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Design and Development of Child Abuse Detecting System (CADS)

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***Abstract*— Child abuse is rapidly increasing throughout the world. It causes lifelong consequences for a child both psychologically and physically. Maltreatment in developing countries mostly went unreported. Various methods have been devised so far to directly help guardians know about any traumatic situation for their children. This research proposes a smartly designed wearable device, Child Abuse Detecting System (CADS) that provides proactive safety features. CADS is based on the Internet of Things (IoT), E-Textile, Wearable Sensors i.e., galvanic skin response (GSR) sensor, heart rate sensor and pulse oximeter and force sensitive resistor (FSR) sensors. For the real-time monitoring of the emotional and physical state of a child, readings from the sensors are sent to the IoT cloud platform. When the readings exceed the thresholds, an alert is sent through the Global System for Mobile communication (GSM). Thus, parents are timely notified about any dangerous or alarming situation along with the location of a child. Unlike existing devices, the use of FSR in CADS provides improved results when compared with devices without FSR.**

***Keywords*— Internet of Things, E-Textile, Wireless Sensor Network, GPS, GSM, Smart wearable**.

I. Introduction

Child maltreatment is abuse and neglect that is a globally increasing problem for ages. It includes all types of physical, emotional, and sexual abuse that affect the child's emotional health and growth. Child abuse has enormous immediate and long-term reverberations, but more closely, it has serious effects on a child's development including physical and psychological problems. Childhood physical abuse predicted a graded increase in depression, anxiety, anger, physical symptoms, and medical diagnoses. Childhood physical abuse also predicted severe ill health and an array of specific medical diagnoses and physical symptoms [1] [2] [3]. Death, disability, physical injury, stress, depression, or suicidal ideation is more common among victims of child abuse. Studies shows that the overall percentage of child abuse nowadays in the world is about 80%, out of which 74% are girl children and the rest are boys [4].

Child Abuse is unfortunately a common occurrence in Pakistan. According to the data released by an NGO, eight children were abused every day in Pakistan in one form or the other while 51% of the victims were girls and 49% were boys. In an underdeveloped country like Pakistan, majority of the cases left unreported due to the family honor, concepts of morality, and cultural taboos.

The main reason for this crime is the lack of awareness in parents to educate their kids in this regard. Children are unable to complain about the abuse they experience on a regular basis. They have no idea what is happening to them at their age. Many children are even unaware that they are victims of child abuse.

Victims of child maltreatment are often not so comfortable to talk about these issues. In most cases, it leads to lifetime trauma for the children. Child maltreatment is difficult to diagnose at the initial stage and children are not able to handle these panic situations.

Children are the future of every nation, but their safety is becoming a crucial issue these times. Parents cannot always be with their children therefore, to protect them, a real-time child abuse detection system is necessary. An advanced system can be built that can detect the location and health condition of a person that will enable us to act accordingly based on electronic gadgets [5]. With the emergence of advanced computing and IoT, real-time monitoring and alert-based control systems have become easy to build. In the proposed system, the data is collected from multiple sensors embedded on a wearable device to observe the children emotional and physical state through the activation of Sympathetic Nervous System (SNS) [6]. The real-time data is sent to the cloud through which the parents can monitor their child remotely and for emergency situations, a GPS and GSM modules are used to immediately inform parents about the location of their child.

II. Literature Review

Rameesa.o, et.al in [7] established a system to aid parents in monitoring their children who work away from childcare.

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Nowadays, most parents work and are unable to be with their children all the time, thus most parents entrust their children to daycare. A daycare Centre, often known as childcare, is a facility that houses many children. Security cameras were installed to safeguard the safety of children in childcare. The proposed child monitoring system can be accessible using Bluetooth iBeacon technology and a website with authentication features. The current floor position of children in daycare is tracked using an Android app.

Anand, L.Vijay, et.al [8] focuses on children's security. The security system consists of wearable devices that will transmit data for comparison with the training dataset, a temperature sensor, pulse rate sensor, BLE module, Smart Band, Women Security Application, GSM Module and GPS Module. As temperature and pulse rate of human body gets abnormal even when a child is running, playing, surprised or excited therefore only a temperature sensor and pulse rate sensor are not sufficient to detect abuse.

N. R. Sogi, P. Chatterjee, et.al [9] describes a smart security wearable device SMARSIA for women in form of a ring which comprises of raspberry Pi zero, raspberry Pi Camera, buzzer, and a button. The device is portable but activated by the victim therefore the victim needs to act rapidly otherwise it is not suitable.

