Integrated Sensor System for Monitoring Stereotypic Behavior in Autism Spectrum Disorder

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ABSTRACT

AUTISM spectrum disorder (ASD) is a complex neurodevelopmental disorder characterized by social and communication impairments and restricted and Stereotyped behaviors. This repetitive, fixed pattern of behavior is associated with autism. There are a wide range of behaviors mentioned as stereotypies. It usually starts in early childhood and its severity is associated with outcomes and severity of autism continues adolescence and adulthood. It is usuallycomorbid with other psychiatric problems and its pathophysiology is not exactly known. However, promising new ideas and evidence are emerging from neurobiology and developmental psychology that identify neural adaptation, lack of environmental stimulation, arousal, and adaptive functions as key factors for the onset and maintenance of Restricted and Repetitive Behaviors (RRBs). By combining these sensors, the system can gather a diverse range of data, including movement patterns, changes in orientation, and physiological indicators such as heart rate. The accelerometer detects repetitive actions characteristic of stereotypic behavior, with a predefined threshold triggering pattern recognition. Simultaneously, the tilt sensor captures shift in the child's position, providing additional context to the detected movements. Furthermore, the heart sensor monitors the child's physiological state, offering insights into arousal levels or stress. Through real-time analysis of data from these sensors, the system can identify potential signs of stereotypic behavior indicative of ASD. Upon detection, appropriate interventions, such as vibrating the device and playing music or voice prompts, can be initiated to engage the child or interrupt the repetitive behavior. This project consists of accelerometer sensor, tilt sensor, heart sensor, Arduino microcontroller. The accelerometer and tilt sensor are used to detect the child activity continuously. The sensor values are fed to Arduino microcontroller. If sensor values cross the threshold value, the vibration trigger the child and voice(music) will be play while in autistic spectrum disorder. The IoT is used to monitor the child activity continuously.

Keywords: Autistic Spectrum Disorders, Language, Chain learning and Accelerometer.

INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by challenges in social communication, repetitive behaviours, and restricted interests. One of the hallmark features of ASD is stereotypic behaviour, which involves repetitive, nonfunctional actions or movements. Stereotypic behaviour can manifest in various forms, such as hand flapping, rocking back and forth, or repeating phrases or actions. These behaviours often begin in early childhood and can persist into adolescence and adulthood, impacting the individual's quality of life and functioning. Managing stereotypic behaviour in individuals with ASD poses significant challenges for caregivers and healthcare professionals. Traditional approaches to intervention have relied on behavioural therapies and environmental modifications. However, these methods may not always be effective, especially in addressing the complex and diverse nature of stereotypic behaviours.

In recent years, technological advancements have opened up new possibilities for monitoring and managing stereotypic behaviour in individuals with ASD. One such innovation is the integration of sensor technology into wearable devices. By utilizing sensors such as accelerometers, tilt sensors, and heart rate monitors, it becomes possible to gather real-time data on the individual's movements, orientation, and physiological state. A system based on WSN that provides a continuous monitoring without limiting the freedom and privacy of the patients. The main goal is to distinguish between data with and without autism movement.

SYSTEM COMPONENTS

Accelerometer sensor: Detects repetitive movements associated with stereotypic behaviour.

Tilt Sensor: Captures changes in the individual's orientation or position.

Heart Rate sensor: Monitors physiological indicators such as heart rate, providing insights into arousal levels.

These sensors work together to collect data on the individual's behaviour and physiological state in real-time. The data are then processed using pattern recognition algorithms to identify instances of stereotypic behaviour. Upon detection of stereotypic behaviour, the system triggers personalized interventions designed to engage the individual and interrupt the repetitive behaviour. These interventions may include vibrating the device, playing music or voice prompts, or providing sensory stimulation.

In summary, the integration of sensor technology into wearable devices offers a promising approach to addressing the challenges of stereotypic behaviour in individuals with ASD. The proposed system represents a novel and innovative solution that has the potential to improve outcomes and enhance quality of life for individuals with ASD and their families.

