Mitigating Autistic Meltdowns

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FUNCTIONAL SYSTEM REQUIREMENTS

REVISION 1
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Functional System Requirements
FOR
Mitigating Autistic Meltdowns

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Change Record

Rev.	Date	Originator	Approvals	Description
-1	[2/23/2022]	[Team 12]		Draft Release

Table of Contents

List of Figures

1. Introduction

1.1. Purpose and Scope

Meltdowns in the Autistic community have been a debilitating issue affecting the quality of life for individuals with Autism and their loved ones. The intention of the 12th Man is to improve quality of life for individuals with Autism through a safe, discreet, and user-friendly device that autonomously predicts and mitigates meltdowns. The 12th Man is intended for those who have ASD but it can also be used by individuals who suffer from panic attacks. Figure 1 shows a proposed block diagram of the project from CONOPS.

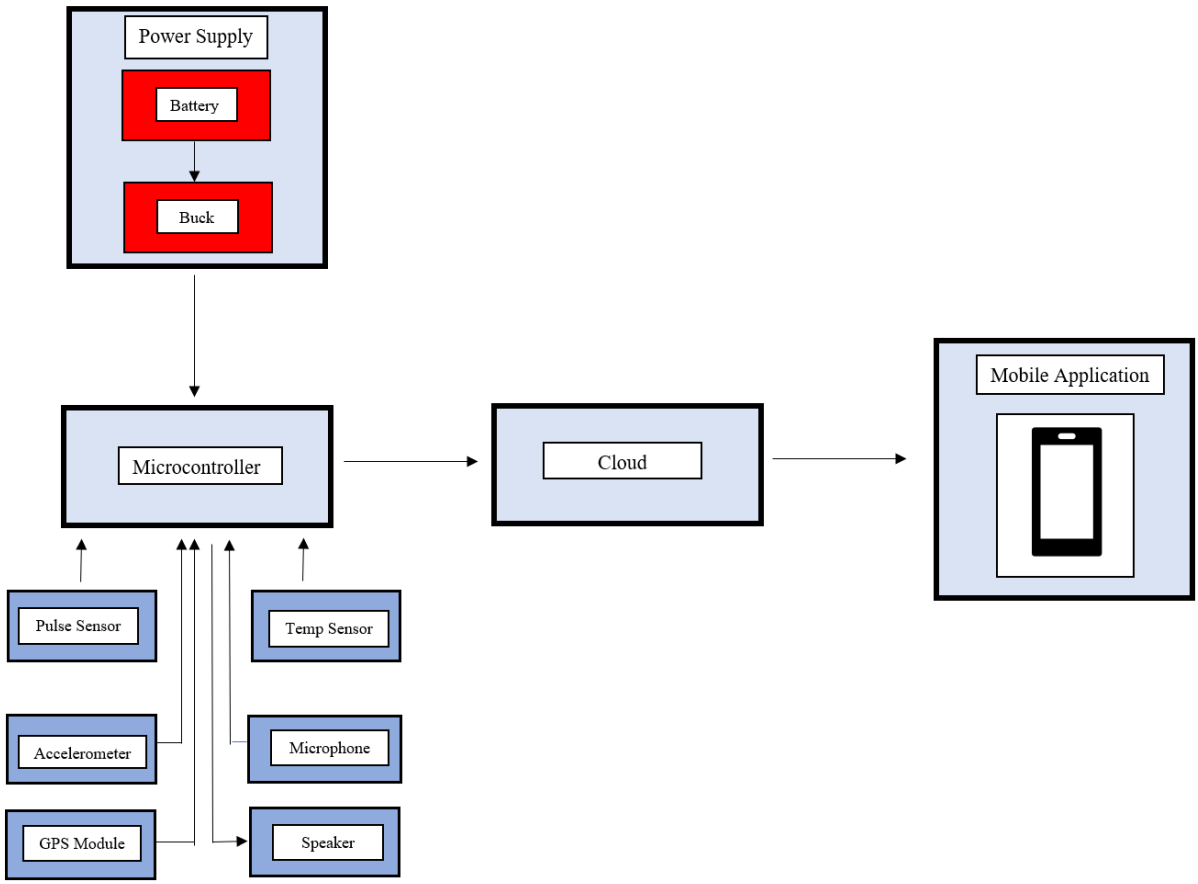

Figure 1: The 12th Man block diagram

The 12th Man is a three stage system composed of a wearable device, artificial intelligence, and mobile application/database. The wearable device shall be composed of a microcontroller, sensors, and a rechargeable battery. Sensors shall monitor the heartbeat, speed, location, and surrounding noise of the wearer. A Raspberry Pi 4 will then send the data to the artificial intelligence, which shall make a prediction about whether a meltdown is likely to occur. If a meltdown is likely to occur, a recording from a loved one will be played through speakers on the wearable. The wearable will also store the data it collects in a remote database. This database will be accessible by a mobile application, which shall provide parents/guardians with information regarding the location and meltdown status of their dependent.

