Heart Rate Outlier Detection For Probable Meltdown Or Tantrum State In Autism Spectrum Disorder

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Abstract: Autism Spectrum Disorder (ASD) is a complex neurological and developmental disorder with emotional uncertainties of intensive and explosive behaviors. These emotional deficits in ASD are treated as ‘meltdown or tantrum’ and it leads to hyperactivity, impulsiveness, aggression, self-injury, and irritability. The abnormal Heart Rate (HR) could further be considered as a probable state of meltdown or tantrum occurrence in ASD. In this paper, an unsupervised machine learning algorithm has been applied over the acquired HR to detect abnormal state by using the Outlier detection algorithm. Hence, this proposed system has been capable of detection of the abnormal state in heart rate which could be an act of physiological outcome during a probable meltdown or tantrum. With the help of graphically interactive environment, it is easier for by clinicians as well as parents to understand and access the meltdown or tantrum related HR behavior.

Keywords: ASD, Meltdown, Tantrum, Outlier Detection, Heart Rate, IoT.

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex and fascinating neurological disorder with high heredity which is characterized by the discrepancy in social deficits and it could have the prevalence with hazardous meltdown or tantrum states [1]–[4]. The meltdown or tantrum in ASD is described as escalating episodes of conflicts & distressing in which intense and dangerous explosions of difficult behaviors could occur frequently. The change in emotions is a very vital gesture to reflect the stage of meltdown or tantrum, but in individuals with ASD often experience difficulty in ascertaining their own and others mental and emotional states [5]–[8]. These meltdowns or tantrums are not goal-related events and the most challenging part for themselves and their caregivers. It was observed by Koo et al. (2018) that 72% parents of ASD individuals were willing to monitor the physiological signals or behavioral parameters of their children to understand meltdown or tantrum level [9]. So, detection and monitoring of physiological signals related to meltdown or tantrum play a very crucial role in providing certain aid to individuals with ASD. For the consideration of atypical and individualized behavior in persons with autism, specialized real-time detection and monitoring system could be required, which could operate on individual features for diverse subjects [10]–[12]. Due to the assorted nature of autism, recording of real-time physiological data using wired electronic devices could be hard. To make the process hasslefree, wireless Internet of Things (IoT) architecture had been used for health care monitoring with fast access, mobility and envisioned to the modern smart health care systems [13]. In the present work, HR anomaly detection system has been proposed and implemented to detect a possible meltdown or tantrum state in individuals with ASD. The utilized hardware is capable to transmit and record the individualized HR in real-time through an IoT server and the outlier anomaly detection model has been implemented on individualized HR signals at the server. For better and easy understanding of the proposed detection system, graphical user interface has been provided which is capable to provide secure remote access to clinicians and parents.

II. MATERIAL AND METHODS

A. Heart Rate Monitoring Wristband

To acquire the HR signal of ASD individuals, specialized hardware “Fitbit” [14] has been utilized in the form of the wearable wristband and the optical heartbeat sensor of the device has been utilized for monitoring HR signal. The recorded data has been processed by the wristband itself and further transmitted to the connected IoT server.

B. Data Acquisition

In the performed analysis, one voluntarily reported ASD child with age of 9 years (male) had participated. The subject has trained to use the proposed device and the individualized HR signals had been recorded from the wristband and further transmitted to the IoT server. The trained & testing of the proposed detection model had been conducted on the basis of the collected data and some anomalies has also added synthetically for testing of algorithm. During initial experimentation in this work had assumed ASD abnormalities in HR are as nearly similar to normal developing individuals. Prior to the implementation and testing of the proposed work, written consent was also obtained from participant and legal caregiver. None of the children received any psychoactive medication during the study. The participant had the right to withdraw from the study at any time. Before the data recording sessions, child was made aware about the training sessions to adapt to experimental settings.