In this work we focus attention on the autistic spectrum disorders (ASD), a group of variable neuron-developmental disorders that first arise during childhood, and generally follows a fixed progress without remission. Manifest symptoms gradually begin after the age of six months, become established by an age of two or three years and tend to continue through adulthood. There are distinguished not by a single symptom but by a characteristic triad of symptoms: impairments in social interaction; impairments in communication; and restricted interests and repetitive behavior.

Although ASD is a life-long disorder with no known cure, several studies have shown that children with ASD can learn how to act in social situations when they can repeatedly practice specific scenarios. However, traditional educational interventions for ASD are costly, inaccessible, and inefficient due to limited resources and weak motivations. In recent years, computer-based interventions have shown potential due to their low-cost, their appeal to children with ASD, and their relatively broader access.

Many children with ASD exhibit a natural affinity for computer technologies that leads to a higher level of engagement and fewer disruptive behaviors in computer based interactions. In particular, virtual reality (VR) technologies allow children with ASD to actively participate in interactive and immersive simulated situations. Several VR-based systems have been developed to teach important living skills, such as driving skills, and social skills, to children with ASD. And results suggest that children were able to appropriately understand, use and react to virtual environments with the possibility of transferring theses skills to real life. In this paper, we are monitoring patient through the IoT and data are stored in the cloud help oh ESP 8266 – 12E NODE MCU. NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems. The term "NodeMCU" by default refers to the firmware. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson, and spiffs.

LITERATURE REVIEW

Shreya Bose, Prakriti Seth Et All Proposed To Screening Of Autism Spectrum Disorder Using Machine Learning Approach In Accordance With Dsm-5 – Ieee, 2023

In this existing paper, several parameters of ASD detection were implemented with open-source ASD datasets and analyzed using several machine learning models like Logistic regression, XGboost, SVC and Naive Bayes. Among these XGboost showed the best performance. The outcomes of such analytical approaches demonstrate that, when suitably optimized, machine-learning techniques can offer robust predictions of Autism Spectrum Disorder (ASD) status. These findings imply that it may be feasible to employ these models for the early ASD detection, thereby enhancing the prospects of timely and effective intervention. XGBoost has given best results throughout all datasets, including cross validation. An accuracy of 100% has been achieved, making the model best for prediction.

Sankar Ganesh Karuppasamy And Divya Muralitharan Et All Proposed Prediction Of Autism Spectrum Disorder Using Convolution Neural Network – Ieee,2022

In this existing paper, physicians can use artificial intelligence (AI) technology to help them implement computerized diagnosis and rehabilitation processes. Neuroimaging-based approaches have been the focus of deep learning algorithms for ASD diagnosis. Neuroimaging techniques are benign disease indicators that could aid in identifying ASD. Neuroimaging procedures, both structural and functional, give doctors much information about the brain's anatomy and activity. Because of the brain's complex structure and function, developing optimal processes for ASD identification using neuroimaging data deprived of using Deep Learning is difficult.

Our proposed work aims to identify Autism Spectrum Disorder(ASD) from a huge dataset based on brain patterns. Using a convolution neural network.

Mihaela Chistol And Cristina Turcu Et Proposed All Autism Assistant: A Platform For Autism Home-Based Therapeutic Intervention – IEEE,2023

In this existing paper, ABA therapists emphasize the importance of practicing therapeutic techniques in the child's natural environment to maintain their effectiveness. Therefore, there is a need to supplement therapy in the home environment where the children spend most of their time. If a parent or caregiver assumes the role of co-therapist and practices with the child, it can result in faster skills improvement. However, many parents lack knowledge about therapeutic protocols. To address this gap, we conducted research and developed educational software for therapeutic interventions for Romanian children diagnosed with Autism Spectrum Disorder (ASD) in a home-based setting. We followed the Double Diamond Model, emphasizing the core principle of Human-Centered Design (HCD) methodology, to design the software with a focus on the special needs of end-users. ABA therapists emphasize the importance of practicing therapeutic techniques in the child's natural environment to maintain their effectiveness. If a parent or caregiver assumes the role of co-therapist and practices with the child, it can result in faster skills improvement. To address this gap, we conducted research and developed educational software for therapeutic interventions for Romanian children diagnosed with Autism Spectrum Disorder (ASD) in a home-based setting.

