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RESEARCH ARTICLE

Design of an interactive smart band for intellectually disabled person

Pavithra M[1], R. Neelaveni[2], Muthuraman K. R[1] and Kamalesh G[1]

Abstract

The urge of patient monitoring demands a huge crisis in the healthcare industry. The situation becomes even worse in case of patients suffering from intellectual disability (ID). In such a scenario, the patient has constraints over adaptive behavior and significant limitation in cognitive functioning and skills, including communication and self-aid. The proposed system monitors the patient's movements. The system is divided into the smart band unit and the mobile application unit. The smart band unit is comprised of ESP 32 microcontroller with inbuilt Bluetooth low energy (BLE) module, temperature sensor and accelerometer chip. The mobile application is connected with the BLE module and receives continuous data packets. If the band crosses beyond the Bluetooth connectivity region or if the strap of the band is removed, then the mobile application is notified with series of alert messages. The system also keeps track of constant temperature survey and any fall detection in case of any abnormal situation by alerting the caretaker's mobile application. Thus the proposed system is aease mechanism ensuring all safety measures and serves the very purpose of patient monitoring crisis.

Keywords: Intellectual disability, Cognitive functioning, Adaptive behavior, Bluetooth low energy

Introduction

A broad neurological condition known as mental disability, or general learning impairment, is characterized by obviously impaired intellectual and adaptive function. It is characterized as having an IQ of less than 70 and the absence of two or more adaptive behaviors that have an impact on daily life. The DSM-V lists logical reasoning, judgment, academic learning, learning through experience and teaching, and practical knowledge validated by clinical assessment and standardized testing as intellectual functions (Basumatary *et al.*, 2018). Adaptive behavior is characterized in terms of cognitive, social, and practical skills related to daily activities that people carry out. Intellectual disability is classified as either syndromic or non-syndromic, depending on whether other disorders cause intellectual disabilities. Mental handicap expresses itself in the form of deficiencies in mental capacities, social skills, and essential daily activities when compared to peers of the same age. Some early signs of mental disability include delayed motor skills, slow or difficulties in learning language skills, poor logical abilities. The clinical aspects of intellectual disability and ASD are similar, which might lead to incomprehension diagnosis. While overlaying these two conditions is common, it can be harmful to a person's health. Those with ASD who also show ID symptoms may be categorized as having a co-diagnosis, which means they are being treated for a disorder they don't have. A high prevalence of symptomatology between ID and ASD exists; roughly 40% of persons with ID also have ASD, while approximately 70% of those with ASD also have ID. Communication and social awareness deficiencies are required as defining characteristics for both ASD and ID (Roopesh *et al.*, 2020).

Proposed Methodology

Several recent trends have boosted the development of tracking systems to monitor patient's progress (Protopappas *et al.*, 2016; Sambanthan & Saravanan, 2015). Along with the performance, it is also required to follow the movements of the patient for safety purposes. The proposed work mainly consists of two major units. One is the hardware

[1]Department of Electronics and Communication Engineering, Kongu Engineering College, Erode, India

[2]Department of Electrical and Electronics Engineering, PSG College of Technology, Coimbatore, India

***Corresponding Author:** Pavithra M, Department of Electronics and Communication Engineering, Kongu Engineering College, Erode, India, E-Mail: mpavithra.ece@kongu.edu

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part containing the smart band and the other is the mobile application unit. Patient monitoring is based on the communication of the mobile application unit and smart band through data packets. The caretaker is sent an alert notification in case if there is no communication between the smart band and mobile application. Figure 1 represents the architecture of the proposed methodology.

