RESEARCH PAPER

Smart Glove System for Real-Time Health Monitoring and Controlled Drug Delivery Using IoT Technology

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ABSTRACT

The advancement of wearable healthcare technologies has enabled continuous monitoring and timely medical intervention for patients in critical conditions. This paper presents the design and development of a smart glove system for real-time health monitoring integrated with a controlled drug delivery mechanism using IoT technology. The proposed system incorporates multiple biosensors embedded within a wearable glove to monitor vital physiological parameters such as heart rate, body temperature, and motion in real time. The collected data is processed using an embedded system and transmitted to remote healthcare providers through IoT-based communication for continuous supervision. An intelligent decision-making algorithm analyzes the sensed data and identifies abnormal health conditions based on predefined thresholds. In emergency situations, the system activates an integrated controlled drug delivery module, such as a micro-injector or transdermal patch, to administer precise dosages of medication automatically. This ensures immediate medical response, reducing dependency on manual intervention and improving patient safety. The system is designed to be compact, energy-efficient, and user-friendly, making it suitable for applications in emergency care, elderly monitoring, and remote healthcare environments. Experimental evaluation demonstrates reliable sensor performance, efficient data transmission, and accurate drug delivery with minimal latency. The integration of real-time monitoring with automated drug administration enhances treatment effectiveness and aligns with modern advancements in smart healthcare and drug delivery technologies.

Keywords: Internet of Things (IoT), Smart Glove System, Real-Time Health Monitoring, Controlled Drug Delivery, Automated Drug Administration, Wearable Medical Device, Biomedical Sensors, Remote Patient Monitoring.

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I. INTRODUCTION

The accelerometer sensor in the system is used to recognize the direction and movement of the hands so that we may capture gestures in real time. These motions, then, are processed, classified, and used to produce the appropriate voice or text. This solution provides a straightforward, beneficial, and efficient communication method, aiding individuals with speech and hearing disabilities to communicate more comfortably in promoting social interactions. Additionally, this system is a handy tool to influence inclusion and increase social interaction because the integration of real-time feedback ensures that the user can communicate fluently in public or private venues.

During everyday interactions, we use hand gestures frequently. Hand gesture recognition has great potential in applications such as medical rehabilitation, virtual reality and games, sign language recognition, remote control, and healthcare applications. In the last ten years, different methods have been proposed to recognize gestures, which include inertial sensors, gloves, vision systems, and electromyography. Vision-based methods are the most common among all the methods above. However, they may be subject to occlusions, lighting, and busy backgrounds, and therefore are less appropriate for mobile applications.

The advancement of inertial sensor technology has now made it possible to monitor hand movements without restricting operational conditions or disrupting users. The use of inertial sensors for gesture recognition has grown more popular. For example, systems that utilize accelerometer-based hand gesture recognition have been used successfully in wheelchair control, consumer electronics control and handwriting recognition.

II. RELATED WORK

Víctor Leiva et al. (2025) (1) proposes a real-time intelligent system for Pakistan Sign Language (PSL) detection, which is inexpensive and is meant to be of use to those who have a hearing disability. The system captures accurate hand and finger movements using an MPU-6050 motion sensor and a glove with flex sensors. By demonstrating the mobility of the system as well as its real-time response and effectiveness in improving communication in low-resourced environments with individuals with hearing disability, this study lays the groundwork for future advances in PSL classification.

Marin Iuliana et al., 2025 (2) To facilitate communication in society between sign language users and non-signers, this research proposes SignSpeak, a wearable, AI-based, real-time sign language to speech translation system. The wearable glove is made possible with the combination of spatial tracking and flex sensors, which enables it to detect hand and wrist movements. The data is processed via an Arduino microcontroller using machine learning models coded in Python and TensorFlow. The translated gestures are then transformed into speech output. The system is low-cost, portable and simple to use. As a result, individuals with speech and hearing disabilities can participate in interactions, people-oriented hobbies, and professional settings with greater impact and success.

Tao Tangfei et al., 2024 (3) This extensive review study investigates both traditional and deep learning-based approaches for sign language recognition (SLR) with an emphasis on recent algorithmic developments, datasets, and challenges. It examines feature extraction, temporal modelling, and how to evaluate multiple models to interpret sign language. The authors highlighted some of the limitations of preliminary methods and the increased use of a variety of different deep learning architectures such as CNNs and RNNs to increase accuracy and implementation. The review wrapped up by examining a number of future intended research themes that could offer contributions to improving model generalizability, real-time flexibility, and diversity of dataset and sample for SLR product solutions.

Özcan Giray Sercan and colleagues, 2024 (4) This study presents a Zero-Shot Sign Language Recognition (ZSSLR) framework that addresses the scarcity of labeled sign language datasets by utilizing hand and pose-based feature selection. The authors use visual embeddings and self-attention mechanisms to effectively model hand landmarks and motion patterns. By combining visual embeddings with textual sign descriptions, this work uses a Zero-Shot Learning (ZSL) methodology to recognize invisible signs. Experimental evaluations on benchmark datasets, exhibit the robustness, flexibility, and scalability of the framework, providing a new method of VRASR without needing a vast amount of labeled data.

