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IoT Enabled Fall Detection System: Enhancing Safety for Cerebral Palsy Children

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Abstract: Falls are uncommon behaviors that pose a serious health danger to children with cerebral palsy (CP). Fall detection and prevention technologies are in dire need due to the rising percentage of CP. The development of these technologies to enhance quality of life, particularly for CPs, is a key focus of emerging technology. A fall detection system in this paper aims to anticipate falls and lower their risk. To reduce the effects of falls, a fall detection system monitors the fall and produces a help notification through IoT technology.

Keywords —Buzzer, cerebral palsy, fall detection, Internet of Things (IoT), Sensor, telegram,

I. INTRODUCTION

Children with cerebral palsy would struggle to walk and might trip and fall a lot, which would make them less active in school and community activities [1]. A fall detector's job in a cerebral palsy child is to keep track of their level of activity and spot falls that occur in the course of daily life.

This proposal outlines the layout of a falling detection and alerting system for the category of children with special needs. The children with CP pins with a fall detector affixed to their bodies (chest). The suggested system makes use of angle and g-force detection with the MPU6050 sensor and data capture to infer fall conditions from CP children. The study carried out in Mysore, India, at the charity Sneha Foundation and Mythri Charitable Trust. The conversation with the parents began with a description of the Fall detection devices, including their benefits, features, etc. Parents expressed several valid concerns after understanding the concepts of fall detection and its characteristics. To solve this problem, we have created a small, wearable fall monitor that automatically processes accelerometer signals and detects falls in real time using tri-axial Accelerometers and Gyroscope sensors. An audible beep and a telegraph notification will be produced by the sensor in response to fall that has been detected.

II. RELATED WORK

Functional restrictions caused by spasticity or altered tone, issues with muscular coordination, organization, and processing of sensory information, and an underlying dysfunctional musculoskeletal system are all common in people with CP [2]. The progress of technology and the difficulties in creating a fall detector have been studied in a trail of articles published. Imbalance issues, a gradual loss of muscle strength, and mobility issues may cause the higher risk of falls seen in individuals with CP. However, there is a dearth of studies exploring the reasons behind falls in CP patients [3]. Boyer and Patterson reported that the majority of children with CP tend to experience greater fall frequency as a general issue rather than because of a particular gait pattern [4].

The focus of the review progressively switched to the impact of a fall on children with cerebral palsy. Accordingly, Ryan et.al states that high prevalence of fractures is probably caused by the interaction of osteoporosis and falls. Falls might also be a factor in the decline in mobility that young individuals with CP frequently describe [3].

A thorough analysis of the current fall detection systems was provided by Chaudhuri et al. [5], which included 57 articles that used wearable devices and 35 that did not.

In contrast to the other survey publications, the authors of this work examined and organized fall detection investigations from the perspective of system evaluation. Results of the comparison revealed that no non-wearable fall detection research included the elderly as subjects in a lab or real-world context, while 7.1% of wearable-based systems observed the elderly in real-world environments throughout evaluation procedures. Of course, recent research hotspots like adaptive, RF-based, and adaptive-based detection approaches are hardly included in the reviews above. In addition, the authors found that pressure sensors, inertial sensors, laser sensors, and cameras were four potential methods for assessing fall risk in elderly people with high accuracy. However, when these methods were used for activity assessments, a wide range of diagnostic accuracy was reported due to variations in parameter selection, signal measurements, and modelling techniques. Putra et al. finds chest-worn and waist-worn sensors gives F-scores of 98% and 92% respectively, and

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significantly reduces the computational cost [6]. Ren and Peng in their systematic review elaborated Fall-related researches and lists pros and cons of different types of fall detection and fall prevention. Taking forward, the authors also put their perspectives on personalized and customized fall detection systems. However, there has not been much research done on CP child who have balance, gait, or walking problems.

This inspired us to develop a Fall detection system for CP-affected children who are also seizure-prone.

III. METHODOLOGY

The two charity trusts chose to conduct research on children with cerebral palsy, and as a result, mythri and sneha schools were given permission to conduct research on the subject. The parents were initially questioned on their children's difficulties with walking and balancing. The children were picked out so they would not need to be constantly monitored and would only trip and fall during seizures. The theory is that a kid who needs constant monitoring does not need a machine to alert their parents when they fall.