Microcontroller (ESP32)

Microcontrollers are compact integrated circuits that are designed to serve specific operational functionalities in embedded systems. Microcontrollers are more likely considered as the heart of the embedded system. ESP32 is one such microcontroller with inbuilt wifi and dual mode Bluetooth module, thus serving the very purpose of the motive[10]. ESP32 is powered by 12 volts battery through a voltage regulator. A voltage regulator is used to obtain a constant output voltage irrespective of different input voltages. ESP32 is connected with temperature sensor, accelerometer sensor, vibration motor and a connecting loop. ESP32 is interfaced with a buzzer in its 4^{th} pin. The buzzer buzzes the beep sound until it successfully connects with the mobile application. This enables the status of connectivity between the smart band and mobile application.

Baud Rate

The baud rate of the source on the communications port is detected by the module, which is set to "auto baud." Only baud rates up to 57600 will be detected. To get it to work, wait 2 or 3 seconds after turning it on, then repeatedly type "AT" instead of "at" or any other key combination until OK message is received. Then the baud rate is set to 115200 with the command "AT+IPR=115200" to eliminate one possible issue during testing .Because the module is ready for auto bauding, set the PC to 9600 or so when initially connected, and then select the required baud rate. The "RDY", "+CFUN: 1", and "+CPIN: Ready" reports are displayed when auto bauding is disabled.Auto bauding is supported by the debug port, which has a maximal baud rate of 115200. 8 bits, no parity, and 1 stop bit with no flow control is the standard arrangement.

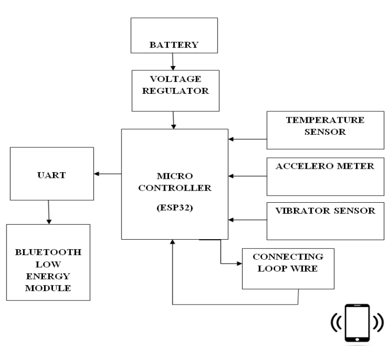

Figure 1: Proposed methodology architecture

Bandwidth

Bit rate is a unit of bandwidth measurement represented in bits per second (bps). Bandwidth refers to a connection's transmission capacity and is important in evaluating a network's or internet connection's quality and speed. A signal must vary in some way in order to transfer data, and the pace at which these changes occur determines the rate at which data may be conveyed. A signal with wider bandwidth can vary more quickly, which means it includes or is suitable with higher frequencies. setFilterBandwidth() function is used for applying the low pass bandwidth filter alternative choices. There are specific allowed values for setFilterBandwidth, including 260, 184, 94, 44, 21, 10 and 5 Hz.

Bluetooth Low Energy Module

ESP32 microcontroller is integrated with inbuilt dual-mode Bluetooth. Dual-Mode Bluetooth devices that accept both Bluetooth Classic and Bluetooth Low Energy (BLE) are known as Bluetooth devices. Bluetooth Classic is a two-way communication link with a high throughput (up to 2.1 Mbps). It's widely used for audio/video streaming and applications that require a constant internet connection (Afaneh, 2018). BLE (Bluetooth Low Energy) was created for applications that require a low data rate, with a throughput of up to 25 kbps (Tosi *et al.*, 2017). As the name suggests, it offers lower latencies than traditional Bluetooth and uses less power. Wearables, smart IoT devices, activity tracker equipment, and rechargeable devices all benefit from it (Mahendraker & Savitha, 2017). The ESP32 in host mode uses serial Bluetooth for receiving and transmitting the data. This enables the control of operating microcontroller from other devices. Firstly the serial Bluetooth header, #include "BluetoothSerial.h" is included to enable serial Bluetooth data transmission to the mobile application client. Once the Bluetooth is initialized, a call back function is executed when there is a Bluetooth event.