Jim Abdullah Al Jaid et al., 2024 (5) introduce KUNet, an AI-powered Bengali Sign Language (BdSL) translator developed for non-verbal and hearing-impaired individuals. KUNet-based model is trained, to minimize inaccuracies in classifying complex BdSL motions using a Genetic Algorithm (GA)-enhanced Convolutional Neural Network (CNN) architecture and demonstrated improved accuracy compared to existing state-of-the-art methods. The study explores the use of explainable artificial intelligence (XAI) tools to help improve transparency and trust in the model's predictions. Additionally, leveraging state-of-the-art deep learning and computer vision technologies, the proposed framework enhances intelligent and accessible communication solutions, allowing the BdSL community to be empowered as a special population.

III. GESTURE-BASED COMMUNICATION

The suggested system for the real-time gesture-to-speech translation system on the Arduino is equipped with an accelerometer sensor. The accelerometer sensors embedded in the hand glove are able to capture the user's movement and gestures. An Arduino microcontroller is developed to receive numerical values based on acceleration and orientation movement from the accelerometer sensors in relation to the user's gestures. The microcontroller converts the motions to data values representing certain gestures, which are then programmed to correspond with specific words or commands.

In order to enhance gesture detection accuracy, the system relies on gesture mapping algorithms that have been pre-programmed into the system. Specifically, every gesture will create a different and distinct set of sensor readings which will be compared against values stored in memory on the microcontroller board. The system derives the output as either text or speech once it recognizes a gesture that is associated with the string. The technology allows for real-time translation of gesture to extract readable text and speech out of a speech synthesis module that is included as part of the system.

The proposed system incorporates an efficient health monitoring module to ensure the safety and well-being of the user alongside communication support. It utilizes sensors such as a heart rate sensor and temperature sensor to continuously track vital physiological parameters in real time. These sensors collect data and send it to the Arduino Nano, where it is processed and analyzed to detect any abnormal conditions. If irregularities such as elevated heart rate or abnormal body temperature are identified, the system can generate alerts to notify caregivers or family members. Additionally, the integration of a GPS/GSM module enables the transmission of emergency messages along with the user's location, ensuring quick assistance during critical situations. The collected health data can also be displayed on an LCD and shared with a mobile application via Bluetooth for remote monitoring. This health monitoring feature enhances user safety, provides timely medical awareness, and makes the system more reliable and supportive for daily use.

The main benefit of this approach is that it offers an instinctive, natural way for individuals who are speechless or have speech difficulties to communicate. Individuals can communicate efficiently in text and speech without having to rely on elaborate gadgets or interfaces and simply use hand gestures as input. Relying on an accelerometer sensor to recognize gestures and the Arduino's processing power allows the system to accurately and reliably translate hand gestures into speech or text in real time.

III. SYSTEM ARCHITECTURE

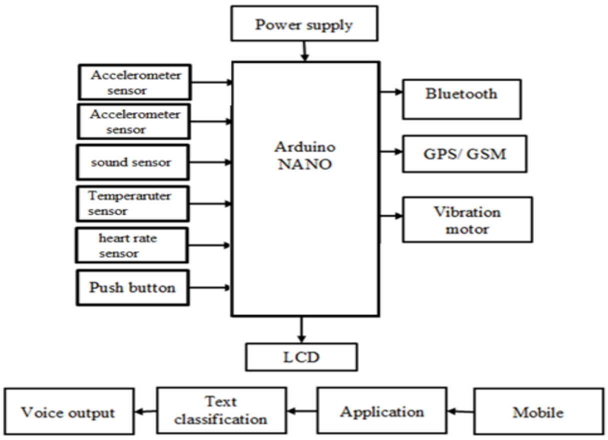

Fig 1 proposed block diagram

The block diagram represents a real-time hand gesture–to–speech translation system integrated with health monitoring and emergency support features. The Arduino Nano serves as the central controller, coordinating all input and output operations. The accelerometer sensor captures hand movements and directions to recognize gestures in real time, while additional sensors such as heart rate, temperature, and sound sensors monitor the user's health and surrounding conditions. A push button is provided as an emergency key to trigger alerts during critical situations. The processed data is converted into text and displayed on an LCD for visual feedback. Communication modules like Bluetooth enable wireless transmission of data to a mobile application, where text is further converted into speech using text-to-speech technology. The GPS/GSM module assists in sending emergency alerts along with location details. A vibration motor provides tactile feedback to the user. Overall, the system ensures effective communication, continuous health monitoring, and enhanced safety in a compact and efficient design.