Figure 2: The 12th Man Wearable Device (Concept Image)

1.2. Responsibility and Change of Authority

The team leader, Joshua Kao, will have the responsibility of ensuring that all the requirements are met. Any proposed changes to the requirements shall be vetted by each team member, and passed on to our sponsor, MarkusAI, for verification and approval. Team members will each have the responsibility of ensuring that their individual subsystems function as outlined in this document. Subsystem responsibility is as follows:

Joshua Kao	Dataset Collection, Microcontroller/Sensors
Jason Kroslowitz	Artificial Intelligence
Andres Perez	Power System
Noah Lockhart	Mobile App and Database

2. Applicable and Reference Documents

2.1. Applicable Documents

Document Name	Revision/Release Date	Publisher
Raspberry Pi Model 4 Datasheet	Release 1 - June 2019	Raspberry Pi Ltd.
TensorFlow Documentation	1.10	Google Brain Team

2.2. Reference Documents

Document Name	Revision/Release Date	Publisher
50 of most important Raspberry Pi Sensors and Components	July 20, 2020	Raspberry Pi Tutorials
Introduction to Raspberry Pi 4: Tackling the Basic Electronic Kits With the Raspberry Pi 4	May 26, 2020	Device Plus Editorial Team

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to

within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

3. Requirements

The following section will provide definitions of all three stages for the proof of concept we are developing. “The 12th Man” refers to the system in its entirety, including the wearable device where sensor data is collected and packaged, the mobile app and server where data is sent; stored; and viewed, and the artificial intelligence which performs inference on the data collected. The term “The 12th Man Wearable” refers to the physical device including the sensors, rechargeable battery, microcontroller, and enclosure. “The mobile application and database” refers to the subsystem where collected data is stored and made available to the user. The term “Artificial Intelligence” refers to the inference performed onboard the microcontroller to predict if a meltdown is imminent or not based on sensor readings.

3.1. System Definition

The 12th Man is a wearable device that shall monitor an individual with Autism to predict the occurence of meltdowns, and mitigate meltdowns should they occur. The project is composed of four subsystems, which include power systems, microcontroller/sensors, artificial intelligence, and mobile application and database.

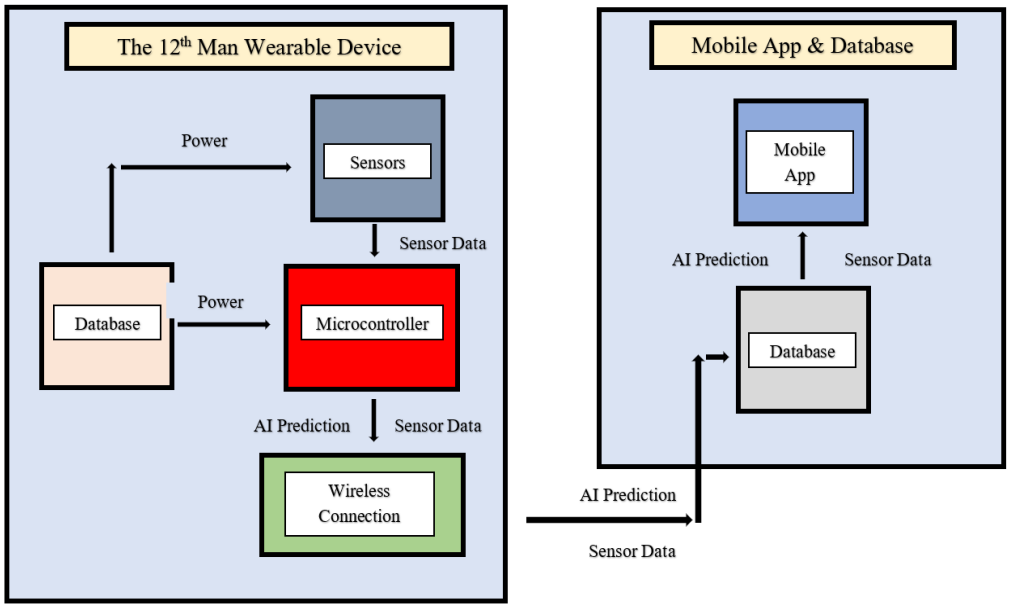

FIgure 3: Functional System Diagram

The power system subsystem shall consist of supplying power to the sensors and microcontroller. The power supply will consist of a lithium-ion battery that will supply power to the GPS module, temperature sensor, and accelerometer. A boost converter shall boost the voltage coming from the battery to supply power to the microcontroller. The system shall have a

battery charger and power-path management integrated circuit to support power management to the battery.

