IMABOT : ESP32-Based Assistive Desk Bot for ADHD Support

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***Abstract*—This paper describes the development of IMABOT, an ESP32-based assistive desk bot designed to help students with Attention Deficit Hyperactivity Disorder (ADHD) with their studies. As they often struggle with focus, impulsivity, and task organization, people with ADHD may find it difficult to maintain productive study sessions. IMABOT addresses these problems by integrating a Pomodoro timer, an auditory alert system, and real-time communication via a mobile application. The ESP32 microcontroller enables seamless communication between the app and the bot, allowing users to customize study schedules and control movement. Through structured guidance, interactive participation, and support during solo study sessions, IMABOT is a useful tool for students with ADHD that improves focus, task management, and study support.**

***Index Terms*—ADHD, Pomodoro timer,real-time interaction, assistive desk bot**

I. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a widespread issue that impacts millions of people worldwide, with a high percentage going undiagnosed. This is especially the case among students, where students are typically faced with challenges like poor academic performance, executive functioning deficits, and procrastination tendencies. However, with the right kind of support and companionship, assistive robots have been found to possess tremendous potential in helping such students with organization and attention. Academic research has shown the benefits of assistive technology in helping people with ADHD improve engagement and task management, with the necessity of creating user-centered solutions that engage people throughout the development process.

Research has proven that socially assistive robots (SARs) are well accepted by students. 91 percent chose to continue using them after a test period [13]. This article introduces IMABOT, a desk robot specifically designed to assist students with ADHD in overcoming challenges. Traditional study methods can be useless for these individuals, hence there is a need for aids that offer guided and interactive support to remain on course and productive.

IMABOT possesses fundamental features like a Pomodoro timer, an audio alert (buzz) system, and a mobile application that supports real-time interaction. The robot, driven by the ESP32 microcontroller, enables users to direct its motion, modify study sessions, and obtain immediate feedback. The OLED screen offers visual indicators of activities, while the dynamic robot gestures enhance interactivity and provide positive reinforcement to the student.

By coupling time management ability with interactive feedback, IMABOT provides a helpful and adaptable intervention for students with ADHD.

II. Literature Review

Attention Deficit Hyperactivity Disorder (ADHD) is a common phenomenon in university students since it is characterized by procrastination, inattention, and impaired executive functioning [3]. Studies have identified a recurring connection between procrastination, symptoms of ADHD, and avoidance of tasks, all of which stem from impaired goal-directed action and self-regulation [14]. The use of technologies, including socially assistive robots (SARs), has been explored as potential interventions to increase task engagement and concentration in ADHD individuals.

Research and studies show that the presence of another, human or robot, enhances performance of familiar tasks but prevents learning of complex skills [4]. Robotic support research for ADHD students, like Atent@, a homework robot

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companion, shows positive results in controlled settings [5]. Similarly, KIP3, a robot buddy, aids ADHD students' concentration on homework, reminding them of better concentration [6]. Research links ADHD, procrastination, social facilitation, assistive technologies, and dorm robots to design a socially assistive robot (SAR) study aid for ADHD university students. Current research affirms that ADHD symptoms lead to more procrastination due to executive function deficits in planning, motivation, and self-regulation [7]. The "body doubling" technique, where one works with an additional for accountability, has potential to help complete assignments for neurodivergent students [9]. Social facilitation theory assumes that performance with others enhances easier tasks but lowers harder tasks due to social inhibition [5]. Current research also supports that robots enhance performance in addition to human presence [8], showing that SARs are viable tools for ADHD support. Assistive technology, like virtual reality and robotic support like KIP3 [6], has been studied for ADHD remediation but few have examined SARs for college practicality. Further, in-dorm robot research has yielded inconsistent findings; while robotic pets became more the norm over time[10], interactive robots like Jibo enhanced students' psychological well-being [20].Since long-term SAR research for ADHD university students is not prevalent, this study aims to fill the gap by assessing a SAR study companion that was designed to enhance concentration and study habits through passive social presence.

