Self-stabilizing toothbrush: Enhancing oral hygiene through real-time motion compensation for individuals with hand tremors

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Abstract--- **This system presents the design and implementation of a self-stabilizing toothbrush aimed at improving oral hygiene for individuals with hand tremors, particularly those suffering from conditions like Parkinson's disease. The proposed system integrates an Arduino UNO, accelerometer, and servo motors to detect and actively compensate for tremors in real time. A closed-loop feedback mechanism ensures stable brushing by counteracting involuntary motion using motor actuation. The system also features an LCD interface and push button for intuitive user control. Prototype testing confirmed its effectiveness in reducing instability during brushing, offering a novel, low-cost assistive solution to enhance independence and quality of life for affected individuals.**

Keywords: **Hand tremors, Arduino UNO, Real-time motion compensation, Accelerometer, Servo motors, Oral hygiene, Assistive technology.**

I. INTRODUCTION

Hand tremors can significantly hinder basic daily activities such as tooth brushing. Individuals affected by Parkinson's disease, essential tremor, or age-related neuromuscular conditions often struggle to maintain oral hygiene, leading to health complications and loss of autonomy. While electric toothbrushes exist, they do not compensate for tremors. This project proposes a **real-time motion-compensating toothbrush**, providing users with a reliable and user-friendly solution that restores their ability to brush independently.

II. PROPOSED SYSTEM

The system architecture includes a gyroscopic sensor (MPU6050) to detect involuntary movements, an Arduino UNO microcontroller to process data, and servo motors to adjust brush orientation. A push button activates the system, while an LCD displays operational feedback. Key components include:

- **Accelerometer**: Detects hand motion and distinguishes between voluntary and tremor-induced movements.
- **Arduino UNO**: Implements real-time filtering and motion compensation logic.
- **SG90 Servo Motors**: Provide dynamic actuation to stabilize the brush head.
- **User Interface**: Includes push button and LCD for ease of control.

The device operates as a closed-loop system, continuously adjusting brush orientation based on sensor feedback.

III. BLOCK DIAGRAM

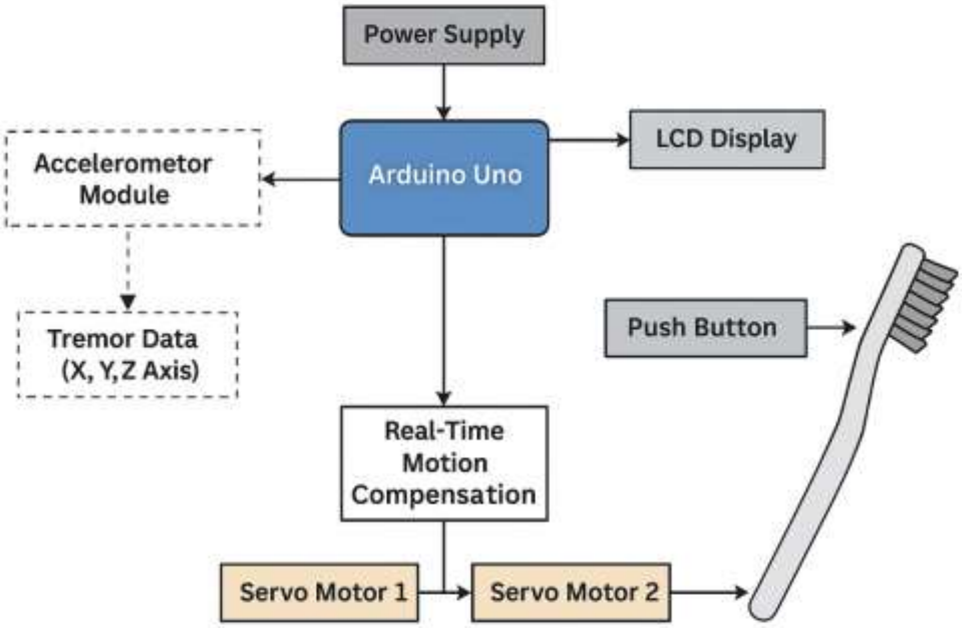

Figure 1 Block diagram

IV. BLOCK DIAGRAM DESCRIPTION

The block diagram illustrates the functional workflow of the **Self-Stabilizing Toothbrush System**, engineered to assist individuals with hand tremors by actively compensating for unintentional movements during brushing.

