Active Tremor Compensation Spoon (ATCS)

Project Synopsis

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by

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Abstract

Parkinson's disease and essential tremor disorders significantly affect a person's ability to perform basic daily activities, particularly eating, due to involuntary hand movements. The Active Tremor Compensation Spoon (ATCS) is proposed as a low-cost, assistive device designed to stabilize a spoon in real time and improve eating independence for individuals suffering from hand tremors. The system utilizes an inertial measurement unit (IMU) to detect multidirectional tremor motion and a microcontroller to process these signals. Based on the detected disturbance, miniature servo motors generate counteracting movements that actively compensate for the tremor, thereby maintaining the spoon in a relatively stable orientation.

The project focuses on developing an embedded control mechanism capable of distinguishing intentional hand motion from involuntary oscillations. A feedback-based stabilization algorithm is implemented to ensure smooth and rapid response with minimal latency. The device is designed to be lightweight, ergonomic, and affordable so that it can be practically adopted by patients in everyday life. Unlike commercially expensive solutions, ATCS emphasizes cost-effective components and an open-source design approach to encourage further research and customization.

This project aims to demonstrate how embedded systems and control engineering can be applied to biomedical assistive technology. Successful implementation of ATCS is expected to enhance the quality of life for Parkinson's patients by restoring confidence during meals and reducing dependence on caregivers. The proposed prototype serves as a foundation for future improvements such as adaptive learning algorithms, miniaturization, and integration with other assistive utensils.

Chapter 1

Introduction

Parkinson's disease and essential tremor disorders severely affect hand stability, making routine activities such as eating extremely difficult for patients. Involuntary oscillatory movements of the hand reduce the ability to hold utensils steadily, often resulting in food spillage, frustration, and increased dependence on caregivers. Although medications and therapies help in managing symptoms, they do not fully eliminate tremors, particularly during precise tasks that require fine motor control. Commercial stabilizing spoons are available in the market, but they are expensive and not easily accessible to a large population, especially in developing regions. This creates a strong need for an affordable, portable, and effective assistive device that can help patients regain independence during meals and improve their quality of life.

Figure 1.1 illustrates the proposed project, Active Tremor Compensation Spoon (ATCS), presents a low-cost embedded solution to address this problem. The system utilizes an MPU6050 IMU sensor to detect real-time hand tremor in multiple axes, while an Arduino Nano microcontroller processes the motion data and distinguishes between intentional movement and involuntary vibrations. Based on this analysis, MG90 servo motors generate counteracting motion to stabilize the spoon and maintain a steady orientation. A feedback-based control algorithm is implemented to ensure quick response with minimal latency. The device is designed to be lightweight, ergonomic, and economical so that it can be used practically everyday. This project demonstrates the application of electronics and control engineering in assistive healthcare, providing an accessible alternative to costly commercial products

1.1 Active Tremor Compensation Spoon (ATCS)

The Active Tremor Compensation Spoon (ATCS) is proposed as a compact embedded system aimed at reducing the effect of hand tremors during eating. The solution is based on the concept of active stabilization, where involuntary hand movements are sensed in real time and mechanically counteracted to maintain the spoon in a steady orientation. The device integrates sensing, processing, and actuation units into a single portable module that can be easily used by patients without requiring any technical expertise.

The system employs an MPU6050 IMU sensor to capture hand motion along multiple axes. These signals are sent to an Arduino Nano microcontroller, which processes the data and identifies tremor-like oscillations. A control algorithm running on the microcontroller determines the amount of correction required and generates appropriate commands for the actuators. This closed-loop approach enables the device to respond dynamically to varying tremor intensity rather than providing only passive support.

