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Design and Implementation of a Wearable Device for Behavior Monitoring and Early Warning of Children With Autism

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Abstract: The prevalence of autism spectrum disorder among children has increased dramatically, highlighting the need for innovative solutions to help caregivers monitor and respond to autistic behaviors. In this paper, we propose a wearable device that integrates IoT sensing technology, wireless communication, and cloud platform visualization development technology to monitor and alert caregivers of repetitive behaviors such as clapping, hair pulling, and head banging, commonly observed in autistic children. The wearable device is equipped with posture recognition technology to monitor and alert dangerous behavior, ensuring the safety of the child. In addition, the device stores data in cloud platforms and provides real-time visualization using the IoT transmission network, allowing caregivers to monitor behavior patterns over time and make informed decisions.

Keywords: Autism; IoT sensing technology; Wireless communication; Wearable; Behavior monitoring; Posture recognition

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The incidence of autism spectrum disorders (ASD) is rapidly increasing worldwide at an alarming rate. The most recent screening data on autism prevalence, released by the Centers for Disease Control and Prevention (CDC) in 2023 and utilizing the 2020 Autism and Developmental Disabilities Monitoring Network (ADDM) analysis of 11 community-based statistical data, indicates that 1 in 36 8-year-olds have ASD, a ratio of approximately 2.8 percent. This figure represents an increase from just over a year ago, when the comparable rate was 2.3%. With a national population of 25,338,393,938 individuals between the ages of 0-14, an estimated 20 million or more are classified as special needs children, of whom three to five million are on the autism spectrum - equivalent to approximately one out of every 68 children. Such individuals possess a low capacity for social integration and acquisition of social skills, thereby imposing significant stress upon family members.

1. Introduction to the need for wearable devices for behavioural monitoring and early warning for children with autism

Children with autism spectrum disorders, commonly referred to as autistic children, exhibit distinct characteristics including difficulties with social interaction, speech impairments, emotional disturbances, narrow interests, and repetitive stereotyped behaviors. These children often engage in self-injurious behaviors such as excessive hand flapping, hair pulling, and persistent head banging. Moreover, they may frequently display a propensity to ignore their surroundings, wander away from safe areas, or separate themselves from groups, thereby posing significant challenges for their caregivers and educators. With the rapid advancement of technology and assistive devices, there has been an increasing focus on the design and application of information technology integrated with special education products.

The development of IoT AI-based behavioral monitoring and early warning wearable devices presents a significant breakthrough in providing individualized technological support for autistic children. This small and lightweight device, measuring only 5cm by 5cm, is specifically designed to be worn by autistic children, allowing for real-time monitoring of their behaviors. By integrating various functions, such as risky behavior identification and mobile electronic fence monitoring, the wearable device aims to enhance the safety and well-being of autistic children.

Utilizing sensor detection technology, IoT network transmission, cloud platform visualization web development, and other advanced capabilities, our objective is to document, organize, and provide feedback on the behaviors of individuals diagnosed with autism. Through the implementation of IoT sensing technology, the wearable device can detect potentially dangerous actions, including collisions and falls, thereby issuing real-time warnings to prevent injury or self-harm. This feature greatly contributes to safeguarding autistic children in their daily lives. Additionally, the device incorporates the latest LoRa chip signal flight algorithm, enabling the implementation of a mobile electronic fence even in environments without satellite or network coverage. Consequently, the device can operate without an internet connection, while an electronic fence can be established to prevent children from wandering or running away. Guardians of autistic children are promptly alerted through text messages or ringtones in the event of wandering or loss, thereby facilitating timely intervention by appropriate personnel to ensure the child's well-being.

The monitored data can be efficiently uploaded to the cloud platform via the IoT transmission network, enabling real-time presentation of the data. Furthermore, multiple platforms can synchronize the generated feedback, which can be conveniently accessed by parents, medical professionals, and other concerned parties. This comprehensive system not only provides valuable insights into the behaviors of autistic children but also enhances collaboration and communication among relevant stakeholders.

2. Functional design and realization

The functional schematic of our work is presented in Figure 2. The wearable device is designed to be worn by autistic children constantly, allowing for continuous monitoring of their posture and movements. By analyzing this data, the device can accurately identify the behavioral status of the child and issue timely warnings and reminders as necessary. Additionally, the device is equipped with capabilities that enable storage of data on a cloud platform and real-time visualization display through the IoT transmission network. This feature provides guardians and healthcare personnel with a comprehensive and up-to-date understanding of the child's status.

