PC122 – B. tech Exploration Project

STEADY SPOON

GROUP - 42

Tolani Dhaval Satishbhai – 202401228
Topaliya Shlok Ashokbhai – 202401229
Trivedi Atharv Kartik – 202401230
Ughareja Niraj Dayalal – 202401231
Utkarsh Kumar – 202401232

INTRODUCTION

SteadySpoon is an innovative assistive device designed to address this problem by leveraging gyroscopic stabilization and real-time servo motor control to counteract hand tremors, allowing users to eat with confidence and minimal assistance.

The device utilizes an MPU6050 gyroscope sensor to detect hand movements in three-dimensional space, measuring the intensity and direction of tremors. This data is processed by a microcontroller (Arduino Nano/ESP32), which calculates the necessary corrective motions and drives servo motors to adjust the spoon's orientation dynamically. By continuously stabilizing the utensil, SteadySpoon ensures that food remains balanced on the spoon, significantly reducing spillage and enabling users to eat more comfortably.
In addition to tremor cancellation, the system incorporates adaptive control algorithms, such as PID (Proportional-Integral-Derivative) tuning, to fine-tune stabilization based on the user's unique tremor patterns. The device is powered by a rechargeable lithium-ion battery, making it portable and convenient for daily use. Its lightweight, ergonomic design ensures comfort during prolonged meals, while the 3D-printed handle provides a secure grip tailored for individuals with limited dexterity.

Our primary objective with SteadySpoon is to restore independence to Parkinson's patients, reducing their reliance on caregivers and improving their quality of life. Beyond practical functionality, this project explores the intersection of biomechanics, robotics, and embedded systems, offering valuable insights into how assistive technology can be optimized for real-world usability. By developing this device, we aim to contribute to the growing field of medical robotics, demonstrating how low-cost, sensor-driven solutions can make a meaningful difference in healthcare.

This project also serves as an educational platform, enhancing our skills in real-time sensor processing, control systems, and human-centered design. Through iterative testing and refinement, we are learning how to balance technical precision, energy efficiency, and user comfort—key factors in developing assistive devices that are both effective and accessible. Ultimately, SteadySpoon represents a step toward more inclusive technology, empowering individuals with motor impairments to regain control over their daily lives.

PROBLEM STATEMENT

1. Severity and Scale of the Condition (Size of the Problem)

- Parkinson’s disease affects millions globally and is one of the most common neurodegenerative disorders.
- It progressively worsens over time, significantly reducing patients' ability to perform daily activities independently.

2. Impact on Daily Usage and Functionality

- Eating is one of the most affected daily activities due to hand tremors.
- Tremors make it difficult to hold utensils steady, directly affecting nutritional intake and mealtime independence.

3. Physical and Emotional Strain

- Frequent food spillage leads to frustration, embarrassment, and reduced confidence during social eating situations.
- Loss of control over basic functions contributes to emotional distress and a sense of dependency.

4. Loss of Independence

- Patients often rely heavily on caregivers during meals, which can diminish their sense of autonomy and burden their support systems.

5. Ergonomic and Usability Challenges

- Many elderly or disabled users struggle with bulky or complex devices.
- Any solution needs to be lightweight, intuitive, and ergonomically designed to accommodate limited dexterity.

HARDWARE DESIGN AND MATERIAL SELECTION

The hardware design of the SteadySpoon is focused on achieving real-time tremor compensation using cost-effective components, ensuring ergonomic comfort, ease of use, and portability. The following is a detailed breakdown of the primary hardware elements and materials used:

1. Microcontroller Unit

- **Component:** Arduino Nano / ESP32
- **Function:** Serves as the central processing unit, interpreting sensor data and controlling the servo motors in real time.
- **Features:** Compact, low power, with sufficient I/O pins for interfacing sensors and actuators.

2. Motion Sensor

- **Component:** MPU6050 (Gyroscope + Accelerometer)
- **Function:** Detects tremors by measuring angular velocity and acceleration along three axes (X, Y, Z).
- **Output:** Sends real-time motion data to the microcontroller for stabilization processing.

3. Actuators

- **Component:** Micro Servo Motors (SG90 or MG90S) – typically 2 units
- **Function:** Actively adjust the spoon’s orientation by countering tremor movements through controlled angular shifts.

- **Placement:** One motor control horizontal motion (pitch), the other controls vertical motion (roll).

4. Structural Frame

- **Component:** 3D-Printed Casing and Handle
- **Material:** PLA or ABS plastic
- **Function:** Houses internal electronics and provides a comfortable, ergonomic grip. Designed to be lightweight, durable, and easily customizable for users with limited hand mobility.

5. Power Supply

- **Component:** Rechargeable Lithium-Ion Battery (3.7V, 1200–2200mAh)
- **Function:** Powers the entire system for portable, cordless operation.

6. Interfacing and Connectors

- **Components:** Jumper wires, soldered headers, screw terminals
- **Function:** Connect various components like the MPU6050, servos, and battery to the microcontroller securely.

