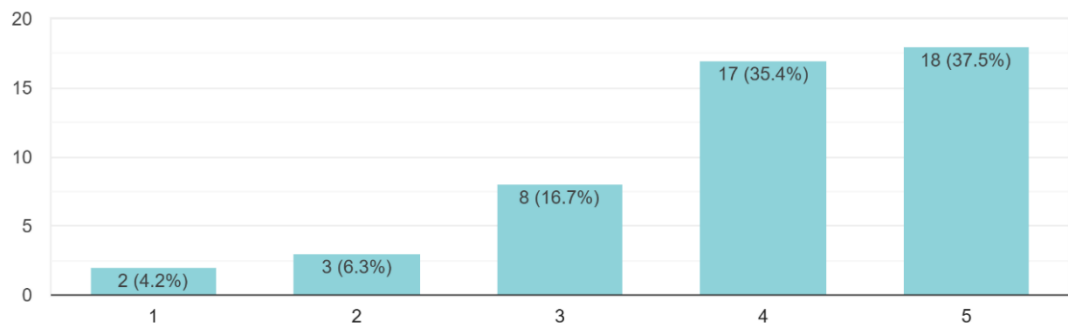
Section 1: The Assistive Device  
48 responses



**Figure (4-4)** Average rating (4.31)

#### 5. How satisfied are you with the durability of your assistive device (its resilience and long-term usability)?

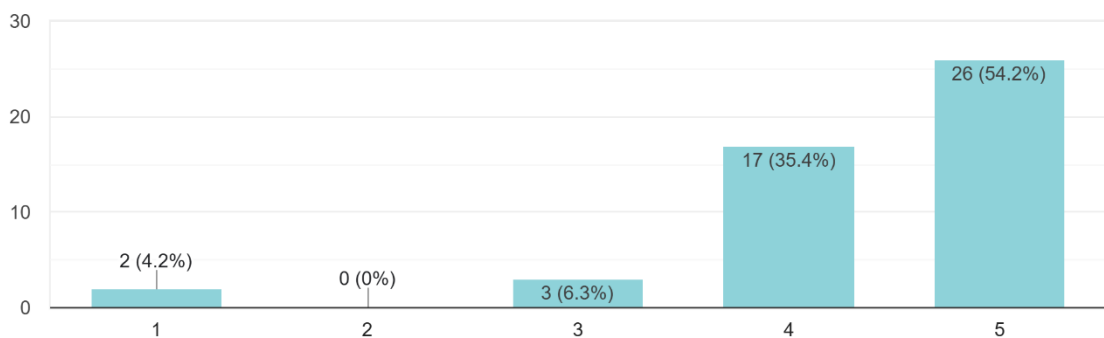
Section 1: The Assistive Device  
48 responses



**Figure (4-5)** Average rating (3.96)

#### 6. How satisfied are you with the ease of use of your assistive device?

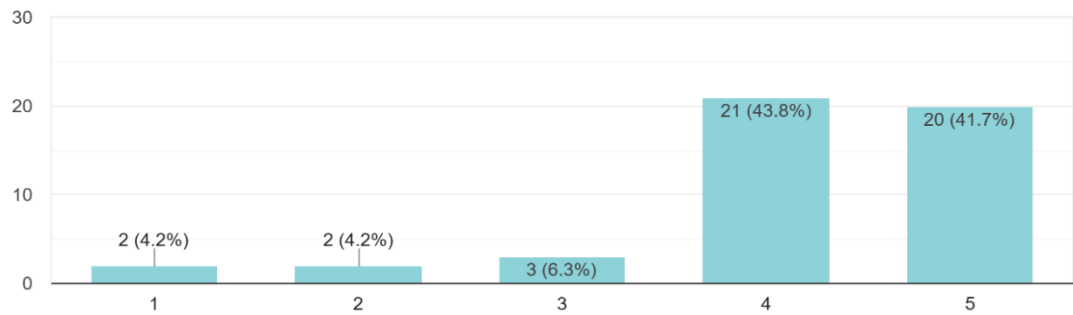
Section 1: The Assistive Device  
48 responses