III. Overall System and its components

A. Algorithm Overview

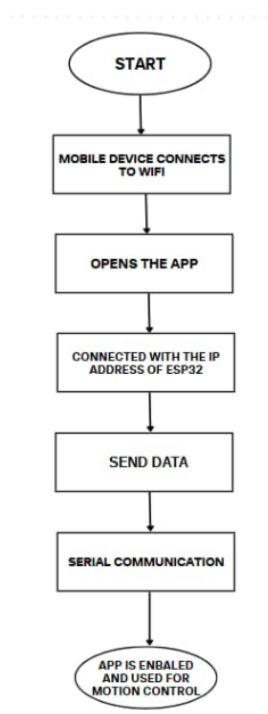

Fig. 1. *Software Algorithmic Flow*

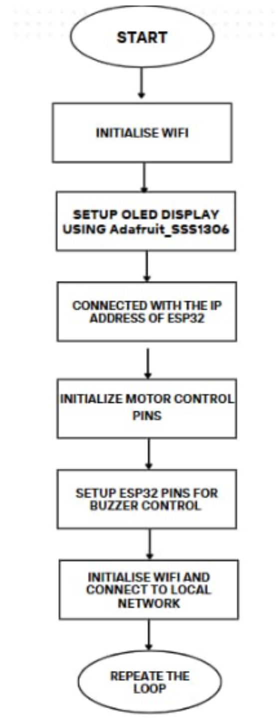

Fig. 2. *Hardware Algorithmic Flow*

1) **Initialize components:** The system initializes all necessary components, including the battery, DC-DC converter, N20 motors, motor driver, and OLED display.
2) **Battery connection:** The 7V LiPo battery is connected to the system and begins supplying power.
3) **DC-DC converter operation:** The DC-DC step-down converter receives the 7V input from the battery and converts it to a stable 5V output.
4) **Powering the ESP32:** The 5V output from the DC-DC converter is supplied to the VCC pin of the ESP32 microcontroller.
5) **User input:** The ESP32 receives commands from the user via Wi-Fi or Bluetooth.
6) **Command processing:** The ESP32 processes the received commands and generates control signals.
7) **Motor driver control:** The control signals are sent to the LN298N motor driver to regulate motor operation.
8) **OLED display updates:** The ESP32 also sends data and control signals to the OLED display, which shows relevant information based on the signals received.
9) **Motor operation:** The motor driver uses the control signals to control the direction and speed of the N20 motors.

B. Key Components

a) **ESP32 Microcontroller**

The ESP32 is the central control unit, handling sensor data, motor control, and display updates. Its built-in Wi-Fi and Bluetooth enable wireless communication, while FreeRTOS support allows smooth multitasking for real-time operations.

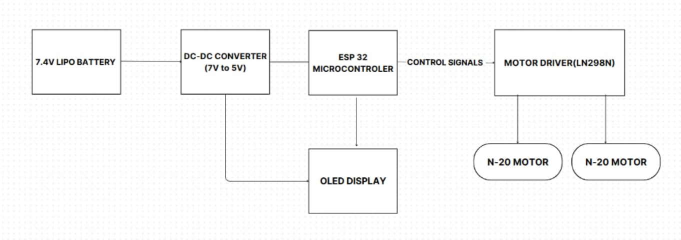

Fig. 3. *General Block Diagram*

b) **L298N Motor Driver**
This dual H-bridge driver controls two DC motors, managing both speed and direction via PWM signals from the ESP32. It delivers up to 1.2A per channel and works within 4.5V–13.5V, making it ideal for small robotics projects.

c) **DC-DC Step Down Converter**
A buck converter steps down the 7.4V from the LiPo battery to 5V, ensuring stable power for the ESP32 and sensors. This protects low-voltage components and helps maintain system efficiency.

d) **OLED Display (SSD1306, I2C Interface)**
This 0.96” OLED display shows task timers, reminders, and system data. It communicates via I2C, offers excellent contrast, and consumes little power—ideal for portable, battery-powered systems.

e) **7.4V LiPo Battery**
A lightweight, high-density 2-cell LiPo battery powers the entire system. It ensures consistent energy delivery for motors and electronics, supporting extended untethered use.

f) **N20 Gear Motors**
These compact DC gear motors provide high torque with low power consumption. Controlled via PWM, they offer precise movement and are perfect for differential drive in small robots like IMABOT.