Design Considerations

- **Weight Distribution:** Balanced design to avoid user fatigue during prolonged use.
- **Compactness:** Minimalist layout to reduce bulk while maintaining functionality.
- **Modularity:** Components are detachable for easy maintenance and upgradation.
- **Safety:** Enclosed wiring and rounded shell edges to prevent injury or shock.

ELECTRICAL COMPONENTS

1. Arduino Nano / ESP32 (Microcontroller Unit)

- **Description:** The brain of the project, responsible for processing sensor data and controlling actuators.
- **Why It's Used:**
    - Reads input from the gyroscope sensor (MPU6050).
    - Runs the stabilization algorithm (e.g., PID control).
    - Sends precise control signals to servo motors.
    - ESP32 is also preferred if wireless communication (like Bluetooth/Wi-Fi) or higher processing speed is required.

2. MPU6050 (Gyroscope + Accelerometer Sensor)

- **Description:** A 6-axis motion tracking device that combines a 3-axis gyroscope and a 3-axis accelerometer.
- **Why It's Used:**
    - Detects hand tremors by capturing rotational and linear motion in real time.
    - Provides crucial data for calculating compensatory motor actions to stabilize the spoon.

3. SG90 / MG90S Micro Servo Motors

- **Description:** Compact servo motors capable of precise angular movement (up to 180° rotation).
- **Why They're Used:**
    - Adjust the orientation of the spoon based on real-time tremor data.

    - Provide fast, accurate movements necessary for real-time stabilization.
    - MG90S is a metal gear variant for higher durability under load.

◇ 4. Rechargeable Lithium-Ion Battery (3.7V, 1200–2200mAh)

- **Description:** A lightweight, portable power source that can be recharged and reused.
- **Why It's Used:**
    - Enables cordless, mobile use of the device.
    - Supports prolonged usage (1–2 hours or more depending on capacity).
    - Lightweight and compact, ideal for handheld applications.

◇ 5. Voltage Regulator (Optional, e.g., AMS1117 5V)

- **Description:** Maintains a stable voltage output to protect sensitive components.
- **Why It's Used:**
    - Ensures that the microcontroller and servos receive a consistent voltage supply.
    - Prevents damage due to battery voltage fluctuations.

◇ 6. Switch and Charging Circuit (TP4056 Module)

- **Description:** A switch is used to power the device on/off; TP4056 is a Li-ion charging module.
- **Why They're Used:**
    - Switch allows users to easily operate the device.

- TP4056 safely recharges the battery via USB without needing external circuitry.

7. Wires, Connectors, and PCB/Breadboard

- **Description:** Standard electrical connectors and a base for circuit assembly.
- **Why They're Used:**
  - Facilitate reliable and organized electrical connections.
  - Allow compact and tidy assembly inside the handle of the spoon.

SOFTWARE ALGORITHM

The software algorithms for the **SteadySpoon** are designed to enable real-time stabilization, optimize motor responses, and ensure adaptive compensation of hand tremors. These algorithms form the core of the spoon's intelligent response system, coordinating sensor data processing, actuator control, and system stability.
By integrating motion detection, PID-based motor control, and power-efficient operation, the system continuously adjusts the spoon's position to counteract unintended hand movements. This allows the device to maintain a stable utensil orientation, thereby improving the user's ability to eat independently and confidently.

- **Key Functional Algorithms:**

1. Sensor Data Acquisition

- Continuously reads gyroscopic and accelerometric data from the MPU6050.
- Converts raw motion data into meaningful angular velocities and displacements.

2. Noise Filtering & Smoothing

- Applies digital filtering (e.g., low-pass filter or moving average) to remove sensor noise and prevent jittery motion responses.

3. PID Control Algorithm

- Implements Proportional-Integral-Derivative (PID) control to calculate the necessary corrective motor movement.
- Dynamically adjusts motor angles to counteract tremors, keeping the spoon steady.
- PID parameters (Kp, Ki, Kd) are fine-tuned based on user-specific tremor patterns.

4. Servo Motor Control

- Converts PID output to PWM signals to drive the servo motors.
- Motors smoothly adjust spoon orientation in real time to oppose the detected tremor axis.