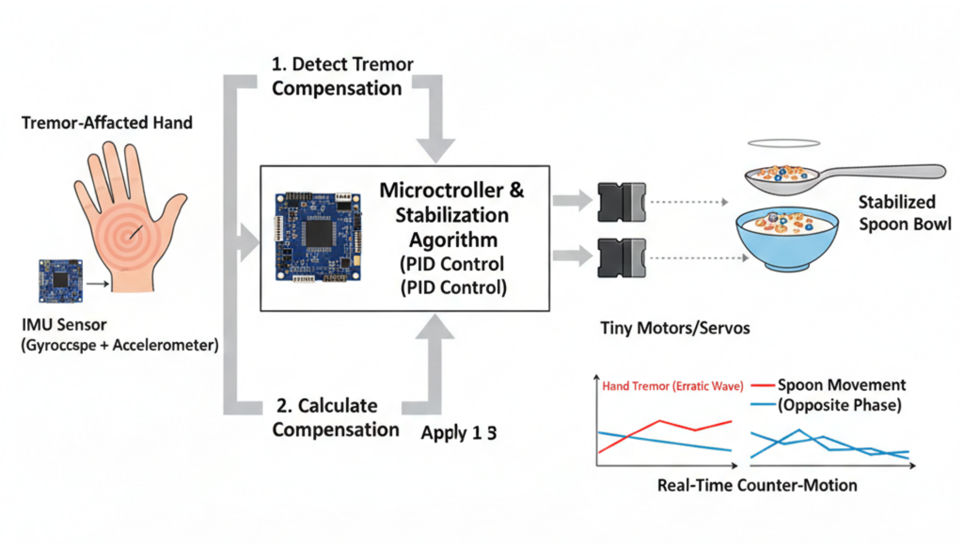

Figure 1.1: Generalized overview of the proposed project

For actuation, MG90 servo motors are used to tilt the spoon in the opposite direction of the detected disturbance. The mechanical structure is designed to be lightweight, ergonomic, and safe for daily use. The overall solution emphasizes affordability and simplicity so that it can serve as an accessible alternative to expensive commercial stabilizing spoons. The modular nature of the design also allows future enhancements such as advanced filtering techniques and adaptive control.

Thus, the proposed solution demonstrates how embedded electronics and control principles can be utilized to create a practical assistive aid that helps Parkinson's patients eat with greater independence and confidence.

Chapter 2

Literature Review

The literature review provides an overview of existing research, methodologies, and approaches related to tremor-stabilizing assistive devices for Parkinson's patients. It helps in understanding the current state of work in the domain of active tremor suppression, identification of motion patterns using IMU sensors, and embedded control techniques used in adaptive utensils. A thorough review ensures that the proposed project is relevant, technically justified, and addresses the limitations of earlier solutions.

2.1 Overview of Existing Work

Several researchers have worked on improving the ability of Parkinson's patients to perform activities of daily living, particularly eating. Earlier approaches mainly relied on passive methods such as weighted spoons and mechanical dampers, which reduced tremor only to a limited extent. With the development of low-cost microcontrollers and motion sensors, recent studies have shifted toward active stabilization using IMU-based sensing and servo actuation. The reviewed works focus on tremor detection, signal filtering, control algorithms, and ergonomic utensil design.

2.2 Review of Selected Literature

2.2.1 Self-Stabilizing Parkinson's Spoon

Anand et al. [1] presented the design of a self-stabilizing spoon using an IMU sensor and microcontroller to counteract hand tremor. The study emphasized real-time motion acquisition and servo-based correction to maintain spoon orientation. Experimental results showed noticeable reduction in food spillage; however, the system required careful calibration and was sensitive to sudden voluntary movements.

2.2.2 Design and active stabilization control of two DoF robotic eating devices for hand tremor patients.

Talaei and Kargar [2] proposed a device for reducing hand tremor during eating using accelerometer-gyroscope fusion and a fuzzy PI controller. Their approach achieved significant vibration attenuation without increasing the weight of the utensil. The limitation of the work was higher algorithmic complexity and dependence on precise sensor tuning.

2.2.3 Design and Fabrication of a Device for Reducing Hand Tremor in Parkinson Patients during Eating.

Another work on robotic eating aids [3] utilized a two-degree-of-freedom mechanism with PID control to compensate for tremor motion. The authors demonstrated that active control outperforms passive weighted spoons. Nevertheless, the prototype was relatively expensive and not suitable for low-cost mass adoption.

2.3 Literature Comparison

To understand the differences among existing approaches, a comparative analysis is presented.

Table 2.1: Comparison of Existing Literature

Ref.	**Methodology**	**Key Features**	**Limitations**
[1]	IMU + Servo Stabilization	Real-time correction, simple design	Very sensitive
[2]	Fuzzy PI Control	High tremor reduction	Complex tuning
[3]	PID-based Robotic Spoon	Accurate stabilization	High cost

2.4 Technique-Based Comparison

A technique-oriented comparison is shown in table below, highlighting tools, evaluation parameters, and outcomes used in previous studies.

Table 2.2: Technique-Based Literature Comparison

Author	**Tools / Techniques**	**Evaluation Criteria**	**Outcome**
Author et al[1]	MPU6050, MCU, Servos	Spillage reduction	Improved eating stability
Author et al[2]	Sensor fusion, Fuzzy PI	Tremor attenuation	70–75% reduction
Author et al[3]	PID control, 2-DOF	Vibration suppression	High accuracy

2.5 Research Gap and Motivation

From the reviewed literature it is observed that most existing solutions are either expensive commercial products or research prototypes with complex control requirements. Passive weighted spoons are affordable but ineffective for severe tremor, while active systems provide better results at the cost of high price and proprietary design. Very few studies focus on a low-cost, open, student-buildable system using easily available components.

These gaps provide the motivation for the proposed Active Tremor Compensation Spoon (ATCS), which aims to develop an economical solution using MPU6050 IMU, Arduino Nano, and MG90 servos with a simple feedback algorithm that balances performance, cost, and practical usability.

Chapter 3

Methodology

This chapter describes the proposed methodology for implementing the Active Tremor Compensation Spoon (ATCS). It outlines the systematic workflow adopted to sense hand tremor, process motion data, and generate stabilizing action using servo actuators. The methodology is designed to ensure real-time operation, low latency, and practical feasibility for daily use.