A multidisciplinary strategy comprising sensors, algorithms, and hardware is needed to implement a fall detecting system. Thus, the methodology follows:-

Skeleton information: like designing the block diagram, analyzing each block with its functionality and integrating each block meticulously.

Data collection: collecting information about many fall types. This clarifies the child's falling frequency, whether the child has balancing problems that require constant supervision or sporadic falls that can be tracked by a fall detection system.

Sensor selection: refers to choose appropriate sensors like accelerometers, gyroscope and Integrating hardware and software. Final stage is to fabricate and encapsulate the components in a sophisticated plastic structure followed by testing and validation.

A. Block diagram of the model

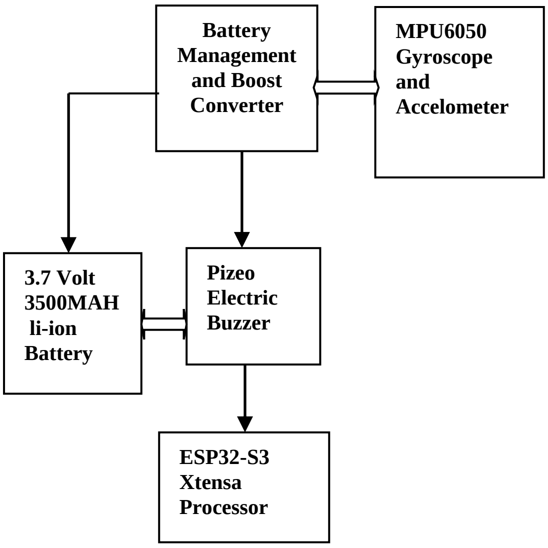

Fig.1: Block diagram of the prototype

The MPU 6050 sensor, which is also used to ascertain the user's style of movement, can be used to identify the user's relative position. These motions are divided into three categories: falling movements, heavy movements, and light movements. Small movements, sitting down or standing up are seen as light movements, while running and walking are regarded as heavy movements. Each user's movement can be classified based on the angle information generated by the gyroscope built within the MPU6050 sensor. Angle information was gathered for 0.1 seconds to identify the user's movement style.

Fig. 1 depicts the suggested fall detector's block diagram. The user's movement will trigger the MPU6050 sensor, which has been engaged, to determine the relative location. The esp32 microcontroller receives angle data at any time in accordance with the user's motion. The microcontroller also emits an output signal that the buzzer will receive after analysing the input signal to determine the user's movement type.

B. Hardware requirement

ESP32-S3 Controller
DC-DC Converter
TP4056
MPU 6050
Piezoelectric Buzzer

A powerful, all-purpose Wi-Fi+BT+BLE MCU module, the ESP32-S3 can perform a variety of tasks, such as voice encoding, music streaming, MP3 decoding, and low-power sensor networks. The ESP32 incorporates a wide range of peripherals, such as touch sensors, Hall Effect sensors, a SD card interface, high-speed SPI, UART, I2S, Ethernet, and I2C. The integration of Bluetooth, Bluetooth LE, and Wi-Fi allows for a wide range of applications to be targeted; Wi-Fi enables a direct connection to the Internet via a Wi-Fi router and a vast physical range, whereas Bluetooth allows for a simple connection to the phone or the broadcasting of low energy beacons for its detection. Because of its low sleep current of less than 5 A, the ESP32 chip is perfect for battery-powered and wearable electronics applications. The module provides a data rate of up to 150 Mbps and 20 dBm output power at the antenna in order to reach the greatest physical range.

The switch, the filter circuit, and the load make up the basic DC/DC converter. A DC/DC converter convert an unregulated DC input to a regulated DC output. A key component of MPPT hardware implementation is a DC-DC converter. In order to regulate the solar input voltage to the MPP and provide impedance matching for the greatest power transfer to the load, MPPT uses these DC-DC converters.