**Figure (4-6)** Average rating (4.35)

**7. How satisfied are you with the comfort of using your assistive device?**

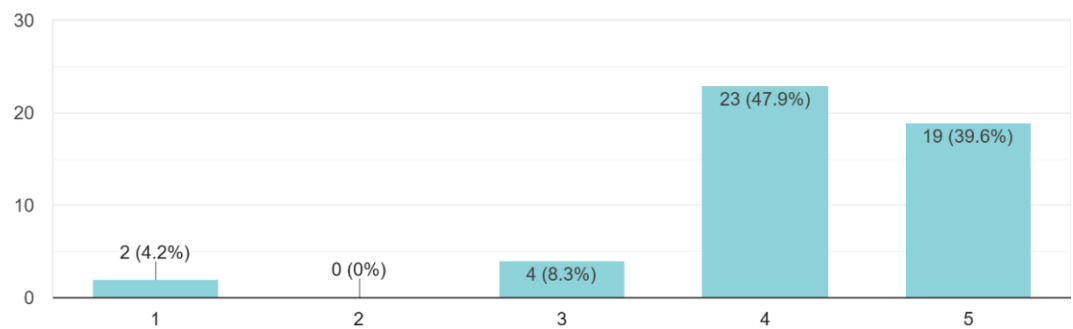
Section 1: The Assistive Device  
48 responses



**Figure (4-7)** Average rating (4.15)

**8. How satisfied are you with the effectiveness of your assistive device (i.e., how well it meets your needs)?**

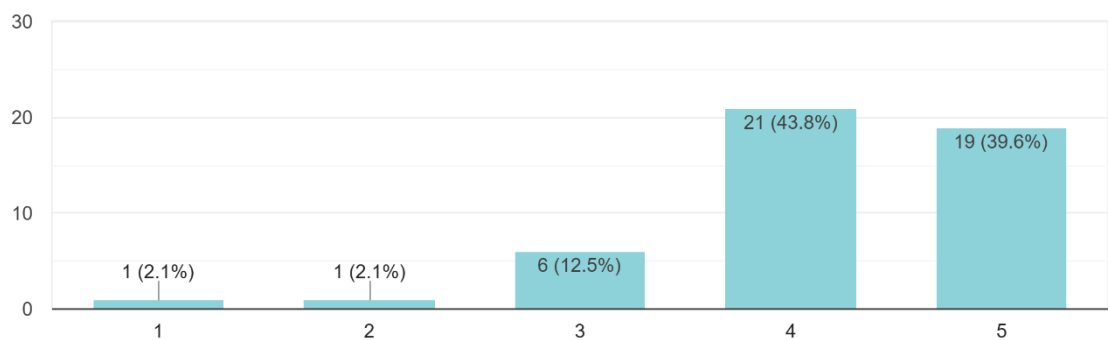
Section 1: The Assistive Device  
48 responses



**Figure (4-8)** Average rating (4.19)

**9. How satisfied are you with the service delivery program (procedures, time taken) through which you received your assistive device?**

