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A Machine Learning Based WSN System for Autism Activity Recognition

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***Abstract*— Autistic children often develop abnormal habits and in some cases they could be unsafe or even dangerous to themselves and their family members. Because of their limited speech ability, their inexperienced parents may underestimate their physical abilities compared to their intellectual level and may not realize that they could easily hurt themselves. Therefore, the need for an automatic alert system for autistic child parent assistance is great, and it will enhance the life experience for both the autistic child and the family.**

In this paper, we present a machine learning based electronic system for autism activity recognition using wireless sensor networks (WSNs). The system accurately detects autistic child gesture and motion. The system is named Autistic child Sensor and Assistant System (ACSA), and is comprised of three main components: the ACSA Wearable sensor device, the companion ACSA Parent Application and the machine learning algorithms developed for autistic movement event detection and processing. The paper describes the system concepts, its components and details of its architecture and operation.

Individuals and families with Autism Spectrum Disorder children can utilize this system as alarming devices that assist them to protect their autistic child regardless of the environment. The proposed system is expected to enhance the life experience for all aides, the autistic child, the parents, and the autistic child whole family.

Keywords: Autistic children support system, Machine learning for Autism activity Sensing, Machine learning for medical WSN applications, Autism Wearable Sensor device

I. INTRODUCTION

Machine learning (ML) is introduced as an efficient tool for performing artificial intelligence (AI) tasks, through the implementation of robust and computationally feasible algorithms [1]. In the last decade, machine-learning techniques have been used extensively for a wide range of wireless sensor network applications [2]. The usefulness of machine learning into WSN lies in utilizing sensors environment data to improve the performance of sensor networks in achieving various tasks without requiring software re-programming. Precisely, machine learning is important for the integrations of multi WSNs, such as in cyber physical systems, andin impeded systems applications. Here, the promise of machine learning is in performing the sophisticated AI tasks of the WSN system without human intervention. It will also support WSN autonomous control and more intelligent decision-making [3]. In particular, research literature shows that the application of machine learning to medical WSNs applications may provide tremendous flexibility and benefits[2]. In this paper, we present a machine learning based system for autism activity recognition using WSNs. The system aims towards accurately detecting autistic child motion and gesture. Autism is a group of mental disorders, collectively called autism spectrum disorder (ASD). An Autistic child may have a wide range of symptoms, and levels of impairment, or disability. Some of them may be mildly impaired by their symptoms, but others can be severely disabled[4]. An Autistic child often has abnormal skills or habits and in some cases, he or she could be unsafe or even dangerous to themselves and to his family members. Here are some specific areas that may result a situation that threaten the autistic child safety or his siblings:

- Children with autism are excessively hyperactive and tend to sleep very little and have a tendency to wander at night.
- Children with autism may run through their house at unpredictable rates, have a tendency to climb out of open windows and bangs or hits the windows.
- Children with autism enjoy being outside and playing and may escape the room they were staying in or wander away from home.
- Autistic children may wander to follow items of interest or to be away from loud noises. They enjoy motion and the outdoors, are constantly on the move and wandering to new things to explore. They may overreact or under-react to certain smells, textures, sounds, sights, and tastes.
- Many children with autism also have language and cognitive function difficulties and have trouble engaging in everyday social interactions, which makes teaching them about danger uneasy task.
- Many Autistic children have difficulty communicating,

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or limited speech ability, or are unable to predict or understand other people's actions, which make it difficult to identify them if they escaped home.

- Children with ASD often have repetitive motions or unusual behaviors, such as repeatedly flap their arms or walk in specific patterns, or subtly move their fingers by their eyes.
- ASD child may stay quiet and speak very little, yet he learns and picks up certain behaviors from movies and cartoons. Because of this, Autistic children may act in a risky unexpected behavior.
- One in four children with ASD has seizures, which, can result in a short-term loss of consciousness, or a convulsions, which are uncontrollable shaking of the whole body, or unusual movements.

In summary, an autism child is at high-risk for wandering, running away or acting in a way that may cause him severe injury or is very harmful to himself or his siblings.