R. Kamalraj and M. Sakthivel in [10] also focuses on the security of children. The proposed system consists of alcohol and smoke gas sensors along with the blood pressure sensor which will check people in the child's surroundings. The smoke sensor can be used to get the details about any smoke from fire accidents.

A. Moodbidri and H. Shahnasser proposed the wearable in the research [11] has an advantage over other wearables in that it can be used with any cellphone and does not need an expensive device or someone who is tech-savvy to work. This device aims to assist parents in locating their children with no difficulty. This device is used only for locating the child, it is not able to detect child abuse.

P, Srivani proposed a project [12] based on women's security. An android-based smartphone with a built-in feature that delivers location-based information is the subject of this research. It uses speech recognition technology to provide self-defense and SMS notifications when a female is in danger. The module in the research proposed by V. Perumal, R.Charulatha, et.al [13] consists of a pressure switch, when the pressure switch is pressed, the buzzer turns on. Spectacles are used by the victim, on the right side of the spectacles the tear gas will be sprayed on the attacker's eyes to harm the attacker physically and on another side, the camera is fixed to visualize the live streaming video. The location along with the messages is sent to emergency contacts.

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Most of the above-mentioned systems need to be governed by the victim, they cannot get activated automatically but children cannot respond immediately to panic situations. Therefore, The CADS does not require any manual interaction from the user. According to our literature review, the general flaw of existing systems is that they are based on heart rate and temperature sensors but, these body parameters can change in any situation. Therefore, this may produce false results. As the focus of this research is child abuse detection therefore, to generate maximum true alarms the proposed CADS used force sensors (to detect external force on a child's body) in combination with heart rate and GSR sensors.

III. Proposed Architecture of CADS

The wireless sensor network is an emerging domain that combines sensors, embedded systems, and wireless communication to develop authentic and secure systems for monitoring activities. For the proposed system, IoT is used to collect sensor data and enable communication between end-device and sensor nodes through the internet, as shown in the architecture of system design (Fig.1). The sensor node is composed of an E-Textile based wearable device with heart rate sensor, GSR sensor and FSR sensor. End-device can be used by parents for real-time monitoring of the children and receiving alert messages and calls from wearable devices.

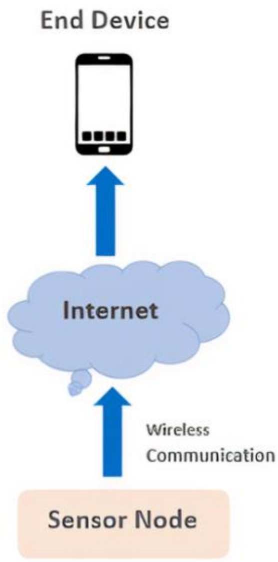

Fig. 1. Architecture of CADS

A. *Design and working of CADS*

The objective is to develop an IoT based E-Textile wearable system that can be able to detect real-time child abuse by monitoring the SNS of a child. The sympathetic nervous system gets activated in panic or stress situations, resulting in increased heart rate, blood pressure, and sweating.

For monitoring of SNS, MAX30100 (Pulse Oximeter SpO_2 & heart rate sensor), and GSR sensor are used. Along with monitoring of SNS, FSR sensors are also used to make the system more accurate to detect abuse. According to the block diagram of the proposed system (Fig.2), the data from the sensors is processed by the ESP826 microcontroller, then the ESP8266 enables serial communication with ESP32 Wi-Fi module and transfers the data serially to ESP3. The ESP32 is used to connect the hardware device to the cloud (thinger.io). Once the connection is established, the real-time sensor data is sent to the Thinger.io platform.

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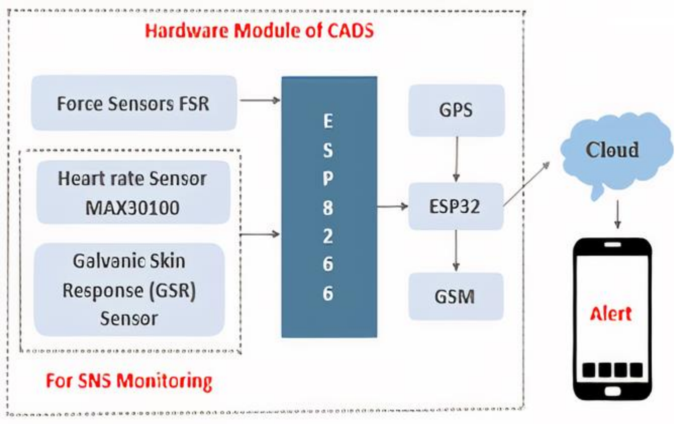