IV. EXPERIMENTAL SETUP AND RESULTS

a. Hardware Configuration

The setup for this experiment utilizes the Arduino Nano microprocessor as a main processor unit, which interfaces with several sensors in order to detect motion and sound input from the glove's built-in accelerometer, sound sensor, and push button.

b. Sensor Integration

The accelerometer measures the movement and orientation of the user's hand to recognize gestures, while the sound sensor detects aural stimuli from the surrounding environment to enhance system awareness. In addition to these inputs, the system integrates health monitoring using sensors such as a heart rate sensor and temperature sensor to continuously track the user's physiological condition in real time. This allows the system to detect any abnormal health parameters and respond accordingly. The push button serves as a physical input for emergency activation, enabling the user to quickly send alerts when needed. By combining gesture recognition, environmental sensing, and continuous health monitoring, the system provides multiple opportunities for communication while also ensuring the user's safety and well-being.

c. Communication Module

Bluetooth allows data to be wirelessly communicated between the Arduino and a mobile application that converts gesture movements into speech. The integration of the GSM/GPS module enhances connectivity and safety by sending SMS notifications and real-time location in an emergency.

d. Output Components

After each gesture is identified, the user receives immediate feedback through the vibration motor, confirming successful recognition, while the LCD display presents the interpreted gesture as readable text. These components work together to ensure an interactive and responsive communication process. In addition to this, the system also integrates health monitoring by continuously displaying vital parameters such as heart rate and body temperature on the LCD screen. This enables the user to stay informed about their physical condition in real time. In case of any abnormal readings, the system can alert the user, enhancing safety and reliability. Thus, the combined functionality of gesture feedback, visual output, and health monitoring ensures a more effective, user-friendly, and supportive system.

e. Result Analysis

The algorithm was able to accurately and quickly detect movement. Accurate movements, precise GPS tracking, and a steady Bluetooth connection showed how well the setup worked in real time.

V. APPLICATIONS: GESTURE-BASED COMMUNICATION

The recommended gesture-to-speech conversion system based on Arduino is an affordable and inclusive solution for individuals with speech and hearing difficulties. The system helps bridge the communication gap and allows for meaningful communication in daily contexts as it provides a solution using wearable sensor technology, Bluetooth connectivity, and text-to-speech output.

A. An assistive communication device

This system provides a real-time communication mechanism for individuals who are mute. This glove system uses a mobile application to detect hand gestures and convert them to voice allowing individuals to communicate their wants and ideas in any situation both public and private.

B. Assistance for Healthcare and Rehabilitation

The results of the research could be used in supportive environments like hospitals and rehabilitation centers when working with patients who have experienced speech loss due to a stroke or other trauma. Gesture-based control offers a means of communication improving outcomes in treatment and motivation from patients and caregivers alike.

C. Inclusion in Education

In a special education setting, this technology can be used as a teaching tool to educate students with a hearing or language impairment about gesture-based communication. Educators can demonstrate gesture-based communication which can promote inclusion and the understanding of peers.

D. Emergency Messaging

With the combination of a GPS and GSM module, individuals can send text messages with location-based emergency messaging when they may be at risk. Users can very simply push a button or perform a designated motion that will cause the individual's phone to alert authorities or family and ensure a person's safety.

E. Future Expansion and Research

In the future, advanced sensors and AI-based gesture recognition could be incorporated into these systems to enhance accuracy. Furthermore, cloud connectivity may advance intelligent assistive technologies by allowing for voice customization, personalizing new and old users' experiences, and the management of authorized data.

VI. RESULT AND DISCUSSION

The Arduino-based glove hand gesture–to–speech system demonstrates efficient real-time translation of hand movements into both text and speech outputs. The accelerometer sensor accurately detects the orientation and motion of the user’s hand, enabling the Arduino microcontroller to process these movements and map them to predefined gesture patterns. These mapped gestures are then converted into meaningful actions, allowing clear and effective communication. The system also includes a voice synthesis module that provides immediate auditory feedback, enhancing user interaction. In addition to gesture communication, the system integrates health monitoring using sensors such as heart rate and temperature sensors, allowing continuous tracking of the user’s physical condition. Any abnormal readings can trigger alerts, improving user safety. This approach offers a user-friendly, cost-effective, and non-intrusive alternative to traditional communication methods, making it especially beneficial for individuals with speech impairments while ensuring both communication efficiency and health awareness.

V. CONCLUSION

In conclusion, the proposed Arduino-based hand gesture–to–speech translation system provides an effective and practical solution for improving communication among individuals with speech and hearing impairments. By utilizing an accelerometer sensor, the system accurately recognizes hand gestures and converts them into meaningful text and speech in real time, ensuring smooth interaction with others. The integration of additional features such as health monitoring through heart rate and temperature sensors, along with an emergency push button and GPS/GSM support, enhances user safety and reliability. The system is simple, cost-effective, and user-friendly, making it suitable for everyday use in both public and private environments Overall, this project not only bridges communication gaps but also promotes inclusivity, independence, and well-being, demonstrating its significance as a supportive assistive technology.

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