



Assistive Smart Glove Integrating Physiological Monitoring And Gesture Communication For Down Syndrome Care

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Abstract: The Internet of Things(IoT) is revolutionizing the healthcare sector, linking better, faster solutions in a fast-evolving and fast-paced era. The titled paper illustrates the design and assessment of a Smart Glove Monitoring System for individuals with Down syndrome. The wearable system combines various sensors such as flex sensors, heartbeat and SpO₂ modules, GPS, and fall detection to ensure ongoing health monitoring and gesture-based interaction. Through the use of IoT through NodeMCU, the system sends real-time health and location information to a cloud platform, enabling caregivers to monitor and react quickly in emergency situations. The glove also has pre-recorded voice reminders triggered by finger gestures, which enable the non-verbal users to communicate simple needs. Experimental results show smooth heart rate and oxygen saturation monitoring, precise gesture recognition within five seconds, and effective GPS tracking in open spaces. Even though indoor GPS accuracy and fall detection dependability need enhancement, the system shows great promise as a low-cost assistive technology improving safety, autonomy, and caregiver assistance for individuals with Down syndrome.

Index Terms - Down Syndrome, Gesture Communication, Smart Glove, Internet of Things

I. INTRODUCTION

Down syndrome is a genetic condition brought about by an extra chromosome 21 and results in delayed growth, intellectual disabilities, and communication problems. People who have this condition usually need constant monitoring, especially in times of health crisis like falling, oxygen desaturation, or cardiac abnormalities. Early intervention in the situation is imperative; nonetheless, communication barriers often hinder such timely assistance, making it imperative for intelligent assistive technologies that can close the gap between the caregivers and people with Down syndrome. Progress in wearable technology and the Internet of Things (IoT) in recent years has the potential to help overcome these challenges. Traditional caregiving heavily depends on continuous human observation, which is both physically and emotionally exhausting, and currently available assistive technology is usually restricted to a single function and doesn't have custom features for non-verbal users or caregivers. To fill this gap, Smart Glove Monitoring System has been created as a wearable IoT-based device that combines vital sign monitoring, gesture-based communication, GPS tracking, and fall detection into one platform.

The system will continuously track the most important physiological parameters, facilitate easy gesture-based communication using flex sensors, send health and location information in real time to caregivers, and offer a low-cost, easy-to-use solution that improves both safety and independence. Through the integration of all these features, the Smart Glove will break through limitations of communication, enhance response times during emergencies, and generally improve the quality of life for both users and caregivers.

II. LITERATURE REVIEW

New developments in wearable technology and IoT have created new opportunities for assistive technology for persons with developmental disabilities, such as Down syndrome. Barbosa et al. (2018) were among the studies that have proven the efficacy of augmentative and alternative communication (AAC) approaches, while Alghamdi et al. (2019) and Chen et al. (2020) were able to prove real-time physiological and activity tracking through IoT devices. Products like the Smart Health Monitoring Glove (Bhutani et al., 2020) and EchoGlove (Vijay et al., 2025) show effective incorporation of gesture recognition and health monitoring into wearable technology.

Yet, most current solutions support individual functionalities or do not present user-centric design for non-verbal users and for caregiver requirements. This motivated our project to design a single, wearable smart glove that integrates health monitoring, fall detection, and gesture-based. Through the support of several sensors and IoT connectivity, the system is designed to help increase the autonomy of users and offer real-time feedback to caregivers, upon building on earlier studies and meeting shortcomings in practical use and integration of multiple functions.

III. METHODOLOGY

The Smart Glove Monitoring System was achieved via an iterative, cross-disciplinary process bringing together sensor fusion, embedded system development, cloud connectivity, and user-driven testing. The glove features flex sensors for finger movement detection, a MAX30100 module for heart rate and SpO₂ monitoring, an accelerometer to detect falls, and a GPS module for location tracking. Flex sensors are programmed to identify certain gestures, which cause pre-stored voice cues through a voice module, allowing non-verbal users to convey critical needs in an effective manner.

The architectural design utilizes an Arduino Uno to control voice playback and analog sensing, and a NodeMCU ESP8266 to aggregate data in real time and upload it to the cloud. Sensor readings and GPS location are transmitted in JSON format to a cloud platform, enabling caregivers to track physiological parameters and location in near real-time remotely. The glove is driven by an 8.4 V battery that is regulated by a buck converter to deliver stable 5 V to all the components. Pilot testing with Down syndrome individuals and caregiver input guided iterative improvements in ergonomics, gesture recognition thresholds, and dashboard interface design. This systematic design makes the device both technically robust and easy to use, combining several assistive features into one wearable system that enables health monitoring, emergency messaging, and caregiver surveillance.

IV. RESULT AND DISCUSSION

The prototype indicated in Fig.1.1 was able to effectively test its main functionalities. Flex sensor gestures were identified within 5 seconds and initiated voice messages like 'I NEED FOOD', 'I NEED USE WASHROOM'. Heart rate and SpO₂ readings were also sent to the cloud platform correctly, with the values being 72–75 bpm and SpO₂ at more than 95%. GPS location tracking worked well outdoors but also had limitations while indoors as shown in Table 1. The power management system was guaranteed to provide stable operation, while ThingSpeak ensured smooth real-time data updates.