If the particular event corresponds to ESP_SPP_SRV_OPEN_EVT , the client is connected to the SPP server. This indicates that the mobile application is connected with the Bluetooth low energy module in ESP32. Thus, there is the transfer of data packets to the mobile application. The Serial Port Profile (SPP) is the most fundamental Bluetooth profile. It is served as an replacement of RS 232 cable. SPP allows each connected device to send and receive data as though they were connected via RX and TX lines. If the particular event corresponds to ESP_SPP_CLOSE_EVT , the client is disconnected from the SPP server. This indicates that the mobile application is not connected with the Bluetooth low energy module in ESP32. Thus, there is no transfer of data packets to the mobile application. The server and the client are the two different categories of Bluetooth Low Energy devices. Both a server and a client application can run on the ESP32. A data structure called Generic Attributes

(GATT) defines a hierarchical data structure and is accessible to linked BLE devices. GATT describes the transmission and reception of standardized messages between two Bluetooth Low Energy (BLE) devices. Each feature, service, and descriptor is given a UUID (Universally Unique Identifier). A unique 128-bit (16-byte) integer is known as a UUID.

Accelerometer

Due to its integrated 3-axis accelerometer and 3-axis gyroscope on a single chip, the MPU6050 chip is utilized to detect motion. A 3-axis gyroscope, 3-axis accelerometer, and a Digital Motion Processor (DMP) are all included in a tiny, 4mm x 4mm container on this low-power, low-cost 6-axis Motion Tracking device. Along with the static acceleration brought on by gravity and the dynamic acceleration brought on by motion, shock, or vibration, it can detect angular momentum or rotation along all three axes. The MPU6050 requires less than 3.6 milliamps while doing measurements and just 5 milliamps when it is not in use. It can be utilized in battery-powered devices due to its low power consumption. Additionally, the module contains a power LED that turns on when it is activated. Accelerometer is used to detect the linear acceleration and gyroscope is used to detect angular rotation. If the values obtained from the chip are beyond the specified range, alert messages regarding the issue are sent to the mobile application. The MPU6050's on-chip accelerometer has four full scale ranges that can be customized: 2 g, 4 g, 8 g, and 16 g. The MPU6050 samples the three axes of motion along the X, Y, and Z axes concurrently using three 16-bit analog-to-digital converters (ADCs). Accelerometer values will be highly sensitive if the range is smaller.

Connecting Loop

A connecting loop wire is interfaced with 19th pin of the microcontroller. It continuously reads some data from the microcontroller. In case if the connecting loop wire is disconnected from the microcontroller, There is no data transaction. This indicates that the strap of the band is removed and creates an emergency situation. Thus a vibrating motor interfaced with the 18th pin of the microcontroller begins to vibrate. Also, the mobile application integrated with the microcontroller will receive a series of continuous alert messages.

Temperature Sensor

The LM135 is an easy-to-calibrate temperature sensor that has a high degree of accuracy. The output voltage of this group of accurate integrated-circuit temperature sensors is proportional to the temperature in Celsius (Centigrade). If the body temperature exceeds 34°C and the strap is connected, the mobile application is alerted with the respective issue and the vibration motor starts vibrating. Otherwise, the band works as usual if the patient is with normal body temperature.

Results

Hardware Setup

The mobile application based patient monitoring serves a safety measurement for intellectually disabled persons. It is an easy, user-friendly mechanism to track user activity. The mobile application work as a simple user interface with increased understandability. Alert messages are sent in immediate action when the output value of the band exceeds the desired value or if the user crosses the Bluetooth connectivity range. The proposed work serves a safety-enhanced full-time patient monitoring system tracking their movement activities and alerting the care taker with instant notification regarding abnormalities. *Figure* 2 represents the smart band with an integrated Bluetooth low-energy module and activity monitoring sensors.

The Hardware setup mainly comprises of the microcontroller integrated with the temperature sensor, accelerometer sensor , vibration motor , buzzer and connecting loop. The schematic diagram of the hardware setup of smart band is depicted in Figure 3.

Mobile Application

Once the mobile application is opened, It allows the user to enter the following details :

- IP address: The Bluetooth Device IP Address (or BD ADDR) is a 48-bit identification issued by the manufacturer to each Bluetooth device. Bluetooth addresses are often expressed as 6 hexadecimal bytes separated by colons. (Eg - 00:11:22:33:FF:EE)
- Mobile number: The Mobile number of the caretaker should be entered. The entered mobile number will receive alert notifications regarding the patient's activity.