Reports about ASD prevalence estimate that in USA in 2011–2012, the prevalence of parent-reported ASD among children aged (6–17) was around 1 in 50 children i.e. 2.00%, a significant increase from 2007 (1.16%)[5]. Other studies suggested that the prevalence rate for ASD in other Westernized, developing nations is about 50/10,000. This means that in a given large population, on average 0.5%, one-half percent of the population, or 1 in 200 children could be diagnosed with an ASD. Boys face about four to five times higher risk than girls [6].

With this prevalence of ASD, it is therefore, very important to investigate ways to prevent autism-related wandering incidents and injuries. Individuals and families with Autism Spectrum Disorder children are in need for system or alarming devices that assist them to protect their autistic child—regardless of the environment. These systems will enhance the life experience for all aides, the autistic child, the parents, and the whole family. In what follows, we present an electronic machine learning based WSN invention, developed for usage by families with Autism Spectrum Disorder children as alarming devices for assistance and protection of their autistic child—regardless of the environment.

II. System Architecture and Operation

In this research, we developed an electronic medical invention named Autistic child Sensor and Assistant System (ACSA) for assistance and protection of autistic children[7,8]. The invention comprised of three basic components: The ACSA Wearable sensor device, the companion ACSA Parent Application and the machine learning algorithms developed for autistic event detection and query processing.

The ACSA Wearable Sensor device is worn by the autistic child on arm, leg, chest, or any other body location depending on each specific child case. The most appropriate location is determined experimentally by the autistic child family and physicians. The ACSA Parent Apps are loaded on parents' smart devices such as mobile phones, tablets, laptops, or any combination thereof. The machine learning algorithms were developed for autism activity recognition and for accurately detection autistic child gesture and motion.

Both ACSA Wearable and Parent Apps are capable of communicating directly to the family existing home automation system in the autistic child house. Upon a situation detected by the Wearable device, a TV, radio, light or any home devices could be turned on to distract the child from his current conditions (such as a repetitive motion) and helping him re-gain focus.

The ACSA Wearable Sensor device includes the following components and capabilities:

1) GSM/SMS Modem for wireless connection and remote operation: a) The device sends text messages to Parent Apps and/or physicians to report various normal and abnormal conditions. b) The device also receives corrective orders or control actions from Parent Apps and/or physicians which are deemed necessary. For example the child is excessively displaying an unusual activity, so both parents who are in the house and the physician in the office get alerted, then the physician may decide to give the child an extra dosage of medication, and order the parents to do so remotely.
2) GPS sensor which constantly determines the child physical location. a) The device automatically knows if the child is within the safe boundaries that he/she is supposed to be in. Otherwise it sends an alert signal. b) The device automatically determines any special environmental requirements for that specific physical location where the child is at the present moment. For example the child went with his parents to a neighbor house for a visit, so the deceive automatically knows that the child is out of his house zone, and therefore, some house-enables features are not enforced, and therefore the device will automatically adopts a deferent levels of alerts thresholds for extra attention.
3) Temperature sensors. The device has two embedded temperature sensors: a) First is mounted on the side of the device which is worn closed to the body skin so it measures the body temperature. b) Second is mounted on the outer side of the device so that it measure of the surrounding ambient temperature. For example, autistic children sometimes get too cold or too hot inside their own houses but yet parents do not get to know it because the child does not speak out. So this device automatically detects that the child body temperature is outside a normal range, or simply the child is in an area with temperature outside an acceptable range, then the device will issue an electric alert.
4) Heart beat sensor which detects any abnormal heart activities such as a missing pulse or abnormal rhythm.

This is specifically important as some autistic children when engaged in good physically activities, sometimes do not realized that they are getting too tired, and hence for them to continue exercising may out them is danger zone. Therefore this device detects the level of heart rate going out of acceptable range and generates an alert.