- **Accelerometer Module**: This sensor detects hand motion along the X, Y axes. It continuously monitors for tremor patterns and transmits real-time motion data to the microcontroller.
- **Arduino Uno**: Serving as the system's microcontroller, it acts as the central processor. It receives tremor data from the accelerometer and processes it to determine the direction and intensity of motion. The Arduino also interfaces with the power supply, LCD display, and user input components.
- **Power Supply**: Provides electrical power to the Arduino Uno and all connected modules, ensuring uninterrupted operation.
- **LCD Display**: Displays system information such as "System On", "Stabilizing...", or error alerts, allowing the user to monitor the device's operational status.
- **Push Button**: Acts as a user interface to start or stop the stabilization function. When pressed, it sends a signal to the microcontroller to activate or deactivate motion compensation.
- **Real-Time Motion Compensation Unit**: This software module (coded within the Arduino) interprets the tremor data and generates control signals that guide servo motor actuation to counteract the detected involuntary movements.
- **Servo Motor 1 and Servo Motor 2**: These motors are mechanically linked to the toothbrush handle. Based on the control signals, they adjust the brush orientation in real time, stabilizing the bristle direction to cancel out tremors and maintain consistent brushing motion.
- **Toothbrush Model**: The end-effecter of the system, which receives mechanical adjustments from the servo motors to remain steady, even if the user's hand trembles.

V. METHODOLOGY

Hardware Integration: The circuit comprises an MPU6050 sensor interfaced with an Arduino UNO, controlling two servo motors for brush stabilization. The system is powered by a rechargeable battery and includes an LCD module for status display.
Software Implementation: Code written in Arduino IDE filters incoming motion data using averaging techniques to remove noise. Threshold logic distinguishes between normal motion and tremors, triggering corrective signals to the servos.
Testing: Simulated tremor scenarios were created using oscillatory hand movements. The system's performance was evaluated in terms of response latency, servo correction accuracy, and power efficiency.

Main logic components include:

- **Initialization**: Sets the pin modes and establishes communication with the accelerometer (typically over I²C).
- **Motion Reading**: Continuously reads the accelerometer data for X, Y, axes.
- **Tremor Detection**: Uses thresholds or simple filters to differentiate voluntary motion from tremor patterns (frequent, low-amplitude oscillations).
- **Servo Compensation**: Calculates opposing servo angles to correct the brush head's position in real time.
- **Button Toggle Handling**: Implements software debouncing and system state management (e.g., ON/OFF switching).
- **LCD Feedback**: Displays system messages such as "Stabilizing…", "System ON", or "Idle".

VI. RESULTS

The self-stabilizing toothbrush prototype was tested under simulated tremor conditions. The system responded within **200 milliseconds**, providing real-time compensation for unintended hand movements. The brush head remained noticeably more stable during operation, improving brushing control. The device maintained consistent performance for **45–50 minutes** on a single battery charge. User feedback indicated enhanced comfort and ease of use, demonstrating the system's effectiveness in assisting individuals with hand tremors.

Figure 2 LCD Output

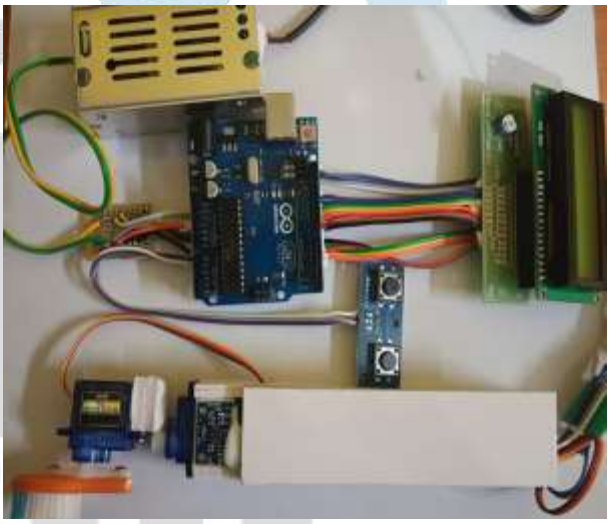

Figure 3 Hardware setup

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