Fig. 2. Block Diagram of the Proposed System

In CADS, MAX30100 is used to monitor heart rate and blood oxygen saturation levels. During activation of the sympathetic nervous system, more sweat secrets by the sweat glands which results in increasing the conductance of skin. The GSR sensor employed in this system enables for the measurement of skin's electrical conductivity. The array of FSR sensor is used to detect unnecessary pressure and force on a child's body which also helps in detecting physical abuse and bullying. Global Positioning System (GPS triggers the real-time location of a child through which parents or guardians can keep track of their child's whereabouts and GSM is used to send messages and calls to parents in case of any emergency situation. Therefore, in the absence of internet, the wearable device keeps parents informed about their child.

TABLE I. Hardware Specifications for the Proposed Model

Components	Model	Op. Voltage
NodeMCU	ESP8266	3.3V
Heart rate Sensor	MAX30100	1.8V3.3V
Grove sensor	Galvanic Skin Response (GSR)	3.3V/5V
Force sensor	Force Sensitive Resistor (FSR)	5V
GPS	Ublox NEO 6M	2.7V~3.6V
GSM	Sim800L	3.4V~4.4V
Wi-Fi Module	ESP32	3.3V

The CADS implements the algorithm based on the deviation of heart rate, GSR values and external force that is applied to child's body. The combination of force sensors, heart rate sensor and GSR sensor can detect real-time child maltreatment. Force sensors detect the external force on a child's body, GSR sensor measures the electrical conductance of the skin and detects the emotional change in the child. Along with GSR, a heart rate sensor is used to monitor the SNS activation in a child. When the abnormal readings of heart rate and GSR are recorded and at the same time force detects on the child's body, the device will send an alert message to parents with the location of a child.

Fig.3. shows the flowchart for ESP8266. The ESP8266 connects all the sensors and takes input from them. It initializes serial communication and sends data to the ESP32 microcontroller.

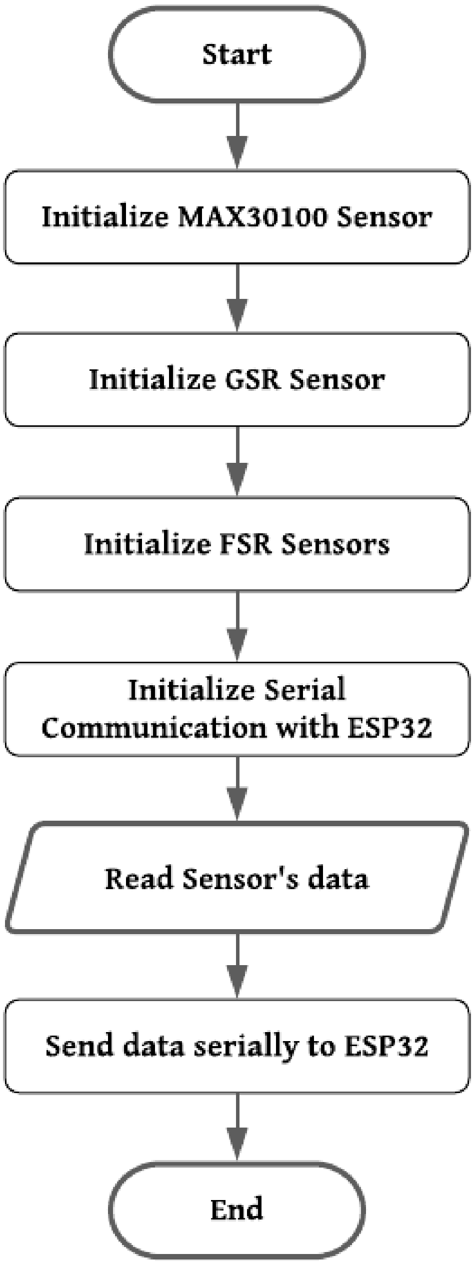

Fig. 3. Flowchart for ESP8266

Fig.4. shows that he ESP32 connects with the thinger.io, IoT platform through Wi-Fi. It receives serial data from ESP8266. The first 500 readings of heart rate and GSR are used to calculate the average. After that, the difference is calculated by comparing each input with the average.