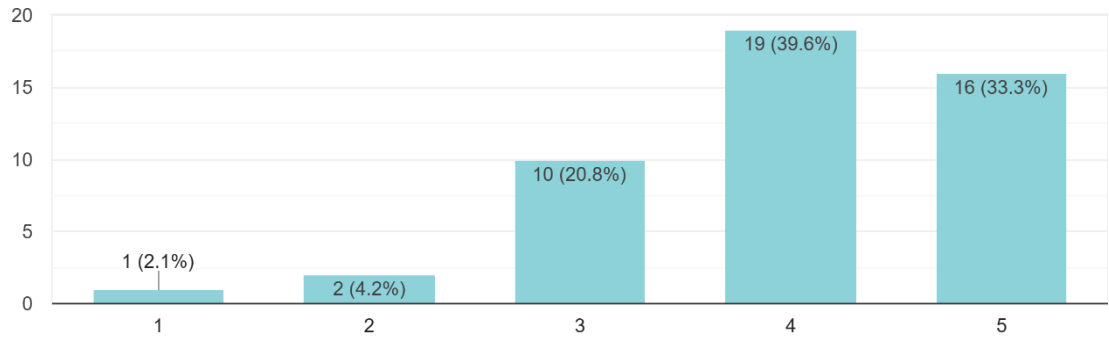
Section 2: Services  
48 responses



**Figure (4-9)** Average rating (4.17)

**10. How satisfied are you with the maintenance and repair services provided for your assistive device?**

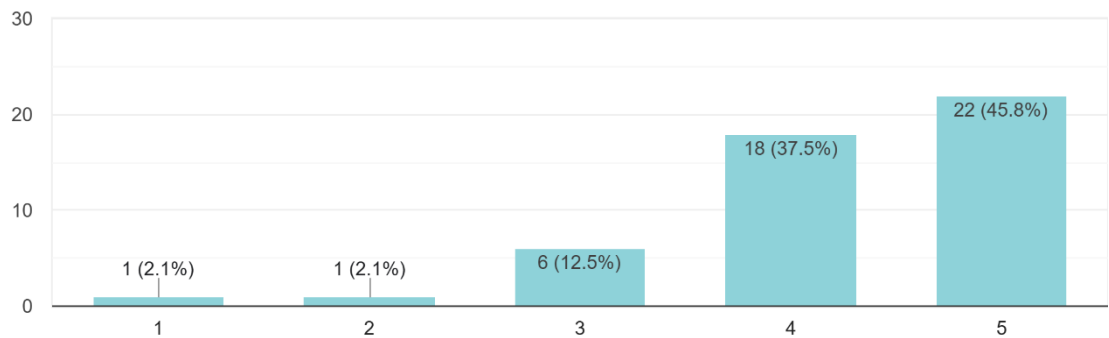
Section 2: Services  
48 responses



**Figure (4-10)** Average rating (3.98)

**11. How satisfied are you with the quality of professional services (information, attention) you received for using your assistive device?**

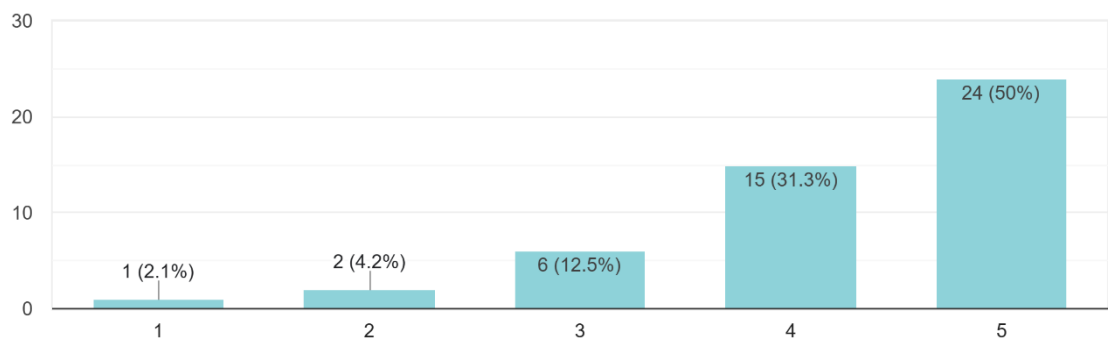
Section 2: Services  
48 responses



**Figure (4-11)** Average rating (4.23)

**12. How satisfied are you with the follow-up and ongoing support services you received for your assistive device?**

Section 2: Services  
48 responses

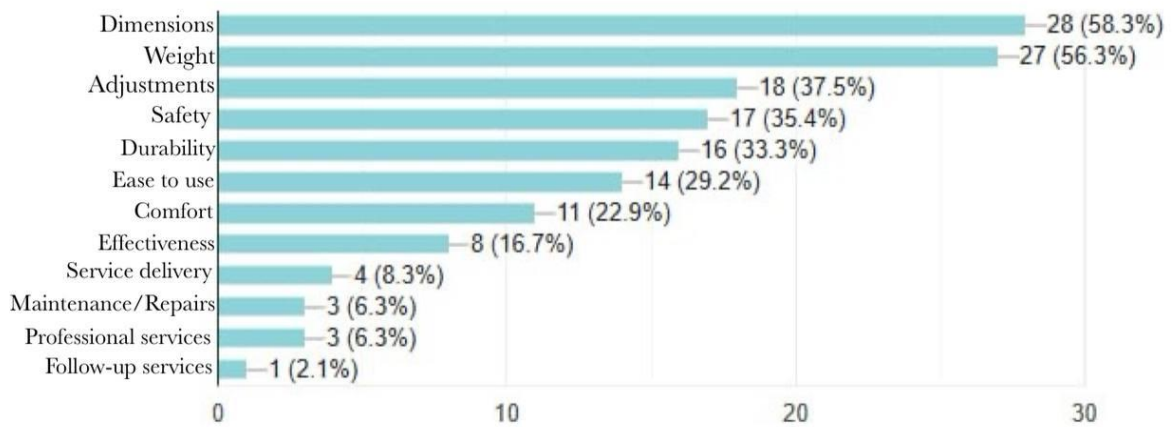


**Figure (4-12)** Average rating (4.23)

Finally, a third section will be included:

### Section 3: Most Important Aspects

Participants will select the three most important aspects from the previous items to highlight key user priorities for future improvements.