Abishek S, Jeyapratap and Drew Parker Et Prpose All To Analysis Of Structural Brain Network Topology Alterations In Autism And Its Relationship With Autism Severity – IEEE, 2023

In this existing paper, the application of a novel connectome measure called Network Normality Score (NNS) to identify brain abnormalities and quantity topological dissimilarities in individuals with ASD. We show that the network topology of structural connectivity is altered in ASD brains relative to healthy controls at the global and system levels.

We demonstrate that structural connectivity differences are more pronounced in certain subnetworks. Finally, we quantify the association between network similarity and behavioral autism severity to show the efficacy of NNS as a neuroimaging measure.

Proposed System

The proposed system aims to leverage this technology to create an integrated sensor system for monitoring and managing stereotypic behaviour in individuals with ASD. By combining multiple sensors into a single wearable device, the system provides a comprehensive solution for continuous monitoring and intervention. By providing timely and targeted interventions, the proposed system is support individuals with ASD and their caregivers in managing stereotypic behaviour more effectively.

Additionally, the system offers the potential for remote monitoring, allowing caregivers and healthcare professionals to track the individual's behaviour and progress over time.

System Design

The proposed system is a wearable device equipped with sensors designed to monitor and manage stereotypic behaviour in individuals with ASD. Leveraging IoT technology, the device continuously collects data on the individual's movements, orientation, and physiological state. This data is transmitted to a centralized platform for analysis and intervention.

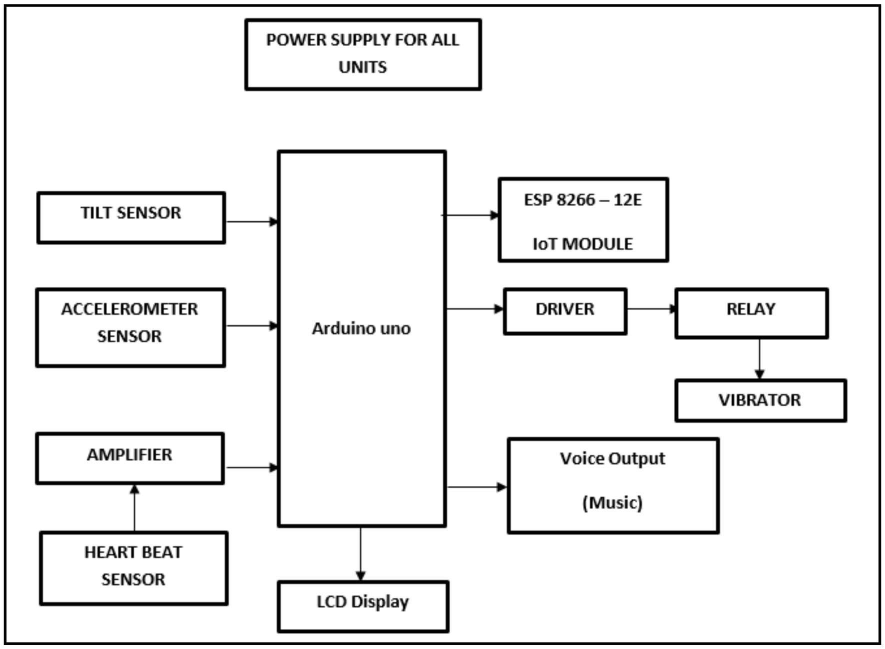
Data collection and transmission
Centralized Platform
Intervention and Feedback
Remote Monitoring and Management

The aim of this paper is to provide a lightweight approach for early detection of nocturnal epileptic seizures using data from 3-D accelerometer sensors, tilt sensor & heart rate. Datasets from patients suffering from heavy autism disorder were used for the development of automatic detection autism.

