HEART RATE MONITOR

PROJECT PROPOSAL

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INTRODUCTION

Heart diseases, often referred to as the “silent killers”, are a formidable threat to our well-being. Unfortunately, many individuals tend to overlook the importance of heart health, leading to dire consequences. Along with the precautions, It is really important for every individual to check their heart rate regularly. But it is not necessary for you to go to the hospital to get a pulse check. Our project focuses on making a wearable heart rate monitor that makes it easy for people to check their heart rate regularly and accurately.

CUSTOMER PROBLEM

CLIENT:

- Chartwell Clair Hills Retirement Community (530 Columbia St W, Waterloo, ON)
- 138 residents [1]

PROBLEM:

- According to the government of Canada, around 1 in 12 Canadian adults over the age of 20 live with a diagnosed heart disease [2]. Moreover, around 85% of the patients with heart failure are over 65 years of age [3].
- One of the goals of the Chartwell Clair Hills Retirement Community is to support its residents through progressive and chronic illnesses [4]. However, due to the average age of residents being 85, there is a significantly higher risk of heart-related illnesses and conditions [1]. Moreover, due to the large quantity of residents, it is difficult to monitor the cardiovascular health of each and every resident simultaneously.
- With our project, we plan on creating a device that can individually monitor the cardiovascular health of every person in the area, and warn its users when they have a specific heart condition or issue. This would allow caretakers to help any resident who is in urgent need of help.

STAKEHOLDERS:

- Retirement Home Residents
  - Since they would be the primary users of the device, their input and comfort with the device are crucial.

- Retirement Homes Regulatory Authority (RHRA)
  - The Chartwell Retirement Residences are licensed by the RHRA and it would be in their interest to ensure the device does not cause any harm to the retirement homes.

- Caregivers and Nursing Staff
  - They are responsible for the care of the residents, it is important for them to have knowledge of the device. Their input is valuable as they can aid in the integration of the devices into the workflow.

- Administrators and Facility Managers
  - They will want to ensure the device aligns with their needs and budget constraints. Moreover, they will be interested in the device's impact and usability.

- Family Members
  - They want to ensure their loved ones are in the best condition possible.

- Investors or Funding Organizations
  - If any funding is necessary, investors or funding organisations will be key stakeholders. They would be interested in the potential return on investment and the viability of the project.

- Teacher Assistant (TA)
  - It is the goal of the TA to help the project steer in the right direction. They can influence various aspects of the project's development.

INITIAL REQUIREMENTS

FUNCTIONAL REQUIREMENTS:

- Adjustable wrist straps
  - The device must wrap comfortably around the user's arm like a wristband. The average male wrist size from the 1st to the 99th percentile varies between 15.59-19.44cm while the female wrist size varies between 13.61-16.82cm [5]. To ensure almost all people can wear the watch, wrist straps will have adjustability between 15-20cm.

- Display the heart rate of the user with a display panel
  - A heart rate monitor on the top of the device will display an integer value between 0-999 bpm. This range should cover the heart rate of any person as a normal heart rate for an adult ranges between 60-100bpm [6]. Moreover, there is no need to include decimal points as the integer values provide all the information needed for the purpose of the device.

- Light an LED and produce a sound to warn the user when the heartbeat is irregular
  - When the heartbeat is too high/low, the device will warn the user with a blinking LED light and produce a warning sound. This will somewhat ensure deaf and blind users both get warned when their heartbeat is irregular. For the purpose of this product, a 200-500lm LED light will suffice. This amount of light requires around 1-10W of energy which is less than the limit of 30W [7]. Moreover, a typical alarm clock tends to be around 80 dB [8]. The warning sound produced by the device will be around this amount to ensure the user is alerted.

- Displays the type of heart issue
  - Based on the heart rate values recorded by the device over time, the device will have a text-based display to show any irregularities with the user's heartbeat. These will include tachycardia, bradycardia, and a premature heartbeat as a starting point. As eyesight becomes an issue over time for most people, the displayed text will be colour-coded to ensure the user is aware of the problem [9].