Additionally, a custom mobile app was developed using MIT App Inventor—a free, open-source platform. The app enables real time control i.e directional control and seamless communication with the bot via the ESP32’s Bluetooth capability. It features a minimalistic, user-friendly interface designed to be intuitive and distraction-free.

IV. Hardware Implementation

1) ESP32 Software (Arduino IDE): The software running on the ESP32, developed using the Arduino IDE, manages several key functionalities for controlling the robot.

2) OLED Display Control:

- **Initialization:** The OLED display is set up using a library like Adafruit_SSD1306, with communication through I2C. Basic settings such as screen size and resolution are configured.
- **Blinking Eyes:** The robot’s ”attention” is displayed on the OLED with blinking eyes. The program defines different eye states (open, closed, partially closed) and controls the blink effect using `millis()` for non-blocking timing. Random intervals make the blinking look more natural. The OLED updates periodically to reflect the current eye state.

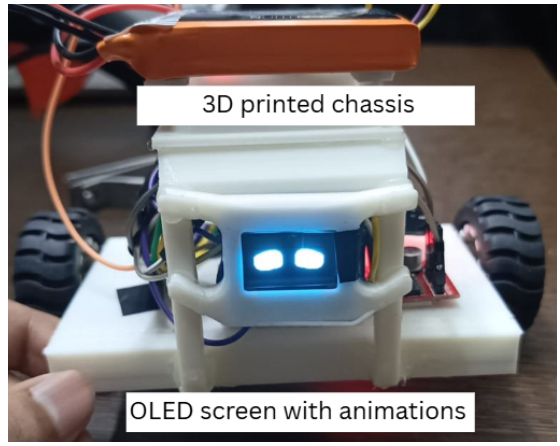

Fig. 4. *Hardware Prototype*

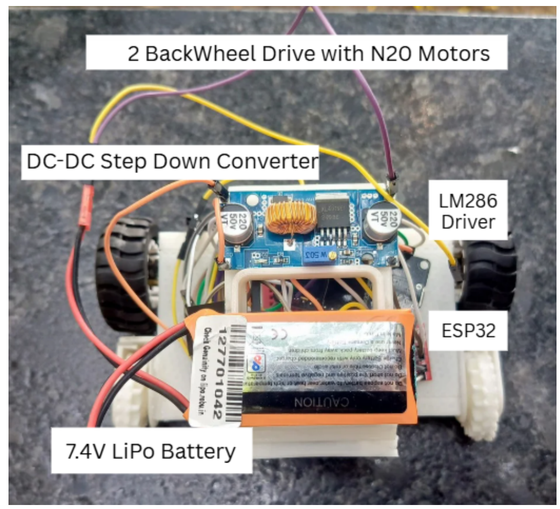

Fig. 5. *Upper View*

3) Motor Driver Control:

- **Pin Setup:** The ESP32 pins are configured to control the motor driver’s direction and speed.
- **Movement Commands:** The ESP32 receives commands via Wi-Fi from the mobile app (such as ”move forward,” ”turn left,” etc.). These commands are processed to adjust the motor driver pins and control the motors. PWM (Pulse Width Modulation) is used to manage motor speed.

4) Buzzer Control:

- **Pin Setup:** A pin on the ESP32 is connected to the buzzer.

- **Timer and Action:** Every 90 seconds, a timer triggers the buzzer. Using `millis()`, the program keeps track of the time and activates the buzzer for 3 seconds by setting the pin HIGH, then LOW. This ensures the buzzer works without interfering with other tasks.

5) Wi-Fi Communication:

- **Network Connection:** The ESP32 connects to a Wi-Fi network using the `WiFi.h` library, with the SSID and password embedded in the code.
- **Server Setup:** The ESP32 acts as a server, listening for incoming connections from the mobile app on a specific port.
- **Command Reception:** The ESP32 constantly listens for commands from the app. Once received, it processes them to control the robot's movements and triggers actions like the buzzer or eye blinking.

