Sensing of Vitals for Electronic-Assisted Therapy

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1. Introduction

1.1 Objective

Alzheimer's disease is one of the most devastating illnesses affecting people in America. It is the 6th leading cause of death in the United States, with one in three senior citizens dying with Alzheimer's or some form of dementia [1]. For the roughly 5.7 million people in America affected with the disease today there are some 16.1 million Americans providing care free of charge, an estimated 18.4 billion hours of care a year valued at over $232 billion [1]. Currently, every 65 seconds someone is diagnosed with the disease, and the number of those afflicted is expected to rise as high as 14 million by the year 2050. Therefore, the number of those providing this care would have to increase as well. Meanwhile, these men and women are dedicating this valuable time to those suffering while receiving very little outside support to make their jobs any easier.

Therapalz is a company that works to help remedy this situation by assisting with the care of Alzheimer's patients. They have developed a stuffed animal that uses haptic sensors to detect the touch of Alzheimer's patients and respond with soothing noises and vibrations, replicating the feeling of a pet in order to provide comfort to the patient and make it easier for the caretakers to do their jobs. However, one of the biggest issues the caretakers face is that they need to gather a lot of data from the patients, such as heartrate or body temperature, that must be physically measured. This can confuse or upset the patients and cause stress to both parties.

Our project's objective is to implement of suite of sensors into the existing Therapalz product that would measure these same health indicators in a much less invasive fashion. By placing the sensors in the paws or head of the stuffed animal we hope to gather the data without alerting the patients and communicate the results over WiFi so that an app developed by Therapalz can be used by the caretakers to monitor the patients remotely and reduce the strain placed upon both caretaker and patient.

1.2 Background

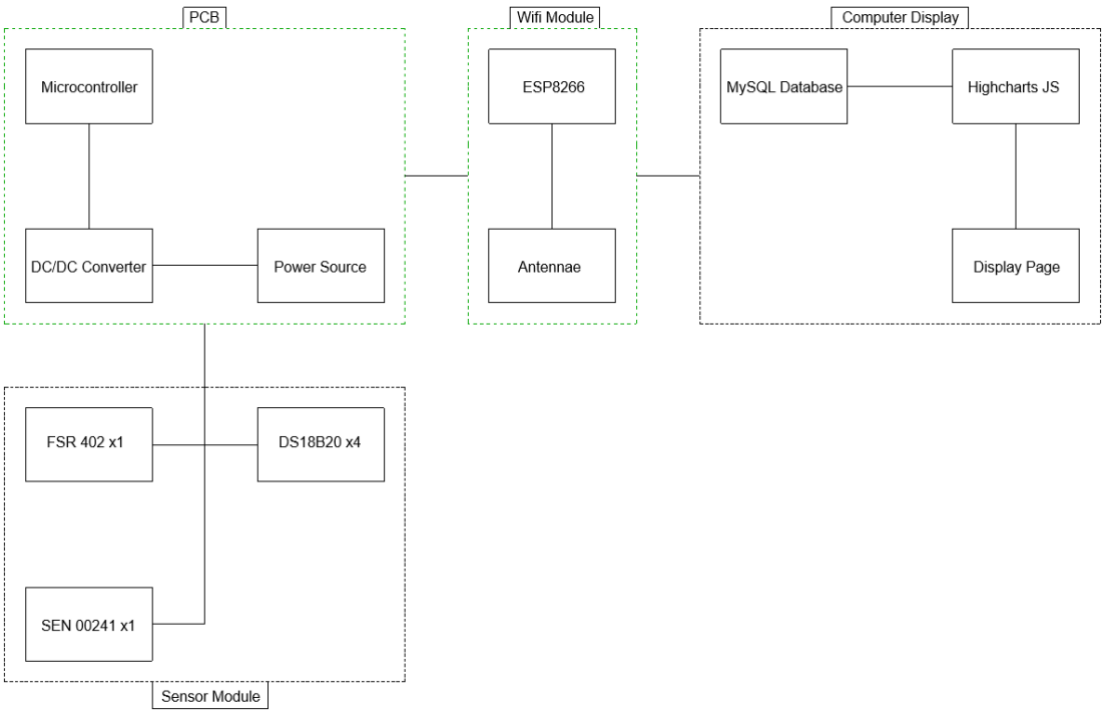
The purpose of this project is to assist the community of caretakers for Alzheimer's patients – to make their jobs easier – and to integrate with the existing Therapalz product. Therefore, our design must be simple enough that it can feasibly fit into the stuffed animal and still function at the level the caregivers require. It must also be cheap enough to be easily replicated, and be affordable to those organizations and individuals that care for Alzheimer's patients, many of which are already operating on thin budgets. Finally, we plan to work closely with the Therapalz in-house design team to integrate our sensors with an application they are developing for caretakers to download on their phones for patient monitoring.