In this system includes the tilt sensor, 3D accelerometer sensors, vibrator, PIC Microcontroller, IoT module, driver circuit with relay and heart beat sensor are used. An accelerometer is a device that measures proper acceleration; proper acceleration is not the same as coordinate acceleration (rate of change of velocity). This is placed in wrist of patient hand.

For example, an accelerometer at rest on the surface of the Earth will measure acceleration due to Earth's gravity, straight upwards (by definition) of $g \approx 9.81$ m/s2.

The basic tilt switch can easily be used to detect orientation. There are numerous uses for these basic sensors, but keep in mind you might need to use some debouncing code, as the sensor isn't immune to small vibrations... These sensors output is given to Arduino microcontroller. Which is a programmable IC. If the above sensor value is exceeds compared with predefined values, which is accrued in the development phase. The PIC controller is sends the signal to the vibrator to trigger the patient body with help of relay driver circuit. And then the voice board will ON to play some music, to relaxes the patient from hypertension due to autism disorder.



BLOCK DIAGRAM DETAILS

Power Supply - A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others. Batteries or USB power source to power the device.

Accelerometer Sensor - The accelerometer continuously measures acceleration forces along multiple axes (x, y, and z). the accelerometer detects repetitive movements associated with stereotypic behavior in individuals with Autism Spectrum Disorder (ASD). When the measured acceleration exceeds a predefined threshold, it indicates the occurrence of a movement potentially associated with stereotypic behavior.

Heart Rate Sensor – The heart rate sensor measures the individual's heart rate. Changes in heart rate can indicate arousal levels or stress, which may correlate with stereotypic behavior. Integrating heart rate monitoring adds another dimension to the system's ability to detect and respond to stereotypic behavior.

Tilt Sensor - The tilt sensor detects changes in orientation or tilt. The titlt sensor is placed in the neck of autism disorder affected patient. It provides additional context to the accelerometer data by capturing shifts in the individual's posture or movement.

Vibrator - The vibrator provides tactile feedback as part of the intervention strategy. When triggered, it delivers vibrations to the individual wearing the device, serving as a sensory stimulus to interrupt the repetitive behavior. A vibrator is a mechanical device to generate vibrations. The vibration is often generated by an electric motor with an unbalanced mass on its driveshaft.

Single Voice - The single voice board plays pre-recorded voice prompts or music. It can be programmed to deliver personalized messages or calming music to engage the individual and redirect their attention away from the repetitive behavior.

Microcontroller - The PIC microcontroller PIC16f877a is very convenient to use, the coding or programming of this controller is also easier. It is a fundamental component in the proposed system. It performs various tasks from processing all sensor inputs to alerting the buzzer.

Driver - A driver is an electronic circuit or other electronic component used to control another circuit or component such as a high-power transistor, liquid crystal display (LCD).

Liquid Crystal Displays (LCD)
A liquid crystal display (LCD) is an electronically-modulated optical device shaped into a thin, flat panel made up of any number of color or monochrome pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector. It is often utilized in battery-powered electronic devices because it uses very small amounts of electric power. LCD has material, which continues the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered from similar to a crystal.

Strucure

LCDs with a small number of segments, such as those used in digital watches and pocket calculators, have individual electrical contacts for each segment. An external dedicated circuit supplies an electric charge to control each segment. This display structure is unwieldy for more than a few display elements. Small monochrome displays such as those found in personal organizers, or older laptop screens have a passive-matrix structure employing super-twisted nematic (STN) or double-layer STN (DSTN) technology—the latter of which addresses a color-shifting problem with the former—and color-STN (CSTN)— wherein color is added by using an internal filter. Each row or column of the display has a single electrical circuit.