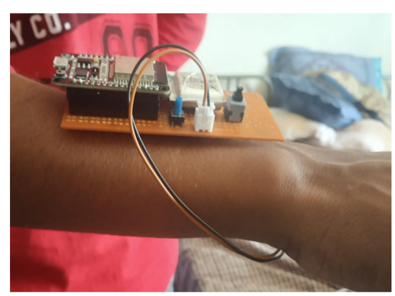

Figure 2: Smart band hardware setup

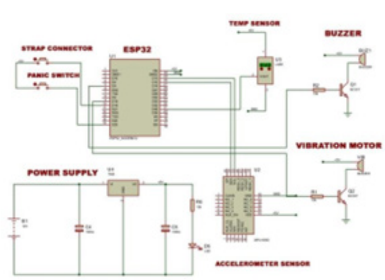

Figure 3: Schematic Diagram of Hardware Setup

- Username: The name of the person who wears the smart band must be entered.

Figure 4 represents the IP configuration page of the application.

The mobile application is designed in such a way that a box appears in the centre of the home page, reporting the status of connectivity. Suppose the Bluetooth low energy module in ESP32 is connected with the app. In that case, the green rectangular box will appear, reporting the status as connected with a successful connectivity symbol at the top of the application. Figure 5 represents the Successful connectivity status with smart band.

Suppose the Bluetooth low energy module in ESP32 is not connected with the app. In that case, the red rectangular box will appear, reporting the status as not in range with an unsuccessful connectivity symbol at the top of the application. Figure 6 represents the unsuccessful connectivity status with smart band.

The setting icon is given at the top-right corner of the application. It allows the user to make any changes in the IP configuration page set before. Figure 7 represents the Settings page of the application.

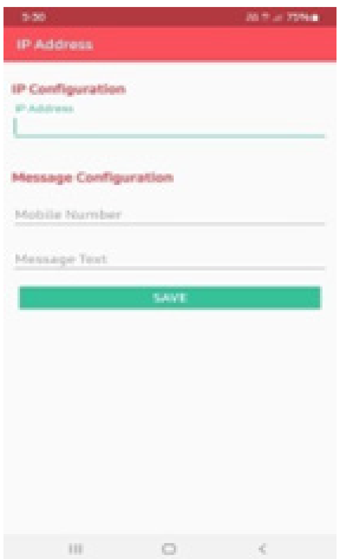

Figure 4: IP configuration page

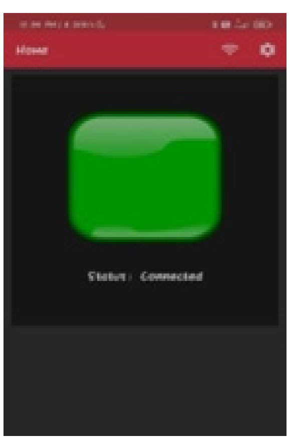

Figure 5: Successful connectivity status

Alert Notifications

Continuous data packet transfer is from the Bluetooth low-energy module to the mobile application. In case if the patient wearing the smart band goes beyond the Bluetooth connectivity region, then the mobile application will not receive the transferred data packets. A cutoff in the data transfer during communication indicates that the patient is going beyond the safe perimeter and needs to be taken care. Thus alert messages are sent to the respective caretaker in such a situation . Figure 8 depicts the alert messages sent to the caretaker when the patient goes beyond the Bluetooth connectivity range.

The connecting loop wire acts as a strap for the smart band. It is connected with input as well as the output port of the microcontroller with continuous transfer of data packets. In case of removal of the strap, Then there is a cutoff in data transfer. Thus the mobile application is notified with series of alert messages stating the issue and the smart band starts vibrating. Figure 9 depicts the smart band removal.