For single cell lithium-ion batteries, the TP4056 is a complete constant-current/constant-voltage linear charger. The TP4056's SOP packaging and low external component count make it ideal for portable applications. Additionally, a USB and wall converter can be utilised with the TP4056. Due to the internal PMOSFET architecture's ability to prevent negative Charge Current Circuit, no blocking diode is necessary. In situations of high power operation or high ambient temperature, thermal feedback controls the charge

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current to restrict the die temperature. A single resistor can be used to externally programme the charge current, and the charge voltage is fixed at 4.2V. The TP4056 automatically terminates the charge cycle when the charge current hits 1/10th of the programmed value after the ultimate float voltage has been attained. The TP4056 also has two charge-indicating status pins, an under voltage lockout, an automated recharging system, and a current metre.

The first integrated 6-axis motion tracking device in the world is the MPU-60X0. It has a 3-axis gyroscope, 3-axis accelerometer, and a Digital Motion Processor (DMP) built into a tiny 4x4x0.9mm box. To give a full 9-axis Motion fusion output, it directly accepts inputs from an external 3-axis compass via its own I2C sensor bus. Manufacturers can guarantee the best motion performance for customers by doing away with the costly and time-consuming process of selecting, qualifying, and integrating discrete devices at the system level with the MPU-60X0 Motion Tracking device. It has run-time firmware calibration, on-board Motion Fusion, and 6-axis integration. The MPU-60X0 is designed to communicate with a range of no inertial digital sensors, such as pressure sensors, via its auxiliary I 2C connector. The MPU-60X0 is footprint compatible with the MPU-30X0 family.

An audio signaling device is a buzzer. A buzzer made of piezoelectric material is utilized as an alarm system. If a buzzer's charged capacitor is allowed to discharge, a beep sound will result. The buzzer's tone has a distinct frequency due to the fluctuating voltage levels. The Piezo electric buzzer used in the suggested work to produce beep sound is depicted in Figure 2.

Fig.2: Physical picture of the buzzer

C. Software requirement

Inter Integrated Circuit (I2C)
Real-time operating system (RTOS)
Micro-python

Inter integrated circuits (I2C) is a protocol developed by Philips for connecting slave device to a master using two wire with a maximum bus capacitance 400pF. Both of the two lines, SCL and SDL, are open drain types. Additional 2.2k resistors are attached to the SCL and SDL lines in order to draw the lines up. According to Figure, SDA is a bidirectional data line and SCL is a unidirectional clock synchronized line.

The free and open source RTOS was created by Real Time Engineers Ltd. particularly for small footprint embedded systems to fit for matching implementations. Only minimally necessary functions, such as memory management, task management, synchronisation, etc., are provided, with no network communication for file system to extraneous external device driver. It has the following characteristics, such as task on Pre-emptive and can handle diverse controller architectures created by its particular manufacturer and written in C using various C compilers. The implementation of semaphores, binaries, and queues enables hardware for lengthy operational times with no limit on the number of jobs that are permitted to run in a desired time with their priorities. Micro Python is a condensed and powerful variant of Python 3 intended for use on microcontrollers and in specific circumstances. A minor piece of the Python standard library is included.

D. Featured Solutions

The ESP32 is designed to be used in applications for wearables, mobile devices, and the Internet of Things (IoT). Its cutting-edge low-power semiconductor features include dynamic power scaling, many power modes, and fine-grained clock gating. For instance, the ESP32 is only awakened when a specific condition is detected, not routinely, in a low-power IoT sensor hub application scenario. Low-duty cycle is utilised to lower the chip's energy usage. The variable output of the power amplifier enables a perfect trade-off between communication range, data rate, and power consumption.

IV. CHASSIS OF THE SYSTEM

The system's physical dimensions are extremely advanced and simple to put on and take off. The system has the proportions illustrated in fig. 3 and weighs 124 grams. The plastic body is built to ensure a safe and user-friendly device and lacks any sharp edges. The device will operate with 4.2V power supply and is rechargeable. The system is designed with only the On-off switch to ensure user-friendly environment. The actual image of the prototype is depicted in fig. 4.