The pixels are addressed one at a time by row and column addresses. This type of display is called passive-matrix addressed because the pixel must retain its state between refreshes without the benefit of a steady electrical charge. As the number of pixels (and, correspondingly, columns and rows) increases, this type of display becomes less feasible. the column lines are connected to a row of pixels and the correct voltage is driven onto all of the column lines.

The row line is then deactivated and the next row line is activated. All of the row lines are activated in sequence during a refresh operation. Active-matrix addressed displays look "brighter" and "sharper" than passive-matrix addressed displays of the same size, and generally have quicker response times, producing much better images. A general purpose alphanumeric LCD, with two lines of 16 characters. So the type of LCD used in this project is16 characters * 2 lines with 5*7 dots with cursor, built in controller, +5v power supply, 1/16 duty cycle.

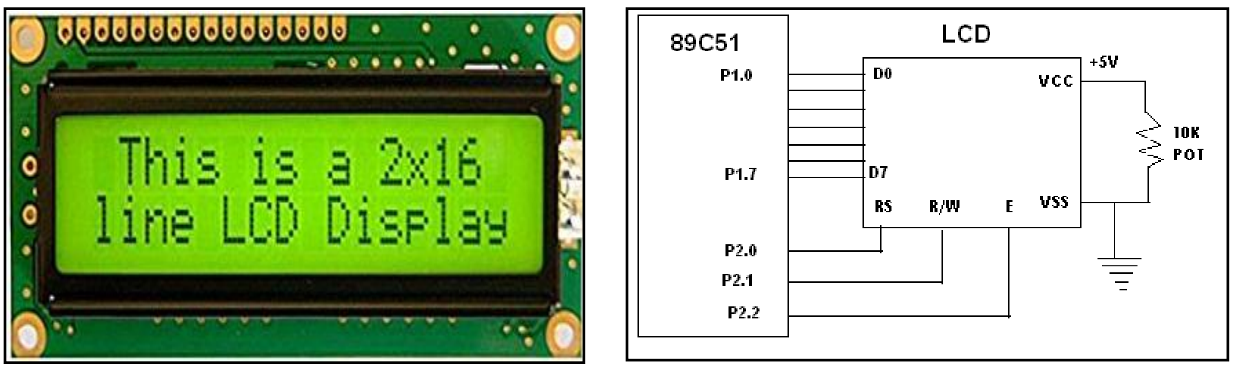


Fig: 2 LCD Interfacing With Microcontroller

Analog VS. Digital

The most important specification of an accelerometer for a given application is its type of output. Analog accelerometers output a constant variable voltage depending on the amount of acceleration applied. Older digital accelerometers output a variable frequency square wave, a method known as pulse-width modulation. A pulse width modulated accelerometer takes readings at a fixed rate, typically 1000 Hz (though this may be user-configurable based on the IC selected). The value of the acceleration is proportional to the pulse width (or duty cycle) of the PWM signal. Newer digital accelerometers are more likely to output their value using multi-wire digital protocols such as I^2C or SPI. For use with adcs commonly used for music interaction systems, analog accelerometers are usually preferred.

Output Range

To measure the acceleration of gravity for use as a tilt sensor, an output range of ±1.5 g is sufficient. For use as an impact sensor, one of the most common musical applications, ±5 g or more is desired. Amplitude stability describes a sensor's change in sensitivity depending on its application, for instance over varying temperature or time.

Output

An accelerometer output value is a scalar corresponding to the magnitude of the acceleration vector. The most common acceleration, and one that we are constantly exposed to, is the acceleration that is a result of the earth's gravitational pull. This is a common reference value from which all other accelerations are measured (known as g, which is ~9.8m/s^2).

