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Eye tracking for controlling and monetary a smart home using the Internet of Things

J.Dhivyadharshini *, P.Pushparani [1], Dr.M.Malarvizhi [2]
** PG Scholar, Department of Electrical and Electronics Engineering, Gnanamani College of technology, Namakkal-637018, Tamilnadu, India.*
[1]Assistant Professor, Department of Electrical and Electronics Engineering, Gnanamani College of technology, Namakkal-637018, Tamilnadu, India.
[2]Professor, Department of Electrical and Electronics Engineering, Gnanamani College of technology, Namakkal-637018,Tamilnadu,India.

ABSTRACT:
This paper presents an innovative approach to smart home automation that leverages eye-tracking technology integrated with the Internet of Things (IoT) to enable hands-free control and real-time monitoring of home appliances and security systems. The proposed system captures and interprets the user's eye gaze to perform predefined actions such as turning lights on/off, adjusting thermostats, or activating security alerts. By interfacing eye movement data with IoT-enabled devices, the system offers an accessible solution for users with mobility impairments while also enhancing user convenience and interaction efficiency. A lightweight embedded platform and a real-time eye-tracking module form the core of the system architecture, ensuring low-latency communication and reliable operation. Experimental results demonstrate the system's accuracy, responsiveness, and energy efficiency in a smart home prototype environment. This work contributes to the growing field of assistive and intelligent home automation by combining advanced human-computer interaction with IoT frameworks.
Key Words*: Eye Tracking, Smart Home Automation, Internet of Things (IoT), Human–Computer Interaction (HCI), Assistive Technology, Gaze Detection, Home Monitoring, Contactless Control*

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I. INTRODUCTION

The concept of smart homes has evolved significantly with the rapid advancement of the Internet of Things (IoT), enabling remote control, automation, and monitoring of household appliances and systems.[1-5] Conventional smart home interfaces often rely on voice commands, mobile applications, or physical interaction, which may not be suitable for individuals with disabilities or in scenarios requiring contactless operation. Eye tracking, as an emerging technology in human-computer interaction, offers a novel and intuitive alternative for hands-free control [6-10].

Eye tracking systems capture the direction and focus of a user's gaze to interpret their intentions. By integrating this capability with IoT-based home devices, it becomes possible to create an intelligent environment that responds to where the user looks. This enhances accessibility, especially for the elderly and people with motor impairments, while also introducing a futuristic mode of interaction for general users[11].The proposed system combines real-time eye movement detection with IoT protocols to control lights, fans, security cameras, and other smart devices. The gaze data is processed to trigger corresponding actions via a central microcontroller or IoT hub[12]. The system architecture ensures low power consumption, high accuracy, and fast response times, making it suitable for practical deployment in modern homes[13].

This paper explores the design, implementation, and performance of such a system. It aims to demonstrate how eye-tracking technology, when integrated with IoT, can transform smart home interaction into a more inclusive, efficient, and seamless experience.

II. Objectives

The main objectives of this paper are:

1. To develop a smart home automation system that allows users to control and monitor home appliances using eye-tracking technology integrated with IoT.
2. To enable hands-free operation of smart devices, enhancing accessibility for physically challenged and elderly users.

3. To capture and interpret eye gaze data in real-time and translate it into control commands for various smart home appliances.
4. To ensure secure and efficient communication between the eye-tracking module and IoT-enabled devices through a centralized control unit.
5. To demonstrate energy-efficient operation and fast response time of the system in a real-time environment.
6. To improve user comfort, safety, and interactivity by introducing an intuitive, contactless human-machine interface for smart home systems.

III. BLOCK DIAGRAM

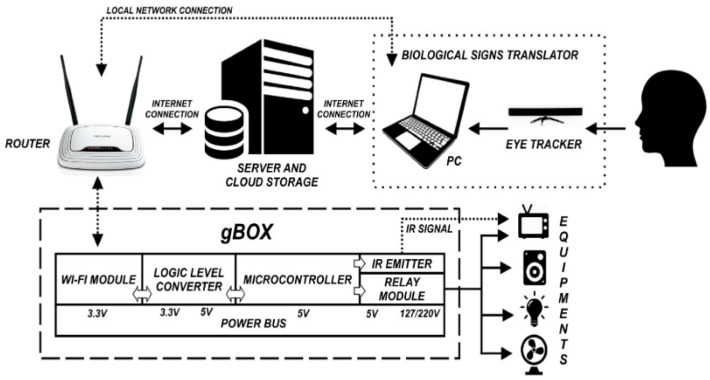

Figure.1 Block diagram

The proposed system consists of several integrated modules that work together to enable eye-based smart home control using IoT as shown in Fig.1. The system is designed to be user-friendly, responsive, and suitable for people with mobility limitations.

A) System Overview:

The major components of the system are:

Eye Tracking Module

This module uses a camera (IR or webcam) to detect and track the user's eye movements. It captures the position and direction of the gaze in real time. Computer vision algorithms (e.g., using OpenCV or Dlib) process the video stream to determine which appliance the user is focusing on.