The microcontroller and sensor subsystem shall gather biometric data and package it into usable data. The biometric data gathered by the sensor subsystem will include the subject's location, speed, heart rate, temperature, and surrounding audio data. It should also collect gyroscopic data if needed. Following the collection of data, the microcontroller will organize the data into usable packages. The data will then be sent to the server along with the Artificial Intelligence's prediction.

The artificial intelligence subsystem will be composed of two parts. The environment acoustic classifier shall receive audio data from the microphone sensor, and shall attempt to classify the environment. A separate artificial intelligence will take as input the data from the heartbeat sensor and the accelerometer, in addition to the output of the acoustic classifier. This model shall make a prediction on the likelihood of a meltdown occurring based on the similarity of the features it receives to the "trigger" dataset on which it is trained. (This process is highly dependent on the individual: Meltdowns can express themselves in a plethora of ways, thus it is of the utmost importance to compile a dataset of triggers specific to the individual).

The database and application subsystem contains two parts as well. The first part is the database. The database will store all the input signals that are being read to the 12th Man. The most important set of data the database will hold are the GPS coordinates and the AI meltdown prediction. The app will pull the GPS location and the meltdown prediction and display them. The user can also use the app to check the connectivity of the input functions to the database.

3.2. Characteristics

3.2.1. Functional/Performance Requirements

3.2.1.1 Frequency of Measurements

Each sensor in The 12th Man device shall take a measurement every five minutes. For the microphone sensor, the data collected will be time-series data, i.e. a 10 second audio recording.

Rationale: Meltdowns that are able to be mitigated will not happen instantly, but rather over an extended period of time, during which warning signs specific to the individual are exhibited. The AI will attempt to learn what the "rumble stage" looks like in an individual and help stop it from progressing.

3.2.1.2 Accuracy of Meltdown Predictions

The 12th Man custom artificial intelligence shall meet a threshold objective of 90% correct identification of meltdown probability. When an individual exhibits any one of their several warning signs of meltdown that the AI has been trained to recognize, a meltdown should be predicted to be highly likely.

Rationale: If an individual is going to have a meltdown, it is of the utmost importance that it is predicted with high accuracy so that mitigation can begin immediately. Failing to correctly

identify, mitigate, and provide alerts for a meltdown to parents/guardians could be devastating to the individual's health and safety.

3.2.1.3 System Operation Time Constraint

The 12th Man will have a battery life of five hours. After this amount of time, the device will need to be recharged.

Rationale: The device will be able to function for five hours allowing the guardian of the individual to monitor one in the event that the individual with autism is to be unsupervised.

3.2.1.4 Wireless Communication

The 12th Man and the app must have a strong 4G connection at the minimum, or be connected to wifi at any given time.

Rationale: The device will send the data to the SQL database through the wifi connection. The database will use this data in order to predict if a meltdown will happen. If a meltdown is about to occur then the app will be notified, through the internet connection.

3.2.1.5 System Latency

The data collected by the sensors on the microcontroller and the prediction made by the AI on this data must be made efficiently and transmitted to the database and the mobile application with minimal latency. (10 seconds at the most).

Rationale: When someone is at the beginning stages of a meltdown, then the device must be able to predict this quickly and begin grounding exercises right away (a few seconds could be the difference between the meltdown being mitigated and the meltdown escalating beyond the point of control). Similarly, the parent/guardian will need to be notified as soon as possible if a meltdown is likely to occur.

3.2.2. Physical Characteristics

3.2.2.1 Mass

The mass of The 12th Man wearable shall be less than or equal to 1 kilogram.

Rationale: The device shall not be cumbersome to the individual. Rather, we are attempting to provide a minimal experience that is discreet.

3.2.2.2 Volume Envelope

The volume envelope of The 12 Man wearable shall be less than or equal to 170 mm in length, 112 mm in width, and 50 mm in height. The wearable device will consist of a 3D printed enclosure housing the microcontroller, power system, and sensors.