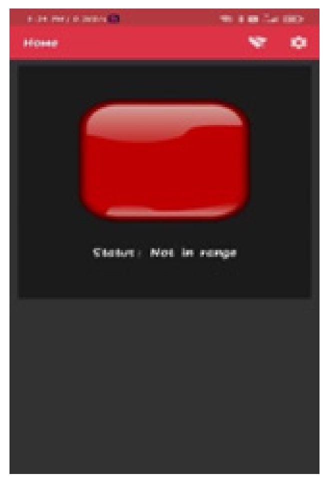

Figure 6: Unsuccessful connectivity status

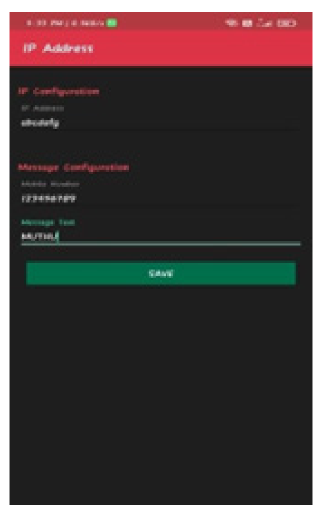

Figure 7: Settings page

Suppose the values obtained from the accelerometer chip is beyond the desired output. In that case, it is indicated that the patient fell down and the mobile application is notified with alert messages. Figure 10 depicts the alert messages when the patient fell down. The mobile application receives alert messages if the patient's body temperature exceeds the specified temperature sensed from the temperature sensor. Figure 11 represents the alert messages for high body temperature Figure 12.

If the smart band is powered off due to low charge in the battery, then the mobile application is sent alert regarding the issue. Figure 13 depicts the band disconnected alert.

Simulations

The person must be within the Bluetooth connectivity region for continuous data transfer between the smart