3.1 Overall Methodology

The proposed methodology follows a sequential process consisting of:

[1].Input acquisition – capturing hand motion using MPU6050 IMU

[2].Preprocessing – filtering noise and separating voluntary motion

[3].Core processing – tremor detection and control computation

[4].Output generation – actuation using MG90 servos

This structured pipeline enables the system to react instantly to involuntary oscillations while allowing intentional hand movement for normal eating actions.

Figure 3.1 presents a generalized flowchart of the proposed methodology.

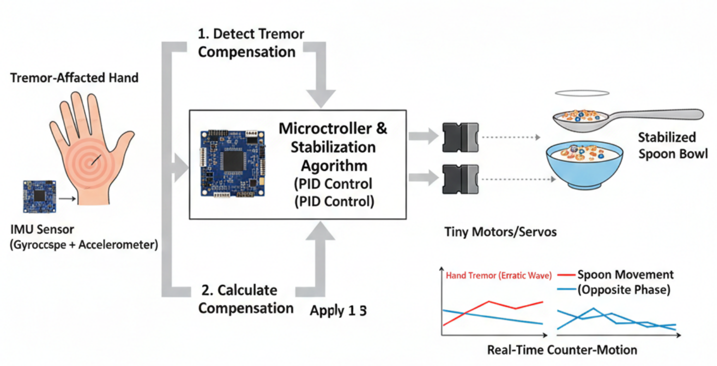

Figure 3.1: Flowchart of the proposed methodology

3.2 System Architecture

The system consists of sensing, processing, and actuation units interconnected through the Arduino Nano microcontroller.

Table below lists the primary system components and their respective functions.

Table 3.1: System Architecture Components

Component	Description
Input Unit	MPU6050 IMU acquires acceleration and angular velocity
Preprocessing Unit	Noise filtering and drift removal
Processing Unit	Tremor detection and control calculation
Decision Unit	Determines servo correction angle
Output Unit	MG90 servos stabilize the spoon

3.3 PID Control Formulation

Let the desired stable orientation of the spoon be represented as θ_d and the measured orientation obtained from the MPU6050 IMU be θ_m. The instantaneous error signal is defined as:

$$e(t) = \theta_d - \theta_m \tag{3.1}$$

The PID controller generates a correction signal $u(t)$ for the MG90 servo motors as the sum of proportional, integral, and derivative terms:

$$u(t) = K_p\, e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de(t)}{dt} \tag{3.2}$$

where, K_p – proportional gain, K_i – integral gain, K_d – derivative gain.

The discrete-time implementation used in the Arduino Nano is expressed as:

$$u[k] = K_p\, e[k] + K_i \sum_{i=0}^{k} e[i]\, T + K_d \frac{e[k] - e[k-1]}{T} \tag{3.3}$$

where T is the sampling period of the control loop.

The servo actuation angle θ_s is obtained by mapping the controller output to the allowable range of the MG90 servo:

$$\theta_s = \text{constrain}(u[k], \theta_{\min}, \theta_{\max}) \tag{3.4}$$

This control law enables the spoon to generate motion opposite to the detected tremor, thereby maintaining a stable orientation during eating.

3.4 Proposed Algorithm

The logical sequence of operations followed in the proposed methodology is described using pseudocode. This representation helps in understanding the flow of execution without focusing on implementation-specific details.

Algorithm: Proposed Methodology Template
START

Input: IMU data (ax, ay, gx, gy)
Output: Servo correction angles

Step 1: Initialization
Initialize MPU6050 and MG90 servos
Set threshold T and gain K

Step 2: Data Acquisition
Read accelerometer and gyroscope values

Step 3: Preprocessing
Apply moving average filter
Remove DC drift

Step 4:Tremor Detection
If signal greater than T
Tremor = TRUE
Else
Tremor = FALSE

Step 5: Correction
Angle = K × filtered-signal
Move servos opposite to motion

Step 6:Loop continuously

END

3.5 Summary

This chapter presented the methodology for the ATCS project, describing the workflow, architecture, mathematical model, and control algorithm. The structured approach ensures real-time tremor compensation using MPU6050 sensing, Arduino Nano processing, and MG90 servo actuation, which will be implemented and tested in the subsequent phase.

References

[1] Kshitij Patne Saloni Anand. *Self-Stabilizing Parkinson's Spoon*. Tech. rep. IJRASET44758. International Journal for Research in Applied Science Engineering Technology (IJRASET), 2022.

[2] Kargar Talaei. *FiMec tremor stabilization spoon: design and active stabilization control of two DoF robotic eating devices for hand tremor patients*. Tech. rep. PMID: 37479895. PubMed, 2023.

[3] Kargar SM Talaei F. *Design and Fabrication of a Device for Reducing Hand Tremor in Parkinson Patients during Eating*. Tech. rep. PMID: 37292439; PMCID: PMC10246595. J Med Signals Sens, 2023.