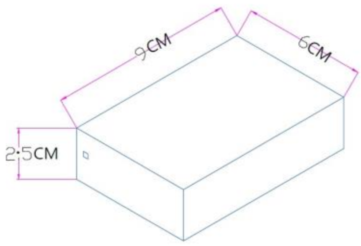

Fig.3: Physical dimension of the prototype (all in centimeters)

Fig.4: Actual image of prototype

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V. Result

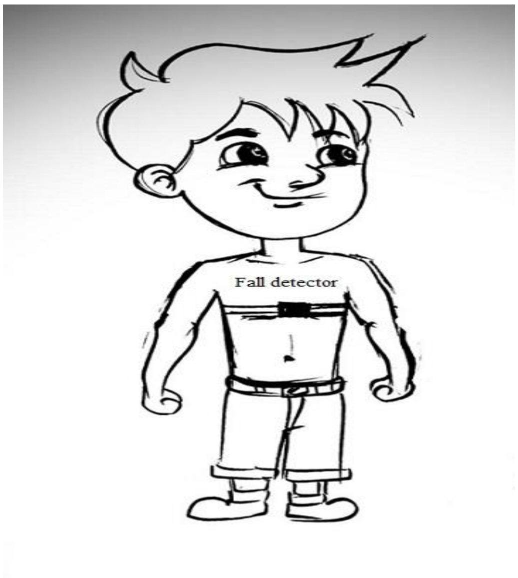

Fig.5: Machine placement at the chest level of the child

The system portrays simple and handy functionality with "one device-one switch". Setting up network connectivity, allocating IP addresses, configuring interfaces, and enabling device communication are all steps in the configuration of IoT (Internet of Things) in Fall detection devices. Once the device is setup, the machine is strapped at the chest level of the child. Numerous scientific studies investigated the ideal placement of wearable sensors to maximize the effectiveness of the fall detector. Jacob et al. [8] described a straightforward fall detection method that was applied to three distinct sites along the thoracic vertebrae to determine and confirm the ideal placement location. T-4 appears to be a very suitable position to install the machine after taking into account the physical behavior of the cerebral palsy children. The graphic in fig.5 shows the child's original appearance for the reader's convenience. When the fall detector detects a sudden fall, two notifications are sent: an alarm beep and a message via the Telegram app with the register number. The telegram window appears as seen in Figure 6. The beep sound alerts the child's parent or guardian at home or in the child's immediate vicinity, whereas the telegram message travels across great distances and the recipient can return to the sender to explain the issue.

Before being used on a child with CP who suffers from frequent seizures, the gadget was first tested with placebo method by placing the device for the normal child to determine its reliability. At every instance of the angle difference, the device ensures the beep sound and telegram information. Only when the battery was low enough did the device not deliver the telegram information. The device is basic and provides no information on the charge status. Only after the sound's intensity (beep sound) decreases will it become apparent.

Fig.6: Telegram app displaying the notification

VI. Future Direction

The created device is only a basic prototype, and we acknowledge that there is a scope for improvisation and further technological advancement. The device needs to be improved in terms of how it shows the charge state and how small it is by lowering its physical dimensions and weight. Since it is attached to the cerebral palsy children, the gadget is vulnerable to falling and water immersion. By developing a water-proof apparatus and rugged chassis, this might be solved.

VII. Conclusion

As a result of our interactions with the parents of children with cerebral palsy and recurrent seizure issues, we became aware of the serious harm that a child experiences anytime it falls. This issue ushered us to develop a fall detector integrating IoT technology. The developed prototype is easy to use and straightforward. The use of a gadget with two fall notification options will decrease the impact or effect of a fall. When they receive the fall notification, the parents of children with diplegic cerebral palsy can immediately take the appropriate action. The system has its own constraints, such as constant internet access, because it is IoT dependent.

The hypothesis achieved by the combination of accelerometer and gyroscope sensors though more improvisation needed. Because cerebral palsy children are being used, the fall detection system itself is at risk of falling. The difficulty arises from keeping the gadget out of the child's grasp despite the fact that it is bonded to the body. From this, it may be inferred that T-4 is the ideal place for it to fit. There is a scope for further potential improvements by enhancing sensor technology, well built rugged and compact structure, data processing algorithms and integrating with other healthcare systems.

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