1.3 High-Level Requirements

- Total cost must be kept low enough so as not to significantly increase the Therapalz cost
- Sensor data must be accurate enough that a caretaker does not need to physically monitor the patients while they use the Therapalz
- Total size must be limited to the capacity of the interior of the Therapalz

2. Design

Our design can be broken down in to four components; the PCB, Wi-Fi modules, sensors, and the app display. The PCB will consist of a DC-DC converter, microcontroller, USB jack, and a DC power jack. The sensors include an accurate thermometer, force sensor, and an IR emitter/detector. A Wi-Fi module will transmit the sensory data to a MySQL database which will log and document the data. With the help of Highcharts JS, the data will be processed in to interactive charts and graphs available for nurses and patients to see on an app.



2.1 PCB

2.1.1 Power Source

A power source is necessary to charge the batteries in the pet for its full functionality once it's charged. Power from the wall outlets is converted and regulated to 4 V, which then charges up li-ion batteries. Once disconnected, the pet will rely on the batteries to output 7-12 Volts for the microcontroller. We expect the patients to be using the pets quite frequently, so we need enough battery capacity to last the pet at least 10 hours after each charge.

Requirement: The battery must be able to store enough charge to provide 7-12V for the microcontroller and enough charge to last at least 10 hours per day.

2.1.2 DC-DC Converter

The DC-DC converter will be implemented in the PCB to provide 4V for the batteries to recharge (Li-Ion batteries are charged at 4.2V and will clip at above 4.3V or not function below 2.7V). It will consist of a decoupling capacitor/low pass filter or ferrite beads to regulate the output voltage with high PSRR and a low tolerance (±5%). This section of the PCB must have adequate routing widths to accept the high input current.

Requirement 1: The DC-DC converter must provide the batteries 4V from the wall outlet.
Requirement 2: The PCB routing width and filter must be adequate enough to regulate a high current and noisy input.

2.1.3 Microcontroller [2]

The microcontroller chosen is the Arduino UNO, which is based on the ATmega328P. It takes in an input 7-12V and operates at 5V. It accepts data received from the sensors, which is analyzed and processed in to useful information (e.g. calculating the period of fluctuating temperature data to estimate breathing rate). It then communicates with the Wi-Fi module to live feed the processed data.

Requirement 1: The microcontroller must be able to communicate over the Wi-Fi module.
Requirement 2: The batteries must supply the microcontroller with a steady 7-12V input.

2.2 WiFi Module

2.2.1 ESP8266 & Antennae [3]

Data that's been processed by the microcontroller is sent via Wi-Fi to the MySQL database, which logs and keeps record of the sensory data. The ESP8266 IC is a cheap SoC that can give our microcontroller access to Wi-Fi. It's also a small board that makes it feasible to implement in the pet. It takes in 3 - 3.6V and is very compatible with the microcontroller's receive/transmitting pins. The built in antenna must have enough gain or be powerful enough to transmit data in a building wherever they are.

Requirement: The ESP8266 must be powerful enough to transmit data to the network in areas with lower connectivity.

2.3 Computer Display

2.3.1 MySQL Database

We will be using a MySQL database to hold the data sent over Wi-Fi because it's a highly reliable database system, while SQL in particular is quick and convenient for adding and managing the data. We require it to be quick at receiving and logging down sensory data because if a sensor accurately measures alarming patterns in breathing for example, the data must be transferred and analyzed quickly in order to alert nurses.