Digital Output

Accelerometers with PWM output can be used in two different ways. For most accurate results, the PWM signal can be input directly to a microcontroller where the duty cycle is read in firmware and translated into a scaled acceleration value. (Check with the datasheet to obtain the scaling factor and required output impedance.) When a microcontroller with PWM input is not available, or when other means of digitizing the signal are being used, a simple RC reconstruction filter can be used to obtain an analog voltage proportional to the acceleration. At rest (50% duty-cycle) the output voltage will represent no acceleration, higher voltage values (resulting from a higher duty cycle) will represent positive acceleration, and lower values (<50% duty cycle) indicate negative acceleration. These voltages can then be scaled and used as one might the output voltage of an analog output accelerometer

Uses

The acceleration measurement has a variety of uses. The sensor can be implemented in a system that detects velocity, position, shock, vibration, or the acceleration of gravity to determine orientation (Doscher 2005). A system consisting of two orthogonal sensors is capable of sensing pitch and roll. This is useful in capturing head movements. A third orthogonal sensor can be added to the network to obtain orientation in three dimensional space. This is appropriate for the detection of pen angles, etc. Verplaetse has outlined the bandwidths associated with various implementations of accelerometers as an input device.

Location	Usage	Frequency	Acceleration
Head	Tilt	0-8 Hz	Xx
Hand , Wrist, Finger	Cont.	8-12 Hz	0.04-1.0 g
Hand, Arm, Upper Body	Cont.	0-12 Hz	0.5-9.0 g
Foot, Leg	Cont.	0-12 Hz	0.2-6.6 g

Image Stabilization

Camcorders use accelerometers for image stabilization, either by moving optical elements to adjust the light path to the sensor to cancel out unintended motions or digitally shifting the image to smooth out detected motion. Some stills cameras use accelerometers for anti-blur capturing.

The camera holds off capturing the image when the camera is moving. When the camera is still (if only for a millisecond, as could be the case for vibration), the image is captured. An example of the application of this technology is the Glogger VS2, a phone application which runs on Symbian based phones with accelerometers such as the Nokia N96.

Some digital cameras contain accelerometers to determine the orientation of the photo being taken and also for rotating the current picture when viewing.

SOFTWARE DESCRIPTION

Sketch

In the getting started guide (Windows, Mac OS X, Linux), you uploaded a sketch that blinks an LED. In this tutorial, you'll learn how each part of that sketch works. A *sketch* is the name that Arduino uses for a program. It's the unit of code that is uploaded to and run on an Arduino board.

Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing. Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

Inexpensive - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50

Cross-platform - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.

Simple, clear programming environment - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.

Open source and extensible software - The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.

Open source and extensible hardware - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

RESULT AND DISCUSSION

Considerations for Heart Rate Monitoring

While the threshold value for the heart rate sensor may vary depending on individual characteristics and physiological factors, it was not directly applicable in the context of stereotypic behaviour detection. However, integrating heart rate monitoring into the system provided valuable insights into the individual's physiological state, complementing the data obtained from the accelerometer and tilt sensor.

Accurate Detection Criteria

The threshold value for the accelerometer was set at 300, enabling the system to accurately detect repetitive movements associated with stereotypic behaviour in individuals with Autism Spectrum Disorder (ASD). This threshold value was determined through extensive testing and calibration to ensure optimal sensitivity and specificity in detecting stereotypic behaviour.

Sensitivity of Tilt Sensor

The tilt sensor demonstrated high sensitivity, with a threshold value set at 1, allowing for precise detection of changes in orientation or position of the wearable device. This sensitivity was essential for capturing subtle movements and providing additional context to the detected behaviour, enhancing the overall accuracy of the system.

Customization and Adaptability

The ability to customize threshold values for each sensor remotely via the IoT platform allowed caregivers to adjust the system's sensitivity based on the individual's specific needs and preferences. This customization enhanced the effectiveness of the system in detecting and managing stereotypic behaviour, leading to improved outcomes for individuals with ASD. The ability to customize threshold values for each sensor remotely via the IoT platform allowed caregivers to adjust the system's sensitivity based on the individual's specific needs and preferences. This customization enhanced the effectiveness of the system in detecting and managing stereotypic behaviour, leading to improved outcomes for individuals with ASD.