5) Repetitive and undesired movement sensor. The device is equipped with three movement sensors: a) Accelerometer 3-degrees of freedom to detect movement acceleration in 3D space, left/right, forward/backward, and up/down. b) Gyroscope 3-degrees of freedom to detect movement orientation in the 3D space, roll, pitch and yaw. c) Magnetometer 3-degrees of freedom to detect movement in absolute reference to the North Pole. With these combined 9-degrees of freedom and its associated advanced ML algorithms , the invention device would be able to detect any abnormal movement or sequence of movements. For example a child waking up in the middle of the night and jumping on the bed in the dark could be very harmful. During the day time, autistic children often develop some form of repetitive movement such as skip jumping , shaking their hands left and right, spinning hands in circular motion, or any bodily abnormal movement. Parents are often too busy to pay attention to repetitious movement which in the long run worsens the child behavior unless it is constantly interrupted by distracting the child from that movement. When such a repetitive movement is detected, the device not only alerts the parents but it will issue an corrective response such as a loud audible sound or electric mussel stimulation pulse to distract the child and break his repeated movement.

6) Sound sensor, While sleeping, some children may choke on their own saliva and they may make abnormal sounds but not loud enough to wake up the parents. This device will detect: a) Any abnormal sounds, breathing patterns or a sequence thereof and issue an alert. b) Any normal sounds, but higher than normal amplitude level.For example, the child may see a nightmare and start making abnormal sounds or shouts with certain words.
7) Real Time Operating System which makes the device time/date sensitive adding intelligence to the way all sensors and actuators are controlled, such as the frequency of sensors detection and level of acceptable threshold, the loudness of alarm, etc.
8) Ambient control where both ACSA Wearable and Parent Apps interact with the physical space and environmental settings around the child using the house existing automation system. For example when a special child enters the kitchen without parent being present, all cabinets containing potentially hazardous equipment or tools will be locked down, until further reactions from the parents. Another example if the child wakes up and shout in the night the lights will be turned on via Parent Apps which will have software compatibility with popular home automation systems such as X-10, Z-wave, or others.
9) Intelligent Battery Control including: a) Inductive recharging where wearable devices charges while the child is still wearing it while sleeping. b) Low battery special handling.

III. SYTEM DESCRIPTION

For a full understanding of the nature of the present invention, reference in what follows are given for ACSA system physical description taken in connection with the accompanying drawings in which:

Fig. 1 Shows ACSA basic system components: The ACSA Wearable Sensor Device and ACSA Parent Apps. Also the figure shows how the ACSA communicates with the existing home automation system.

Fig. 2 Shows the internal components of the Wearable device including the sensors such as accelerometer, gyroscope, GPS, GSM, temperature sensors, heart rate, etc. and the output actuators such as speaker, static shock, other alarm outputs.

Fig. 3 is a flowchart representation of the wearable ACSA's logical operations and operative features relating to the detection of and response to a repetitive behavior state.

Fig. 4 is a schematic diagram of structural and operative features in blocked form of an embodiment of ACSA.

Fig. 5 is an external view of an embodiment of a ACSA.

Fig. 6 is a schematic diagram of structural and operative features in blocked form of an embodiment of the present invention comprising a Sensor, ambient control module, caretaker device, and environmental elements.

IV. AUTISM EVENT DETECTION AND QUERY PROCESSING ALGORTHIMS

In ACSA system , various machine learning algorithms were developed for autism activity recognition and for accurately detecting autistic child gesture and motion utilizing various device sensors measurements.

All of : the temperature sensors which measure the body and the surrounding ambient temperatures , the heart beat sensor which detects any abnormal heart activities and the sound sensor which detects any abnormal sounds of the child, collect measurements that are processed by the associated ML algorithms to detest and define the associated abnormal autistic event. The ML techniques for these sensors rely mainly on defining a specific predefined threshold values for the sensed phenomenon in order to alarm the device OS manager of any violations.

For the child motion sensing, ML algorithm process the measurements collected by the repetitive and undesired movement device and its three movement sensors. The Accelerometer sensor detects movement acceleration in 3D space, the Gyroscope detects movement orientation in the 3D space, and the Magnetometer detects movement in absolute reference to the North Pole. All these sensors work independently to detect the child body motion. Their sensors measurements are exploited by the related Machine learning algorithms to predict the autistic activity classification and definition.

The autistic motion event and query processing are often complicated and require more than a pre-defined threshold value[9].As a result, a ML classifier to combine the independent sensors predictions are used. The classifier aims toward the maximizing the posterior probability of autistic motion event detection. and classification.