**Figure (4-13)** User Priorities Analysis

## CONCLUSION AND FUTURE WORK

### 5.1 Conclusions

- As the human body ages, a natural decline occurs in both bone density and neural function, leading to a range of health challenges.
- Among the most critical of these challenges are neuromotor disorders, which significantly impair fine motor control and hinder individuals from performing essential daily activities such as feeding themselves without external assistance. • Given the absence of a definitive cure for such disorders, an Adaptive Feeding Aid Device was developed using microcontrollers and sensors to support affected individuals in regaining a level of autonomy.
- The device is specifically designed to adapt to involuntary hand tremors and reduce their effects, thereby enabling users to eat with greater ease and comfort. • The initial prototype was constructed using sustainable materials and successfully programmed through an Arduino microcontroller.
- Nevertheless, the current version of the device is heavier than some available commercial alternatives, which could potentially result in discomfort during prolonged use.
- Although the device effectively reduces involuntary movements, it does not fully eliminate tremors, primarily due to limitations in the hardware and the efficiency of the implemented signal processing algorithms.
- Moreover, the use of servo motors introduces a slight delay in response time, likely attributed to the limited processing capacity of the Arduino and the complexity of the control code.
- Despite these limitations, the project successfully fulfilled its initial objectives, demonstrating that the integration of basic hardware components with intelligent algorithms can yield viable solutions to real-world medical challenges.
- Future enhancements in the device's performance could be achieved through advanced research, exploration of alternative hardware components, and further optimization of the control algorithms.

- Considering the rapid pace of technological development and the increasing innovation in assistive technologies, there is significant potential to design more efficient and user-friendly devices for individuals with neuromotor impairments.
- However, realizing this potential necessitates ongoing interdisciplinary research, proficient programming skills, and the application of advanced signal processing methods, all of which are vital to enhancing patient support and improving overall quality of life.
- Polylactic Acid (PLA), a biodegradable bioplastic derived from renewable resources such as corn starch or sugarcane, was selected as a primary material in the construction of the stabilized spoon. PLA is widely utilized in 3D printing due to its ease of processing, low melting point, and environmentally friendly characteristics. It is particularly suitable for this application owing to its lightweight nature, high dimensional accuracy, adequate rigidity for daily use, biocompatibility, and cost-effectiveness. These properties collectively contribute to the user's comfort, the device's durability, and overall functional safety.

## 5.2 Future Work

These advancements will aim to overcome current limitations and ensure the device meets the needs of users more effectively. The key areas for future work include:

### 1. Hardware Optimization

The current components of the device will be replaced with lighter and more compact materials to reduce its overall weight, thus improving comfort for prolonged use. Additionally, more responsive and precise servo motors will be integrated to provide faster reaction times, which will better counteract hand tremors.

### 2. Advanced Signal Processing

To improve the accuracy of tremor detection and compensation, more sophisticated filtering algorithms, such as Kalman filters and machine learning-based smoothing, will be implemented. The use of inertial measurement units (IMUs) with higher sensitivity will also be explored to enhance motion tracking.

### 3. Microcontroller Upgrade

The device will transition from the current Arduino microcontroller to more powerful systems such as Raspberry Pi, ESP32, or STM32. This upgrade will enable more complex computations and allow for faster real-time processing, enhancing the overall performance of the device.

### 4. Battery and Power Management

A more efficient power system will be designed to extend the battery life without increasing the size or weight of the device. This will ensure that the device can be used for longer periods throughout daily activities without frequent recharging.

### 5. Ergonomic Redesign

Further user-centered design testing will be conducted to optimize the shape, grip, and materials of the device. This redesign will focus on maximizing comfort and ease of use, especially for individuals with limited dexterity.

### 6. Software and User Interface

The development of a mobile app or desktop interface will be pursued, enabling caregivers or users to customize the sensitivity settings, monitor usage, and update the device's firmware.

### 7. Clinical Testing and Validation

Collaboration with medical professionals and rehabilitation centres will be sought to conduct clinical trials. This will provide valuable feedback from real users to validate the device's effectiveness and safety in real-world condition.

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