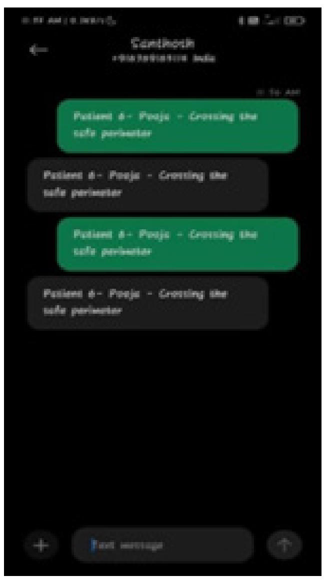

Figure 8: Crossing safe perimeter alert

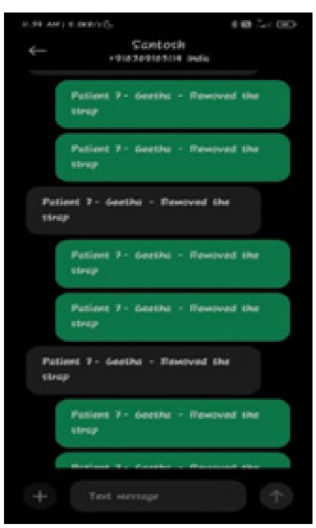

Figure 9: Smart band removal alert

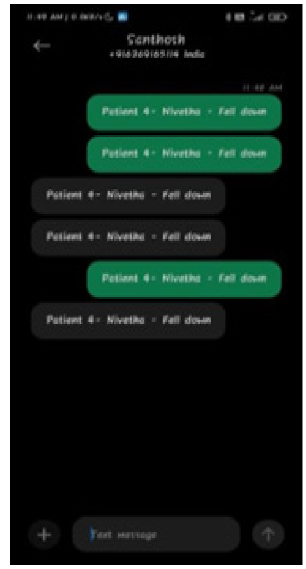

Figure 10: Fell down alert

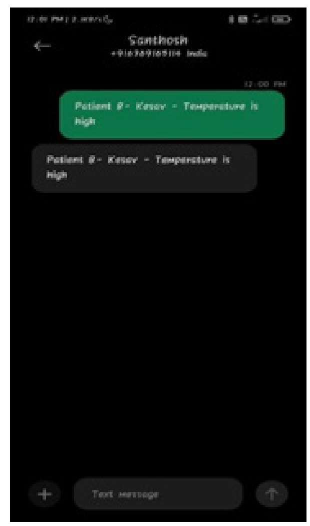

Figure 11: Body temperature alert

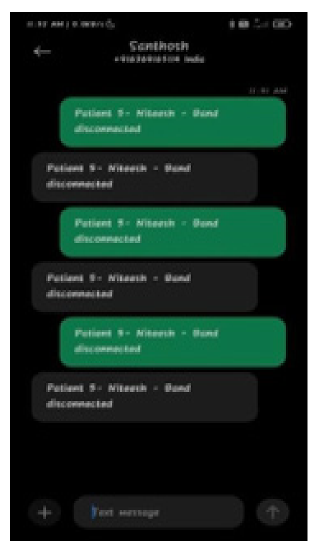

Figure 12: Smart band disconnected alert

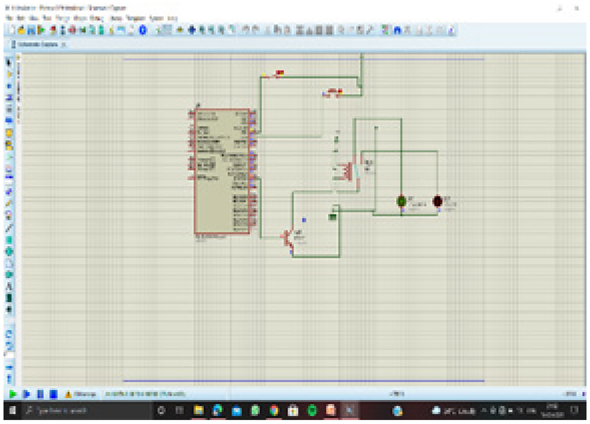

Figure 13: Status within the Range

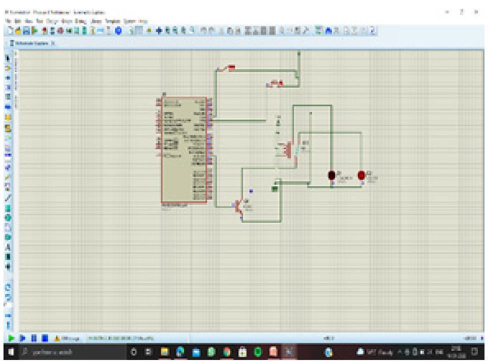

Figure 14: Status beyond the Range

band and mobile application. This ensures that the person is within the safe perimeter. It is depicted in a simulation by glowing a green Light emitting diode (LED) by triggering a relay. The Green LED glows if the switch connected to the input port is triggered. This indicates that the green LED glows when the band and the mobile application is within the connectivity range and there is a stable data packet transfer. This represents the status of the connectivity is successful. Figure 13 represents the status within the range.

If the person is beyond the Bluetooth connectivity region, there is no continuous data transfer between the smart band and the mobile application. This ensures that the person is beyond the safe perimeter. It is depicted in a simulation by glowing a red LED by triggering a relay. If the other switch connected to the same input port is triggered, The red LED glows. This indicates that the red LED glows when the band and the mobile application is beyond the connectivity range and there is no stable data packet transfer. This represents the status of the connectivity is unsuccessful. Figure 14 represents the status beyond the range.

Conclusion

The proposed system will be a good replacement for the traditional mouse system that is in existence. The physically disabled person can have ease in controlling and its user friendly. The user can have a real-time accessing experience and they can access anything they want without facing any difficulties. Therefore a simple and efficient system for tracking and operating the mouse in all aspects is proposed, So that the user can work independently without external assistance.

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