V. Conclusion and Future Work

The research discussed in this paper, is used to facilitate Sensing of autistic child activates. It is designed to assist a care taker of a child diagnosed with autism. The device is comprised of various wearable WSN devices and the companion Parent Apps , and associated machine learning algorithms for autism motion event detection. One aspect of the device is its ability to detect a repetitive behavior state in the autistic child . Individuals and families with Autism Spectrum Disorder children can therefore, utilize this invention as alarming devices that assist them to protect their autistic child. The proposed systems is expected enhance the life experience for all aides, the autistic child, the parents, and the whole family.

This paper concentrates on the system concepts, its components and details of its architecture and operation. Future research works involve detailed study of the ACSA system extracted features used by the machine learning schemes to detect the autistic child activities and the details of these machine learning algorithms. Besides, an in-depth study will be carried out for performance evaluation of the ACSA proposed algorithms; in terms of data samples collection, types of the experimental protocols and analysis of the performance evaluation criteria.

Such future research is necessary for the success and adoption of ACSA system. ACSA system implements numerous sensors which are mounted on the body of a very active autistic child and its therefore quite important to reduce the cost investment of the ACSA system and increase further its robustness. Online and self-adaptive machine learning and data mining approaches are promising solutions that need to be investigated to handle this problem[10].

VI. Acknowledgment

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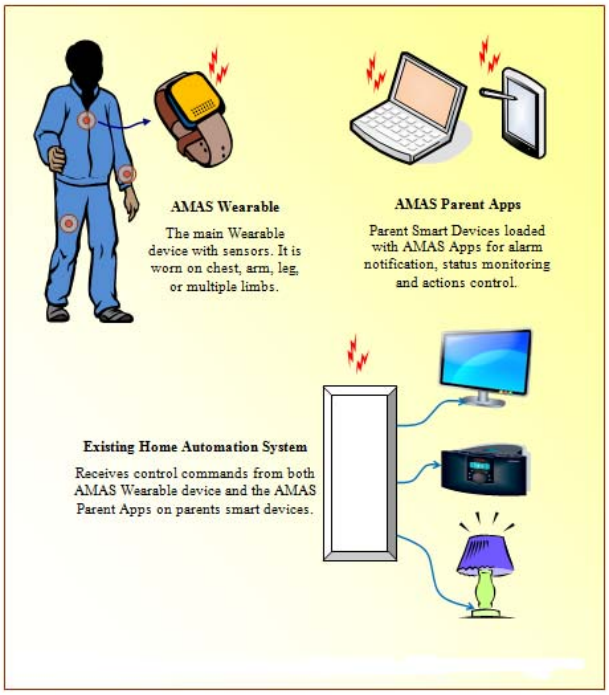