V. Software Implementation

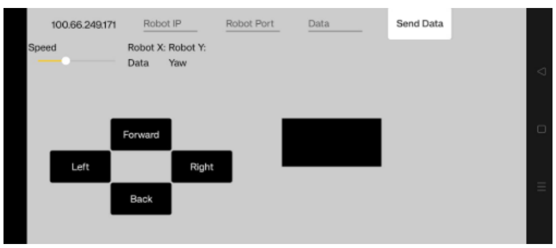

Fig. 6. *Screenshot of the App made in MIT App Builder*

A. Communication Flow

The overall software interaction is as follows:

1) **ESP32 Initialization:** The ESP32 boots up, initializes essential components such as the OLED display, motor driver, and buzzer, and connects to the Wi-Fi network, acting as a server.
2) **MIT App Inventor Application:** The user launches the MIT App Inventor application on their mobile device.
3) **App Connection:** The app connects to the ESP32's IP address and port number over Wi-Fi.
4) **Control Button Press:** When a control button is pressed in the app:
    a) The app encodes the desired action (e.g., move forward, turn left) into a command string.
    b) The command string is sent over Wi-Fi to the ESP32.
5) **ESP32 Command Handling:** Upon receiving the command, the ESP32:
    a) Parses the command to determine the required action (e.g., move forward).
    b) Controls the motor driver pins to execute the action (e.g., moving the robot).
6) **OLED and Timer Management:** Simultaneously, the ESP32 independently manages:
    a) The blinking animation on the OLED screen based on internal timing logic.
    b) The 90-second timer, triggering the buzzer for 3 seconds once the interval is reached.

B. Connectivity Logic

1) **Wi-Fi Client (App):** The mobile app acts as a Wi-Fi client, attempting to connect to the ESP32 server by specifying its IP address and port number.
2) **Connection Management:** The app uses connection management blocks, such as the WiFiClient component in MIT App Inventor, to handle connecting and disconnecting from the ESP32.
3) **Communication Protocol:** Once connected, the app sends control commands over the Wi-Fi network to the ESP32, which then processes and executes the actions as described in the Communication Flow.

VI. Results and Discussion

This project successfully produced an ESP32-based assistive desk bot for ADHD support by integrating interactive features like task reminders, motion detection, and facial animations, thereby enhancing user engagement. The system effectively enhances focus and time management through structured reminders and real-time interactions. The design provides ADHD sufferers with an accessible tool because it is inexpensive and simple to use, making it suitable for both personal and educational settings.

A. Usability Testing

People with ADHD engaged with the bot during prototype testing. Significant discoveries include:

- Improved adherence to prescribed procedures.
- Enhanced concentration due to interactive engagement.
- Positive feedback regarding usability and personalization.

B. Performance Evaluation

We looked at metrics like response time, accuracy of user presence detection, and reminder adherence. Future iterations will include AI-powered adaptive features to offer personalized engagement.

Future Scope

The potential of the IMABOT project as a valuable tool for individuals with ADHD could be greatly enhanced through future advancements in both hardware and software. A key improvement would be the integration of AI-driven task scheduling and prioritization. Machine learning algorithms could analyze user behavior to suggest optimal task arrangements, helping users manage their day more effectively. Additionally, incorporating the MPU6050 sensor for voice commands and gesture recognition would enable hands-free interaction, reducing the reliance on smartphones and creating a more seamless experience.

Future iterations of IMABOT could also benefit from the inclusion of Simultaneous Localization and Mapping (SLAM) technology for auto navigation. This would allow the robot to navigate freely within buildings, assisting users in reaching their destinations or completing tasks with greater ease. Another promising development would involve integrating biometric sensors to monitor the user's physiological responses. The data could then be used to dynamically adjust task reminders based on the user's focus and level of attention, offering a more personalized experience.

With cloud and IOT connectivity, IMABOT could further assist users in their daily lives by enabling smart home automation. The bot could control household devices such as lights and alarms, as well as synchronize tasks across multiple devices, ensuring a more efficient and interconnected routine. These innovations would not only make everyday activities more efficient, but also make IMABOT an even more effective tool for supporting individuals with ADHD.

With the rapid advancement of AI models and improved face recognition technology, IMABOT has great potential for further enhancement. In the future, integrating a Raspberry Pi could significantly expand its capabilities, enabling more complex processing and smarter interactions. As AI continues to evolve, IMABOT could become even more intuitive and adaptable.

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