Rationale: The system must be able to hold all components while still being discreet for the user.

3.2.2.3 Heartbeat Sensor and Device Placement

The heartbeat sensor is unique in that it is not physically connected to the wearable as the other sensors are, but rather, shall be worn around the chest using a strap. The wearable itself shall be placed on the hip and shall feature a strap with a buckle.

Rationale: Heartbeat measurements are most accurate using a sensor that is placed directly across the chest, such as the one that we will be using. Additionally, we determined the most discreet location for the wearable to be the hip.

3.2.3. Electrical Characteristics

3.2.3.1 Inputs

The inputs that The 12th Wearable is able to handle and gather is the power supplied by the components as well as digital data collected from sensors. The sensors will communicate with the microcontroller to receive data .

Rationale: By design, the wearable device is able to be properly powered and readily available to gather data.

3.2.3.2 Power Consumption

The maximum peak power of the system shall not exceed 15W watts. The components will not need to consume a large amount of power to function which shall allow the battery to maintain sustainable battery life. The microcontroller will be the notable component that would draw the most current thus have the highest power consumption.The battery shall then be recharged when there is insufficient energy for the device to consume.

Rationale: The demanding power consumption will not exceed what is required for each component to function properly to ensure the battery shall be sufficient to power the device after a full recharge.

3.2.3.3 Input Voltage Level

The input voltage level of each component shall be in between 3.6V-5V.

Rationale: The battery will be a 3.7V Lithium Ion battery and shall supply power to sensors while the microcontroller shall be supplied with 5V after stepping up voltage coming from the battery with a boost converter.

3.2.3.4 System Data Output

Data collected by the wearable device by the GPS module, temperature sensor, heart beat sensor, accelerometer, and microphone. Data will be stored in a database for the mobile application to fetch. The database will hold GPS coordinates, and the AI predictions of a meltdown.

Rationale: The 12th Man shall include a mobile application for users to view alerts and location of the individual wearing The 12th Man.

3.2.3.5 System Audio Output

The 12th Man wearable shall play an audio recording from a loved one when a meltdown is predicted.

Rationale: This would help mitigate a meltdown however the speaker may draw more current.

3.2.3.6 Wiring

The power supply components and sensors shall be connected on a printed circuit board or PCB.

Rationale: A printed circuit board will help make the wearable device as compact as possible.

3.2.4. Environmental Requirements

3.2.4.1 Wind

The artificial intelligence system that does acoustic classification of the environment in which the individual is located is highly susceptible to wind. Should the individual be in a windy environment, the acoustic classifier will classify the environment as such, regardless of if there is a large conversation also occurring (i.e. failing to classify a large outdoor gathering, which poses danger of overstimulation, due to large amount of wind noise).

3.2.4.2 Rain

The 12th Man is not waterproof. The user must be cautious in wet environments.

Rationale: Exposure to water may cause short circuiting in the wearable device resulting in damaged components.

3.2.5. Failure Propagation

3.2.5.1 Diagnostics

The 12th Man will show the biometrics collected by the wearable on the mobile app. If biometrics are not visible the user can identify if any sensors are no longer receiving data or if there is a connectivity issue.

3.2.5.2 Database Connection

The user will be able to see if the app is not connected to the database properly.

Rationale: Allows users to see if the app is able to pull data.

3.2.5.3 GPS Connection
The user will be notified if the GPS coordinates are not being sent or received correctly.

Rationale: The location of the wearer must be presented in the app at all times.

3.2.5.4 Input Sensor Signals
A test will be added to make sure that each device that is taking an input, the accelerometer, microphone, GPS, heart rate sensor, is sending data to the database.

Rationale: If any of the input signals are no longer sending data, then the device will not be able to detect meltdowns.

4. Support Requirements

4.1.1 User Interface
Users will need to have an Android smartphone to obtain and run the app. The user should also be able to afford and access a data plan or wifi.

4.2.1 Usage of Wearable Device
The user must be wearing the heart rate sensor on their chest for the system to work reliably.

4.3.1 Maintenance
The user should check reading daily to see if the device is working properly before going into an unsupervised area.

Appendix A

AI	Artificial Intelligence
ASD	Autism Spectrum Disorder
CONOPS	Concept of Operation
GPS	Global Positioning System
I/O	Input/Output
mm	Millimeters
PCB	Printed Circuit Board
SQL	Structured Query Language
V	Volts
W	Watts
4G	Mobile Communication Standard