C. Unsupervised Analysis using Outlier Algorithm

The collected data was not classified or labeled data, so the problem might be categorized as completely unsupervised and model selection could be a big challenge. Various Outlier detection techniques such as Support Vector Machine, Isolation Forest, Elliptic Envelope, and Local Outlier Factor, were available for anomaly detection in unsupervised data, [15]–[20] but the Isolation Forest (IF) had performed far better the other available anomaly detection algorithms [21]. Since in the present work, the detected data of heart rate could play crucial role in detection of the meltdown or tantrum occurrence in ASD, the IF Outlier detection technique had been considered as best candidate for further implementation of the proposed system.
III. PROPOSED SYSTEM
The architectural view of the proposed system is shown in figure 1. This proposed system was bifurcated in three layers as first layer represented as data acquisition & transmission layer, second layer was IoT server layer, and the third layer played the role of monitoring & analysis layer. Data acquisition & transmission layer included the hardware wristband for data acquisition and this first layer was also responsible to transmit data through wireless connectivity to the internet-connected server. The acquiring data for operational activities for analysis was the major responsibility of the second IoT server layer. The third layer provided the graphical monitoring & analysis view of the each ASD individual at each caregiver site. The workflow diagram of the proposed system is shown in figure 2. Further, the step-wise working detail of this system is described as follows:

Step 1. The input data of HR signal had been collected by the hardware. The users are capable to adjust the sensitivity of the system at the end of the IoT server by adjusting Outlier detecting range that lying between 0 to 100 percent.
Step 2. The individualized HR from the wristband were transmitted to IoT connected server.
Step 3. After initial training of the unsupervised IF algorithm, an individualized model for each ASD individual was created.
Step 4. Now a trained system is ready to classify in an unsupervised manner.
Step 5. Further, the streamed data was analyzed by the proposed trained model and the output could be displayed on graphical interface at the application end connected to the IoT server.

IV. RESULTS
Results of HR data anomaly detection system using IF algorithm has shown in figure 3 to 5. Here the highlighted dots are the detected anomaly in HR signal at three different Outlier fraction rates such as 1, 5, and 10 percent.

The continuous Outlier signals may be treated as a probable state of meltdown or tantrum. The distribution of HR data and IF Outlier detection at different fractions rates (i.e. 1, 5, and 10 percent) are shown in figure 6. With the increase of fraction rate, the outcome of IF anomaly
detection algorithm has directly increased its limits. Hence, by using sensitivity adjustments according to the need of caregiver or professional will help to identify probable meltdown or tantrum state with more precision.

Figure 3: IF Outlier Detection at Fraction 1 Percent

Figure 4: IF Outlier Detection at Fraction 5 Percent

Figure 5: IF Outlier Detection at Fraction 10 Percent
V. GRAPHICAL MONITORING AND ANALYZING

Since the proposed design is a computer-based model, the output and working might be tedious for the parents and clinicians, so for the ease of parents and clinicians, an interactive graphical environment of the proposed system had been designed which made it easier to understand and access the meltdown or tantrum related abnormalities in HR. After the implementation of the proposed detection model over the collected physiological parameters to classify the state of meltdown/tantrum, the output was reflected through internet-connected graphical monitoring interface. The proposed graphical monitoring interface which could be accessed remotely by clinicians and parents at any time & anywhere since the proposed design could update the data in real-time for highlighting HR to identify probable meltdown or tantrum state. The graphical monitoring tool for meltdown/tantrum detection in ASD might be used securely after entering login credentials. The probable meltdown/tantrum state shown in as presented figure 3 to figure 5 had been reflected in the graphical user interface. This tool could work on different platforms such as MS-Windows, Linux-Ubuntu, etc. This user interface is interactive and responsive to fulfill the goal of user friendly environment. The graphical interface is presented in figure 7.

Figure 6: Distribution of (a) Collected Heart Rate Data, (b) IF Outlier Detected Heart Rate at Fraction 1 Percent, (c) IF Outlier Detected Heart Rate at Fraction 5 Percent and, (d) IF Outlier Detected Heart Rate at Fraction 10 Percent
VI. CONCLUSION
To overcome of uncertainty in detection of the state of meltdown or tantrum in ASD without predetermined and expert knowledge, HR Outlier detection based probable meltdown or tantrum detection system was developed in the present work. The proposed model was efficiently capable of detecting the uncertain states in individuals with ASD. This anomaly detection could be further used in the improvement of behavior related issues in ASD. The graphical interface tool was also been provided for easy access by clinicians and parents, which help in analyzing the probable meltdown or tantrum. In future, more specialized hardware devices could be developed by considering other physiological signals like Galvanic Skin Response (GSR), Skin Temperature, etc. and might be used more sophisticated algorithms for concrete and detailed results.

REFERENCES