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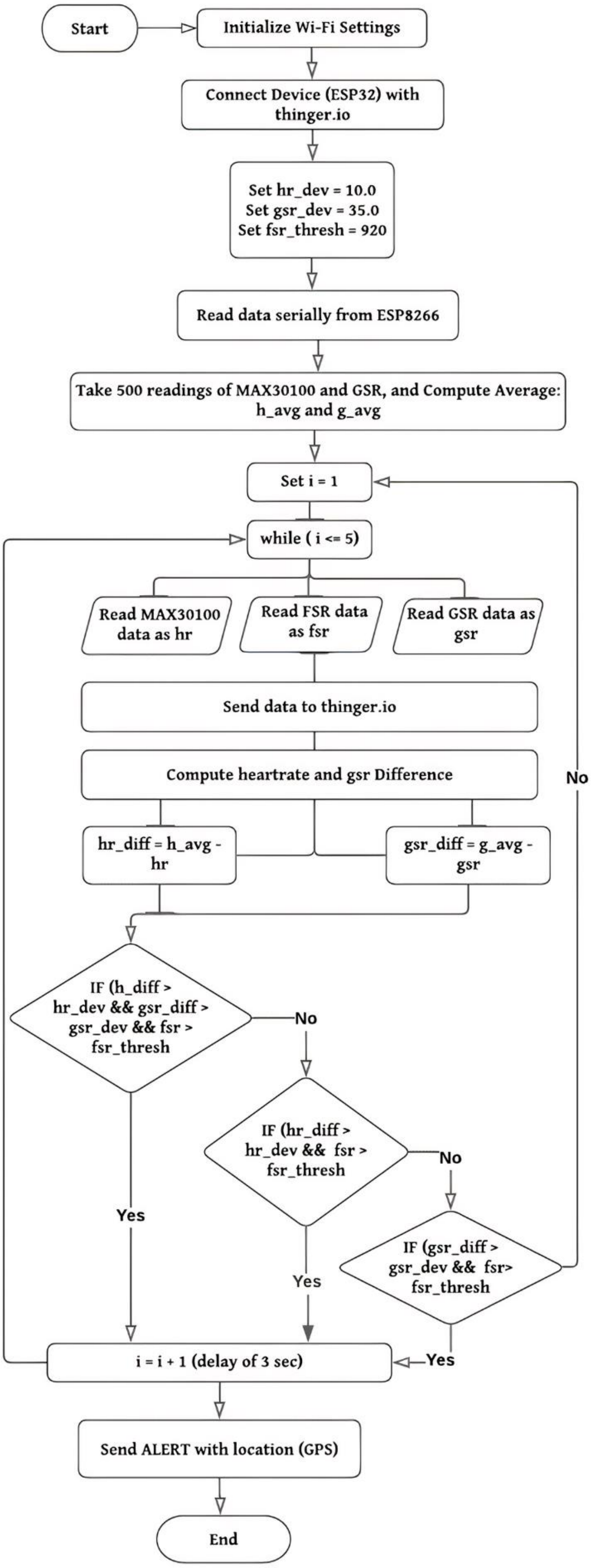

Fig. 4. Flowchart for ESP32

- hr_dev: deviation set for heart rate readings.
- gsr_dev: deviation set for GSR readings.
- fsr_thresh: threshold set for force sensors.
- hr_diff: difference of heart rate values.
- gsr_diff: difference of GSR values.
- h_avg: average heart rate of child.
- g_avg: average GSR of child.

Based upon the analysis, different conditions are specified in the flowchart that are considered as alarming conditions. When any of these conditions become true for a period of 15 seconds, the device will generate an alert for parents. The comparative analysis of existing and proposed system is shown in Table II.

TABLE II. Comparative Analysis of Existing and Proposed System

Features	Existing Systems	Proposed System
Feasibility	More focused on women and adults.	The E-Textile used in the system makes it easy to wear and convenient for children.
Data Visualization	Mostly Application-based.	Cloud-based user-friendly dashboard for parents.
Sensors used	Heart rate, Temperature sensor.	Heart rate, Galvanic Skin Response Sensor, and Force sensors.
Notification System	Can generate false results due to limited parameters.	Less prone to false results.
Wearable device	Mostly outerwear such as smart watches, smart bands, and rings.	Innerwear that is unseen to culprit.

IV. WORKING ANALYSIS

The CADS consists of a smart wearable device based on E-Textile. The flexible nature of E-Textile gives more comfort and easy-to-wear for children. The array of force sensors embedded on fabric covers the sensitive area of the child's body. The wearable (innerwear) as shown in Fig.6 connects to the prototype circuit of CADS through FSR headers.