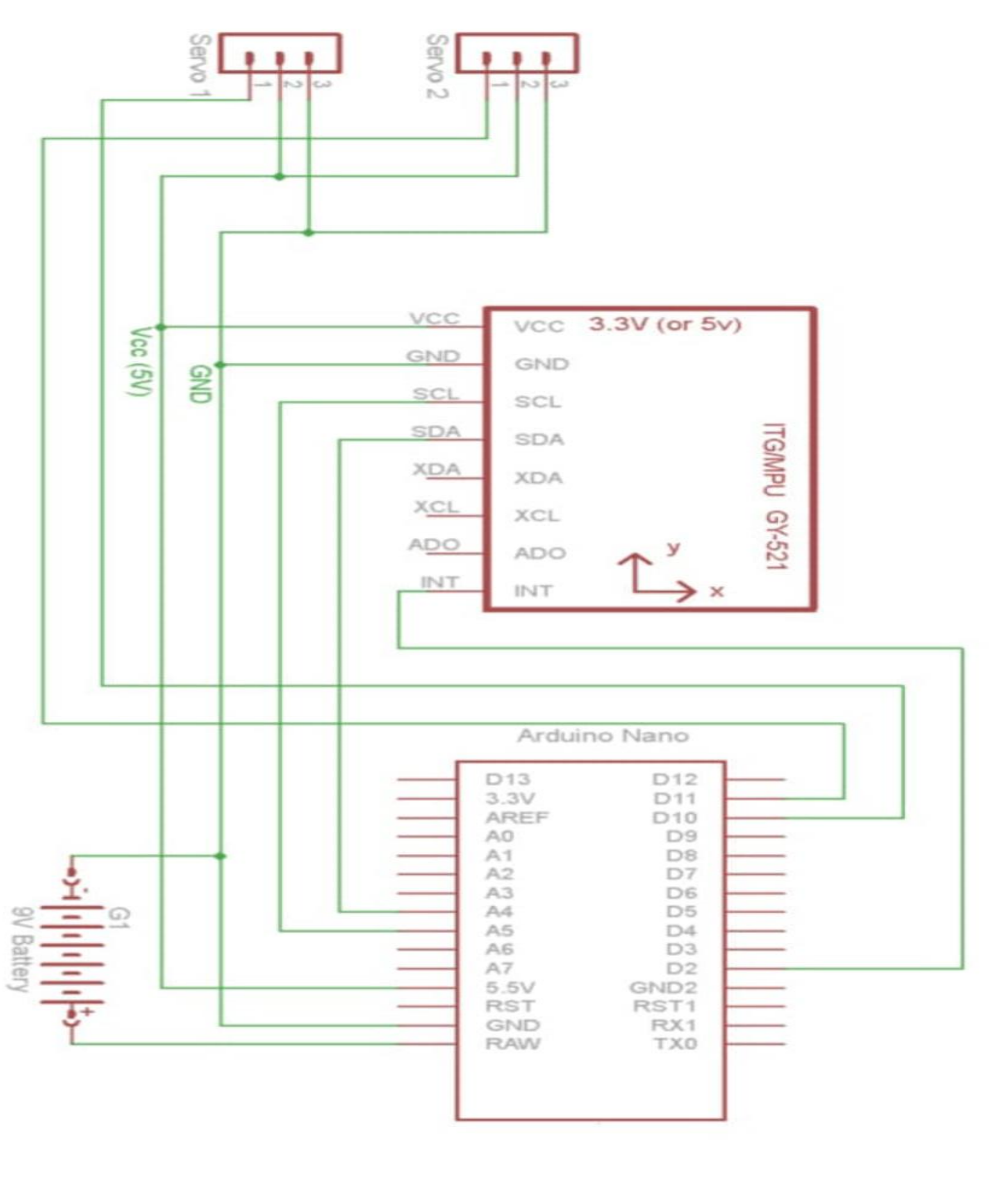
5. Calibration and User Adaptation

- Includes a startup calibration routine to initialize neutral positioning.
- May include long-term learning (in advanced versions) to adapt to individual tremor patterns over time.

-> Software Platform

- **Programming Language:** C/C++ using Arduino IDE or ESP-IDF
- **Development Tools:** Arduino IDE / PlatformIO
- **Libraries Used:**
  - Wire.h – I2C communication with MPU6050
  - Servo.h – Control servo motor angles
  - MPU6050.h – Sensor interface
  - PID_v1.h – PID control implementation

CIRCUIT DIAGRAM



COST ESTIMATION

Component	Quantity	Unit Price (₹)	Total (₹)
Arduino Nano	1	₹2500/ 3000	₹2500/ 3000
MPU6050 (Gyroscope + Accelerometer)	1	₹1200	₹1200
SG90 Servo Motor	2	₹200	₹400
3.7V 1200mAh Li-ion Battery	1	₹150	₹150
TP4056 Charging Module (Micro USB)	1	₹14	₹14
Spoon and Casing	~100g	₹300	₹300
Miscellaneous (Wires, Switch, Breadboard, etc.)	-		₹500- 1000
Total Estimated Cost			**₹6,064**

CONCLUSION

The SteadySpoon project presents an innovative and practical solution to a common challenge faced by individuals with Parkinson's disease and similar motor disorders. By integrating real-time motion sensing, intelligent control algorithms, and compact actuation systems, the device successfully stabilizes hand tremors and restores the user's ability to eat independently. The use of cost-effective components such as the MPU6050 sensor, Arduino microcontroller, and micro servo motors ensures that the solution remains accessible and affordable for a wider population.

Beyond its technical achievements, this project highlights the importance of human-centered design in assistive technology. It not only enhances the quality of life for users but also reduces the dependency on caregivers, promoting autonomy and dignity. Furthermore, the development process provided valuable experience in embedded systems, control theory, and ergonomic design, laying the foundation for future advancements in medical robotics.

In summary, SteadySpoon demonstrates how thoughtful engineering, and low-cost innovation can make a meaningful impact in the healthcare domain, empowering individuals with tremors to regain control over everyday tasks.

REFERENCES

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4.) Wikipedia