TECHNICAL REQUIREMENTS:

- STM32F401RE microcontroller
  - STM32F401RE is a microcontroller from the STM32F4 series that has an ARM Cortex-M4 core and is suitable for systems that require fast and efficient code execution with low power usage [10]. The microcontroller needs to be able to handle up to 30W of power.

- C++ programming language
  - The programming language of the microcontroller needs to be able to execute code fast with as little energy as possible. C/C++ is one of the fastest languages to execute code in as it can be precompiled to an executable [11]. The C++ program needs to be able to receive input and output values to update the display of the device in a millisecond.

- Internal circuit
  - The internal circuit of the device will be invisible to the user but play a main role in the overall functionality [12]. It is important that the circuit is able to handle up to 30W of power.

- 3D printed components
  - 3D printing is a method of creating a three-dimensional object layer-by-layer using a computer-created design [13]. Certain parts will need to be 3D printed to keep the internal

hardware of the device intact and to ensure nothing is poking out. The 3D printed components will have to be resistant to around -10-45° Celsius temperature to ensure the device does not break apart due to Canada's harsh weather.

SAFETY REQUIREMENTS:

- The device will have adjustable wrist straps to ensure the user is not uncomfortable while wearing the device and does not damage their wrist.

- The device will be covered in 3D-printed material to protect it from damage. If it does get damaged, this will ensure the hardware components stay inside the device and don't injure the user.

- Ensure the device does not use more than 30W of power or store more than 500mJ of energy by testing it with a multimeter as it discharges energy without a power source.

PRINCIPALS

PRINCIPAL 1 - OPTIMIZATION:

- The timestamp of the local maximum of each heartbeat needs to be calculated to measure the heart rate and classify the type of heart issue the user may have. The sensor will provide a voltage value at each timestamp, *V(t)* where the local maxima of *V(t)* represent heartbeats. Since the slope of the function at a maximum will be zero, finding the timestamp of a heartbeat requires setting the derivative of *V(t) = 0* and solving for *V(t) [14]*.
    - $\frac{dV}{dT} = 0$

- An alternative method of finding this timestamp would be to find all points of *V(t)* that are greater than a threshold value that is fine-tuned.
    - $V(t) \geq a$

- In C++, this can be performed with the code below:
    - ```
      vector<int> maxIndices(vector<int> voltages, int threshold) {
              vector<int> results;
              for (int i=0; i<voltages.size(); i++) {
                      if (voltages[i] > threshold) {
                              results.push_back(i);
                      }
              }
              return results;
      }
      ```

PRINCIPAL 2 - LOGIC GATES:

- An ON/OFF switch will be designed from scratch to power on and off the device. This will act as an AND gate whenever a battery
      ```

connects to the hardware components such as the LED and the display. This can be described as a C++ function [15]:

- bool gate(bool battery_bool, bool switch_bool) {
  return battery_bool & switch_bool; // (0 & 1 = 0), (1 & 1 = 1)
  }
    - In this case, battery_bool will always be 1 while the switch_bool (0 or 1) is controlled by the user physically from a switch.

PRINCIPAL 3 - CIRCUIT DESIGN:

- To <u>connect the hardware components of the device</u> such as a battery and LED lights, circuit design will be used. Circuit design is the process of designing circuits. While designing these circuits, the required voltage, resistance, and current will be calculated to ensure each component of the device has sufficient power. For this, certain mathematical formulas such as Ohm's Law will be used [16]:
    - $\Delta V = IR$
    - $\Delta E = Pt$
    - $\Delta E = \Delta VQ$
    - $Q = It$
    - Here, *ΔV* is the potential difference, *I* is the current, *R* is the resistance, *ΔE* is the potential energy, *Q* is the charge, and *t* is the time. All of these formulas can be manipulated to figure out the required values at each portion of the circuit.

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