The wearable device's primary function is to monitor the child's posture and movements, which serves as a key aspect in assessing their behavioral patterns. It employs advanced algorithms and sensor technologies to precisely detect and analyze the child's behavior. Based on this analysis, the device can effectively identify potential risks or abnormal behaviors and promptly alert the appropriate individuals. This real-time warning system greatly contributes to ensuring the safety and well-being of the autistic child.

The combination of continuous monitoring, timely warnings, and real-time visualization provides a holistic approach to understanding and managing the behavioral status of autistic children. By leveraging technology and data-driven insights, this wearable device contributes significantly to improving the overall care and support for autistic children, empowering parents and healthcare personnel in their efforts to provide the best possible care and attention

2.1 Hazardous Behavior Identification Function

The IoT-based Behavioral Monitoring Series Sensor aims to detect hazardous behaviors such as collisions, self-injury, and falls in children with autism. It provides real-time warnings prior to such incidents to prevent them. The sensor features an integrated QMI8658C chip, which combines a 3-axis gyroscope and a 3-axis accelerometer, enabling it to accurately identify behaviors like collisions and falls.

The detailed analysis is as follows:

Firstly, the sensor utilizes the QMI8658C chip, which is a highly precise Inertial Measurement Unit (IMU) capable of measuring both acceleration and angular velocity. Leveraging MEMS technology, the chip ensures fast response times, low power consumption, and a compact form factor. The sensor's robust housing is waterproof and dustproof, allowing it to function effectively in challenging environmental conditions.

Secondly, the sensor operates by detecting changes in acceleration and angular velocity when autistic children exhibit risky behaviors such as crashing, self-injury, and falling. This data is transmitted to a cloud platform server for processing and subsequently analyzed using machine learning algorithms to determine whether the child is in a dangerous state. If deemed at risk, the sensor promptly sends a real-time warning signal to alert parents or guardians to take appropriate measures.

Lastly, this sensor finds application not only as a behavioral monitoring and early warning device for autistic children but also

extends to other fields like sports monitoring and health monitoring. In sports monitoring, the sensor can track athletes' efforts and identify potential injury risks. In health monitoring, it aids in tracking daily activities of the elderly, helping to identify fall risks.

2.2 Mobile electronic fence monitoring function

The mobile electronic fence monitoring function is a critical feature of behavioral monitoring and warning equipment for children with autism. Autistic children may wander away from their guardians or companions for various reasons, necessitating a device that can alert guardians or companions in real-time. The mobile electronic fence monitoring function addresses this issue through the signal flight algorithm of the latest LoRa chip—a low-power, long-range, and cost-effective wireless communication technology that enables reliable data transmission even in radio interference environments.

The LoRa chip's signal flight algorithm enables the device to detect if an autistic child has left the group or run away by measuring the distance at intervals of no more than 5 seconds with no fewer than three measurements to determine the average value. The range of the electronic fence is not less than 2 kilometers. When the device detects that the child has strayed, it will immediately send an early warning reminder via SMS or ringtone. Moreover, Beidou/GPS positioning functionality automatically activates in the alarm state so that the guardian or accompanying person can quickly locate the autistic child. This function empowers guardians or escorts to better protect autistic children from getting lost or encountering danger.

In summary, the mobile electronic fence monitoring function employs the latest LoRa chip's signal flight algorithm to create mobile electronic fences in satellite-less and network-less environments. When an autistic child leaves the group or runs away, the device sends an early warning reminder via SMS or ringtone and automatically activates Beidou/GPS positioning features to help the guardian or accompanying person quickly locate the child. This function enhances guardians or escorts' ability to safeguard autistic children and prevent them from getting lost or encountering danger.

3. Summary

This study aims to address the behavioral challenges faced by autistic children and the guardianship needs of their parents. It proposes the development of a functional design using Internet of Things (IoT) and cloud platform technologies to create a wearable device with the capability to detect and warn against dangerous behaviors. Emphasis is placed on considering the experiences of autistic children and incorporating humanized design principles. This includes focusing on the device's appearance, comfort, and portability, while minimizing sensory stimulation that may affect autistic children.

The continuous implementation of national policies in China reflects the increasing importance placed on special education and intelligent teaching. However, there is a relative lack of research on the application of artificial intelligence in conjunction with special education. Consequently, there is a need for China to build and enhance assistive technologies tailored for special education based on the actual circumstances. Looking ahead, there is a strong demand for the design and implementation of more personalized scientific and technological aids in this field.

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