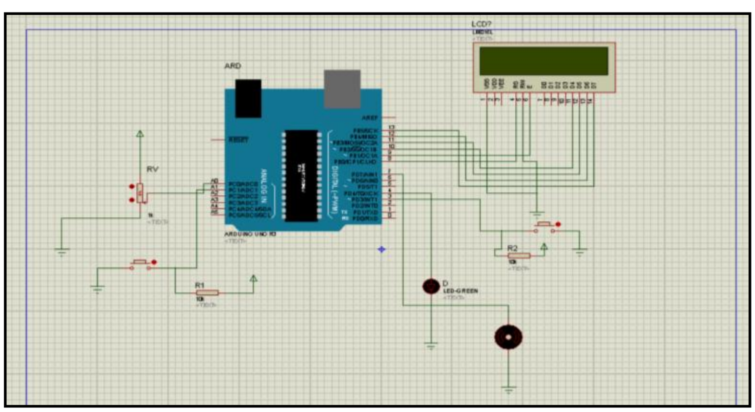
Sensor	Threshold Value
Accelerometer	300
Tilt Sensor	1
Heart Rate	ABOVE 80 below 50

Image of Autism Children

Level of Autism Detection

HEART RATE SENSOR	ACCELEROMETER SENSOR	TILT SENSOR	COUNT	AUTISM DETECTED/AUTISM NOT DETECTED
At120/80=normal	300	0	1	Autism not detected
Above 120/80=abnormal	300	1	2	Autism not detected
Below 120/80=abnormal	300	0	1	Autism not detected
	500	1	5	Autism detected
	700	1	8	Autism detected
	900	0	10	Autism detected

Simulation Image Created On Proteus



Proteus stimulation including the Arduino board and any other peripherals. This study presents a novel approach utilizing accelerometer sensors, tilt sensors, heart sensors, and an Arduino microcontroller to continuously monitor the child's activities. The sensor data is processed by the Arduino, and if values surpass predetermined thresholds, a vibrating stimulus is triggered, accompanied by the playback of calming voice or music. The Internet of Things (IoT) is integrated to enable real-time monitoring of the child's activities. This paper presents the development and evaluation of the Autism spectrum disorders prevention system, which can provide a naturalistic social interaction platform for children with ASD and their peers, increase the opportunities for communication and cooperation within the collaborative games and collect quantitative data regarding collaborative and communicative performance of the participants. The feasibility study tested the acceptability of the system among children with ASD and obtained a preliminary assessment of the system.

CONCLUSION

Technology-assisted systems can provide a quantitative, individualized rehabilitation platform. Presently-available systems are designed primarily to chain learning via aspects of one's performance alone restricting individualization. System signals that were acquired with a satisfactory level of accuracy and thereby confirm the feasibility of an anxiety-sensitive system to be used as a social communication skill learning platform for children with autism. This paper presents the development and evaluation of the Autism spectrum disorders prevention system, which can provide a naturalistic social interaction platform for children with ASD and their peers, increase the opportunities for communication and cooperation within the collaborative games and collect quantitative data regarding collaborative and communicative performance of the participants. The feasibility study tested the acceptability of the system among children with ASD and obtained a preliminary assessment of the system.

FUTURE WORK

Autism spectrum disorders prevention system will be further improved to support more naturalistic collaborative gameplay platform. We are now working on designing the ASD with the haptic interfaces that is able to produce physical feedback to the user. We expect the haptic ASD system could increase the sense of cooperation between partners. Additionally, more participants are needed in the future for the user study to assess the practical value of the system for children with ASD. In order to explore the influence of the system on the communication ability of the participants, we plan to continue with the analysis of the participants' conversations in terms of the game-oriented content and the social content and perform a statistical analysis of the change in the content of the conversation.

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