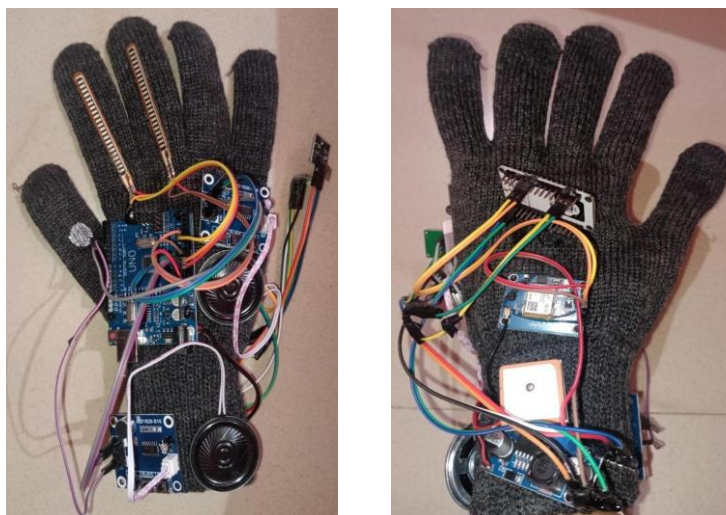


Fig.1.1 Top view and bottom view of Smart glove

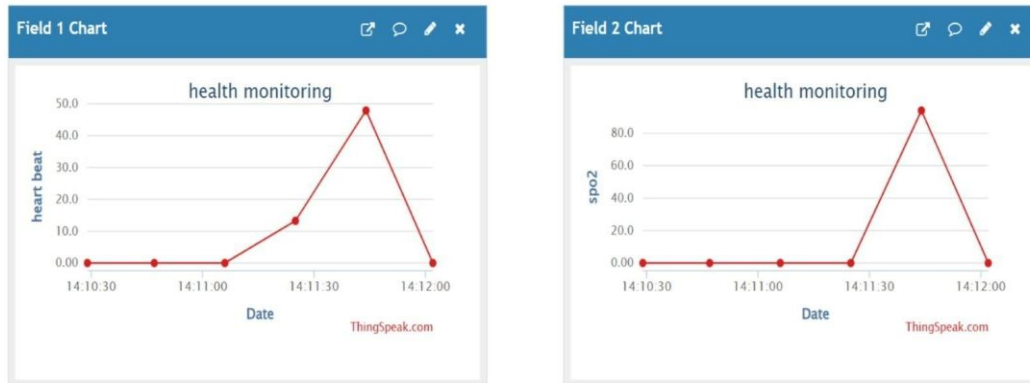


Fig.1.2 Obtained results from heart rate and SPO₂ sensor

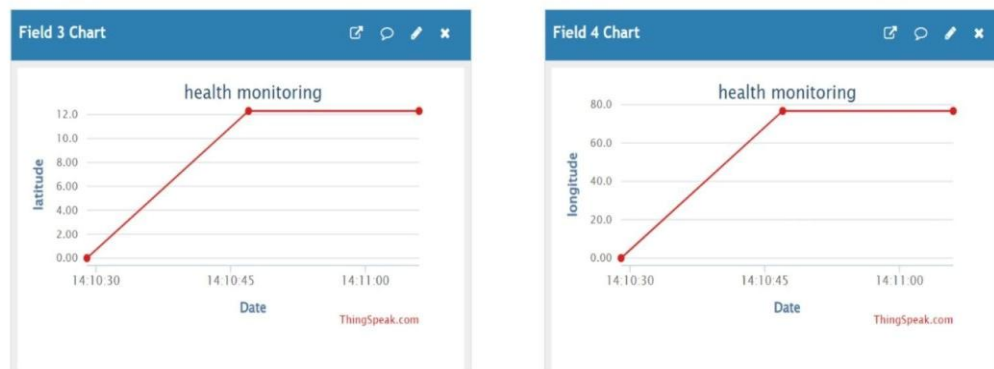


Fig.1.3 Obtained results of effectively captured latitude and longitude in open areas

Table 1: Summary of Experimental Results

Parameter	Sensor Used	Observed Value	Remarks
Heart Rate	MAX30100	72–75 bpm	Within normal range
SpO ₂	MAX30100	>95%	Stable readings
Gesture Response	Flex Sensor	< 5 sec	Prompt audio playback
GPS Tracking	GPS Module	Accurate (outdoors)	Indoor accuracy limited

V. CONCLUSION AND SCOPE FOR FUTURE WORK

The Smart Glove Monitoring System is an affordable, scalable solution for supporting people with Down syndrome. It offers constant monitoring of vital signs, gesture-controlled communication, and caregiver alerts in real-time using IoT technology. GPS indoors and fall detection need improvement, but the system shows great promise to increase safety and independence for special needs users. Future research will target the incorporation of indoor positioning precision using hybrid localization, sensor fusion enhancement, increasing gesture vocabulary via machine learning. Enhancing ergonomic comfort for long-term wearability and performing extensive clinical usability tests.

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