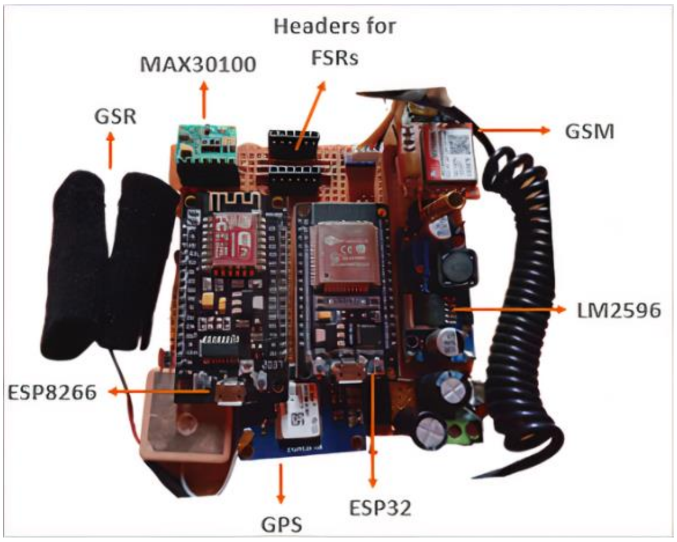

Fig. 5. Prototype of CADS

Fig. 6. Wearable (Innerwear) for CADS

The CADS was tested in a normal scenario and secondly in a simulated environment close to real-life danger situations on different subjects of age between 8 to 12. While testing in a normal condition versus inducing the fear during the experiment, a significant change was observed in the child's heart rate and GSR readings which concludes that the activation of sympathetic nervous system was successfully detected by the sensors. Along with inducing the fear, some amount of external pressure was also exerted on the body of the child which was significantly detected by the FSR. The following graphs show the difference between the normal results and fear-inducing results.

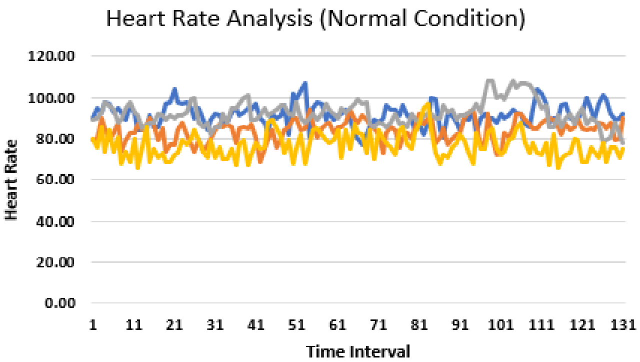

Fig. 7. Analysis of Heart rate for four subjects in normal scenario

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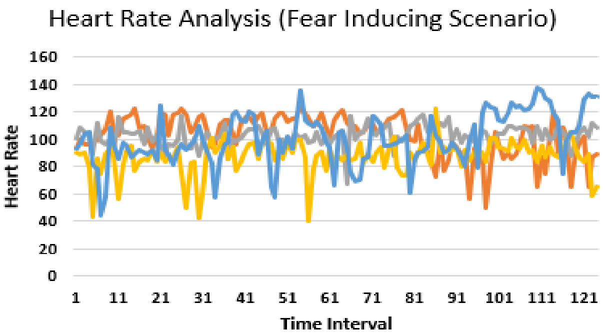