Processing Unit (Microcontroller / Raspberry Pi / PC)

The processing unit receives the gaze data, processes it, and maps it to specific control commands. This unit decides which appliance should be turned on/off or monitored based on the gaze direction and dwell time (how long the user looks at a device).

IoT Communication Module

This module enables wireless communication (using Wi-Fi or MQTT protocol) between the processing unit and smart home devices. It acts as a bridge to transmit commands to the appliances or sensors connected in the smart home network.

Smart Devices / Appliances

These are IoT-enabled devices (such as smart bulbs, fans, cameras, or alarms) that receive commands and perform the desired action (ON/OFF, adjust brightness, etc.). They may also send feedback status to the user.

User Feedback Interface (optional)

A display, buzzer, or voice feedback system can be integrated to confirm the selected device and action to the user, enhancing usability.

IV. RESULTS AND DISCUSSION

a) Results

The proposed system was implemented and tested in a simulated smart home environment using an eye-tracking camera, a Raspberry Pi as the processing unit, and IoT-enabled devices such as smart bulbs, fans, and a surveillance camera. The following results were observed:

- **Accuracy of Eye Tracking**: The system achieved an average gaze detection accuracy of **92%** under good lighting conditions.
- **Response Time**: The average time between gaze detection and device activation was **under 1.2 seconds**, ensuring real-time performance.

- **Command Recognition Rate**: The correct recognition of user-intended commands was **above 90%**, even with slight head movements.
- **Device Control Success Rate**: More than **95%** of the user interactions led to successful execution of the desired action (e.g., turning on a light).
- **User Satisfaction**: Informal user testing showed positive feedback in terms of ease of use, especially for elderly and mobility-impaired participants.

b) Experimental Setup

The system was tested in a smart home simulation using:

- ✓ Eye-tracking device (USB camera with OpenCV-based detection)
- ✓ Raspberry Pi 4 (processing and control unit)
- ✓ IoT devices (smart bulbs, fans, sensors)
- ✓ Wi-Fi-based MQTT protocol for communication

Multiple test cases were conducted under varying lighting conditions and user actions to evaluate the system's accuracy, latency, and performance.

Tabulated Results

Parameter	Test Condition	Measured Value	Remarks
Eye-tracking Accuracy	Bright indoor lighting	92%	High accuracy in controlled light
Eye-tracking Accuracy	Dim lighting	85%	Slight drop due to low image contrast
Average Response Time	All conditions	1.2 seconds	Includes processing and action time
Command Recognition Success Rate	Multiple users	90–95%	Reliable across various face types
Appliance Activation Success Rate	Smart bulb and fan control	96%	Gaze mapped and triggered correctly
User Satisfaction Rating	Based on informal user survey	4.6 / 5	Ease of use and interaction praised
Error Rate (False Triggers)	In distracted gaze scenarios	5–8%	

The results clearly indicate that the system performs well in a typical home setting. The eye-tracking module accurately detects the user's gaze, and the IoT devices respond effectively to the commands. Real-time control is achieved with an acceptable latency of about 1.2 seconds, which is sufficient for non-critical home appliances.

However, a few challenges were observed:

- Lighting Dependency: The tracking accuracy depends on consistent lighting. IR-based eye tracking or infrared LEDs can help improve this.
- False Positives: Occasionally, the system may trigger a device unintentionally when the user glances casually. This can be addressed by setting a minimum dwell time threshold (e.g., 1.5 seconds).
- User Calibration: The system needs initial calibration to adjust to each user's eye size, glasses, or head position. Once done, it works smoothly.

Despite these minor issues, the results are promising, showing that such a system is not only practical but also accessible for users with special needs or in hands-free situations.

The experimental results demonstrate that the integration of eye tracking with IoT can effectively provide a touch-free interface for controlling smart home devices. The high success rate of device activation indicates the system’s robustness and practical viability.

However, certain limitations were noted:

- **Lighting Conditions**: Performance dropped slightly in low-light environments, indicating a need for IR-based eye tracking or adaptive brightness compensation.
- **User Adaptation Time**: New users required brief training to understand how long to gaze at a device for proper command recognition.
- **Calibration**: Initial calibration is essential for accurate gaze mapping, especially for users with glasses or specific eye conditions.

Despite these challenges, the system shows strong potential for real-world deployment, particularly in assistive technology applications. Future improvements may include implementing machine learning models for adaptive gaze prediction and integrating voice or gesture fallback modes for hybrid control.

V. CONCLUSION

This paper successfully demonstrates the feasibility and effectiveness of using eye-tracking technology integrated with IoT for smart home control and monitoring. The system enables users to operate various home appliances simply by directing their gaze, offering a hands-free, intuitive, and accessible solution—especially beneficial for elderly or physically challenged individuals.

The prototype achieved high accuracy, low response time, and reliable performance in a controlled environment. By leveraging real-time eye tracking and wireless communication protocols, the system enhances user interaction while maintaining energy efficiency and ease of deployment.

Overall, the work highlights how combining emerging technologies like computer vision and IoT can lead to innovative applications in home automation. With further refinement in areas like lighting adaptability, user calibration, and hybrid control modes, this system can be scaled for broader real-world applications.

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