Requirement: Accept data and log everything in the database on the fly.
Requirement 2: Documented data should not be deleted anytime.

2.3.2 Highcharts JS

Highcharts JS is a charting library in JavaScript, which is useful for developing interactive charts on a website or mobile interfaces. The data collected from the database can live update the mobile application and fluidly documented and represented as charts, graphs, and trends. The app needs to accurately read data from the database and push it on to the app too. One advantage of using interactive charts is because it allows patients or nurses to look back at data and find trends or patterns that may beneficial to know.

Requirement 1: Quickly document and illustrate data in to interactive charts for patients.
Requirement 2: Easily allow users to access data from the past.

2.3.3 Display Page

The display page has to be interactive and easy for users to navigate through live data, data history, etc. It will incorporate Highcharts JS and should be accessible on phones and laptops.

Requirement: Easy navigation through the site/application and readily available data.

2.4 Sensor Module

2.4.1 FSR 402 [4]

The FSR 402 is part of a force sensing resistor family, which decreases its resistance as a response to an increase in pressure to it body. It needs to be sensitive enough to take accurate readings when a patient holds on to a pet's paws, while also being resilient so data won't be skewed over time. With a given voltage across the resistor, we can detect the changes in resistance by reading the current through the resistor. This data must be processed in the microcontroller to signal that the paws are being held on to, which can then activate the infrared sensors to measure heart rate.

Requirement: The FSR 402 must be both accurate at detecting force and durable after lots of wear.

2.4.2 DS18B20 [5]

The DS18B20 is a 1-wire digital thermometer meaning it can measure temperature in Celsius and its data can be passed through just 1 wire (e.g. Microcontroller port to thermometer to ground connected in series). Its supply voltage must be between 3 - 5.5V and its drift is ±0.2 ˚C. Logistically, we will have 4 DS18B20's placed around the pet in optimal locations to take more accurate results from patients.

Requirement 1: The supply voltage must be between 3 – 5.5V.
Requirement 2: It must be placed at ideal locations around the pet for better readings. It also needs to be accurate and durable.

2.4.3 SEN 00241 [6]

The SEN 00241 is a pair of infrared emitter and detector. They operate at 940nm and provides a peak current of 50mA. These will be placed on the paws in order to read blood flow on the thumbs/fingers of the patients. It must also be durable and accurate in order to remove the need of recalibrating/repairing it. The fluctuations in intensity read by the detector correlates with heart beats and this has to be processed in the microcontroller.

Requirement 1: It must be accurate and durable over time.
Requirement 2: It must be placed on the paws optimally in order to take accurate readings of blood flow.

2.5 Risk Analysis

There are a couple of modules that will be more challenging than others, but the one that poses the most problem is the microcontroller module. We also need to make sure to be extra careful, such as not forgetting simple things like a port on the PCB so we can upload code, since ordering PCB's take time. Moreover, the Arduino code may be a problem depending on how quickly the Wi-Fi can transmit the data and push it onto a MySQL database effectively without any loss. As far as sensors go, the hardest part would be optimizing where they should be located, since each patient has their preferred way to handle a pet.

3. Safety & Ethics

In terms of safety, as this is an electrical device contained within a stuffed animal we will need to ensure that our modifications maintain the same safety standards as the existing electrical components of the Therapalz. We will thoroughly test all components of our design in order to confirm that no one will come to harm by using this product. This will serve to prevent the possibility of the product catching fire and harming the patients or caretakers.

As our sensors will serve to gather personal medical information on the patients, potentially without their direct knowledge given their condition, we must be sure to maintain their privacy to the standards of their caregivers. This will be in keeping with the first tenant of the IEEE code of ethics, "to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment" [7].

Additionally, Therapalz will be working with two other design teams on different tasks to improve their product. Therefore, we must be sure that our development does not impede their work as they do the same for us, in keeping with the 10th tenant of the IEEE ethical code "to assist colleagues and co-workers in their professional development and to support them in following this code of ethics" [7].

Other than these specific instances, we must maintain the IEEE code of ethics in any other situation it may arise in, and be sure to report and professionally deal with any other safety concerns that may come up in the execution of our design.

References

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