Figure 1: ACSA wearable Sensor &ACSA Parent Apps

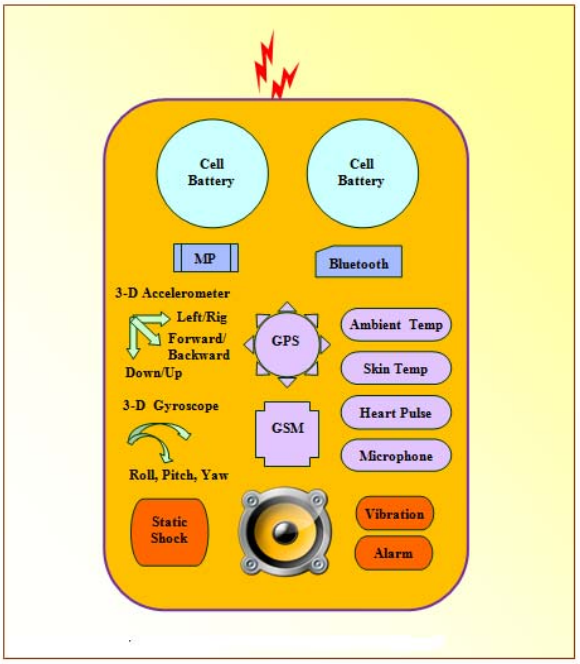

Figure 2: ACSA Wearable Sensors Block Diagram Showing internal Componenents

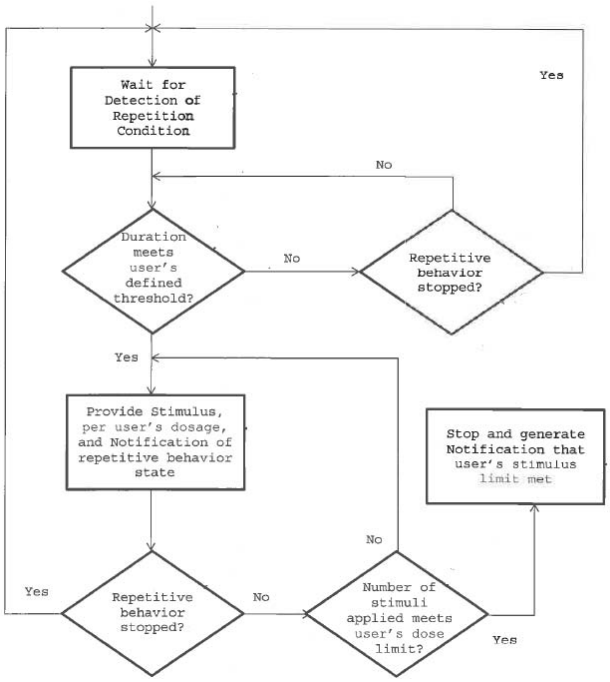

Figure 3; A flowchart representation of the wearable ACSA's logical operations

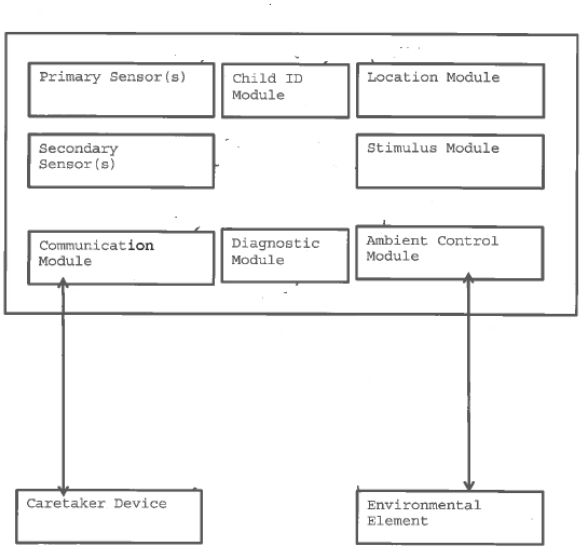

Figure 4: A Systematic diagram of structural and operative Features

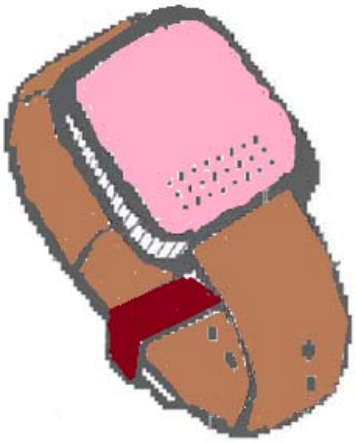

Figure5: An external view of an embodiment of a ACSA.

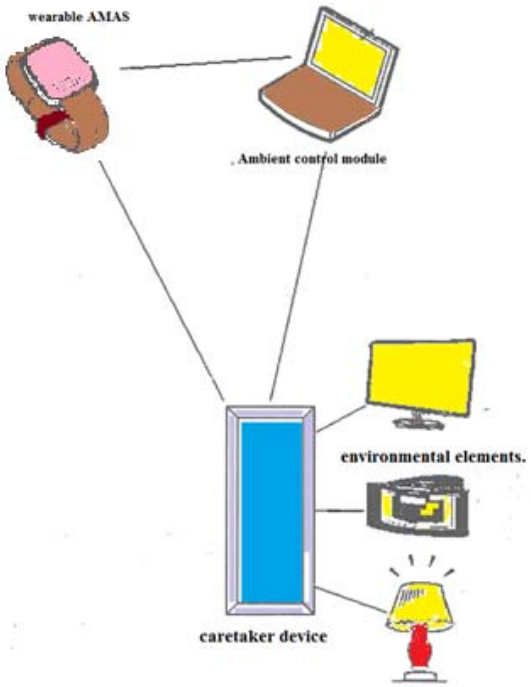

Figure 6: A schematic diagram of ACSA structural and operative features