Fig. 8. Analysis of Heart rate for four subjects in fear inducing scenario

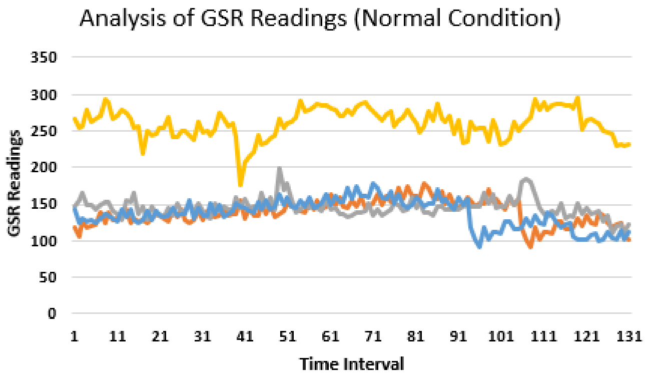

Fig. 9. Analysis of GSR for four subjects in normal scenario

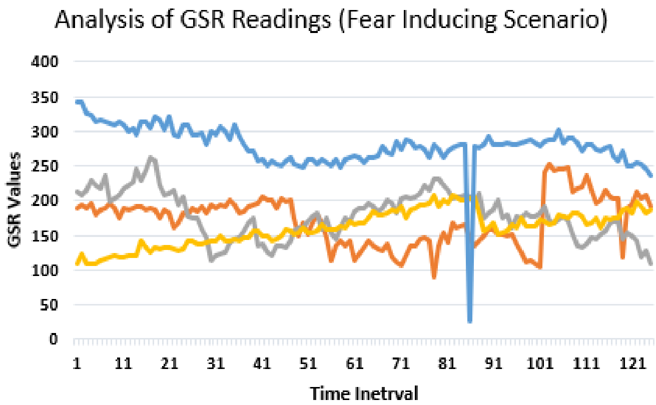

Fig. 10. Analysis of GSR for four subjects in fear inducing scenario

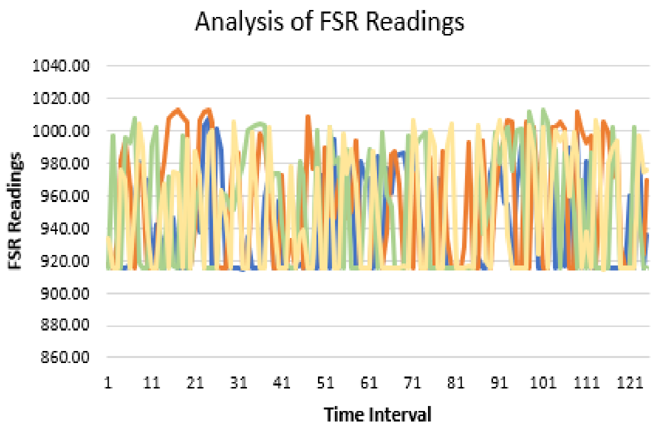

Fig. 11. Analysis of FSR for four subjects in normal scenario

Table III shown below summarizes the analysis of normal scenario. During analysis, a fair difference in heart rate and GSR readings was noticed in a similar age group of children therefore, the average is calculated for each subject to set the thresholds. If the difference in reading exceeds the average standard deviation, the device will consider it an alarming situation as shown in the flowchart of CADS.

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TABLE III. Statistical Analysis of normal scenario data

Subject	Age	Gen	AVG MAX30100	Std. Dev MAX30100	AVG GSR	Std. Dev GSR
1	9	F	91.6	5.4	138.7	17.2
2	12	F	92.3	6.0	260.3	19.9
3	8	M	84.0	5.2	145.2	13.0
4	11	F	76.8	6.2	137.2	19.1

Table IV concludes the analysis and calculation performed on data in a replicated harassing environment.

While inducing fear, a significant difference was observed between standard deviations of normal scenario versus replicated scenario. The average standard deviation observed in heart rate is approx. 13, the average standard deviation in GSR values is approx. 31 and the average FSR reading is approx. 950. Based upon this analysis the algorithm for the CADS is designed.

TABLE IV. Statistical Analysis of fear inducing data

Subject	Age	Gen	AVG MAX30100	Std. Dev MAX30100	AVG GSR	Std. Dev GSR	Average External Force FSR
1	9	F	103.0	14.6	158.8	27.6	941.5
2	10	F	87.1	12	278.8	33.4	952.9
3	9	M	102.9	8.2	179.7	31.4	956.4
4	11	F	100.5	18.4	172.4	35.1	950.3

V. Realtime Results

The data collected from the sensors is sent to the cloud, thinger.io for the real-time monitoring of child abuse. The dashboard created on Thinger.io is used for the visualization of data. By the access of this dashboard, parents can remotely track their child’s location, and their emotional and physical state through heart rate, GSR and FSR sensors.

Fig.12 (Top to bottom) Dashboard. Child Abuse Monitoring Dashboard b-

Fig.12 shows the dashboard created on thinger.io cloud platform. The dashboard displays the real-time data coming from the sensors in different views for better understanding.

VI. Conclusion

This paper focused on the security of children by designing and developing the Child Abuse Detecting System. The

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wearable device using E-Textile specifically with three sensors (MAX30100, GSR and FSR) increased the accuracy of detecting unusual and alarming situations. Usage of standard deviation, instead of a single threshold, improves the efficiency of the system, and it results in generating more true alarms. This research can be extended in future by introducing smart nano-sensors. The use of nano-sensors will be feasible to integrate and may accurately detect required parameters from the body. The use of advanced machine learning algorithms can make the system precise and error-free.

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