CodeBlue

Project Requirements

Modular Phone App for Cardiac Arrest Detection

Version 4.0

April 10, 2023

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1. Background

BC RESURECT consists of clinicians, scientists, etc. in British Columbia (BC) that are focused on improving survival from sudden cardiac arrest. BC RESURECT created Canadians Saving Arrest Victims Everywhere (CanSAVE) with a goal to further increase survival rates across Canada by improving recognition of sudden cardiac arrest, reducing response times for CPR and defibrillation prior to paramedic arrival, and improving brain protection and brain recovery, and helping survivors live their best lives [1].

According to the BC Cardiac Arrest Registry, current survival rates from cardiac arrest are <5%, primarily because the majority of cardiac arrests are unwitnessed and thus, people suffering a cardiac arrest do not receive immediate life-saving treatment (CPR) [2]. Our clients are a part of CanSAVE and are working on developing wearable technologies that can automatically detect cardiac arrest and alert first responders to apply life-saving medical treatment.

2. Project Outcome

The main objective of this project is to develop a phone app, internally named CodeBlue, that supports connection to wearable devices wirelessly and makes optimal decisions based on available sensor data to monitor for Cardiac Arrest (CA) and contact Emergency Medical Services (EMS).

This project can benefit the general public while especially benefiting high risk individuals, such as the elderly population and high performing athletes. A successful product that can monitor for sudden cardiac arrest (SCA) and notify EMS can lead to saving an additional 4,000 lives a year [1].

3. Functional Requirements

3.1 Minimum Viable Product (MVP)

3.1.1 Summary

Functional requirements for CodeBlue are split into two categories: MVP and stretch goals. The MVP that satisfies the client's needs is an Android mobile app that supports the four following features:

	Functional Requirement Summary
F1	Receives cardiac data wirelessly from a peripheral app
F2	Supports Bluetooth connection and communication
F3	Uses cardiovascular data input to perform cardiac monitoring
F4	Implements Emergency Procedure that includes calling 911
F5	Continuously monitors cardiac data in background mode
F6	Push notifications trigger EP and can be received in foreground and background mode
F7	Sends request holding anonymous cardiac data to cloud server that hosts the cardiac monitoring algorithm

Table 3.1.1 - List of functional requirements

3.1.2 Requirements Details

F1 - Receives cardiac data wirelessly from a peripheral app

CodeBlue needs to be able to receive cardiovascular data at a high frequency and accuracy. This will be simulated by streaming existing cardiovascular data in time series format from a peripheral app to the mobile app.

F2 - Supports Bluetooth connection and communication

CodeBlue needs to support wireless connection through Bluetooth so that cardiovascular data can be streamed from wearable devices. Integration with

actual wearable devices is out of scope for CodeBlue for reasons specified in constraints section 5.2. For CodeBlue, we ensure one type of wireless connection is supported and test that data can be received wirelessly.

F3 - Uses cardiovascular data input to perform cardiac monitoring

CodeBlue uses collected cardiovascular data and a custom algorithm to make a decision on whether or not the user is having a CA. The custom algorithm consolidates one or more data streams and uses a decision process to determine if CA is present.

F4 - Implements Emergency Procedure that includes calling 911

Upon cardiac arrest detection, the app triggers an Emergency Procedure (EP) that includes the following, in order:

1. A 30 second delay for the user to terminate the EP and prevent alerting EMS in case of a false positive CA detection
2. Call 911 through user's mobile phone
3. Pass user's location information to EMS
4. Vibrate the phone in order to alert potential bystanders that can provide cardiopulmonary resuscitation (CPR)

F5 - Continuously monitors cardiac data in background mode

CodeBlue continues receiving and analyzing cardiac data when it is backgrounded or the phone is locked. This includes executing the Emergency Protocol and placing an EMS call should a cardiac arrest be detected when CodeBlue is in the background.

F6 - Push notifications trigger EP and can be received in foreground and background mode

CodeBlue must initiate an Emergency Protocol procedure upon receiving a positive cardiac arrest detected notification from the server. The EP procedure must be triggered whether the app is running in the foreground, in the background, or if the phone screen is closed.

F7 - Sends request holding anonymous cardiac data to cloud server that hosts cardiac arrest monitoring algorithm

Codeblue uses a lightweight monitoring algorithm, hosted on a cloud server, which can be built upon to improve detection ability in the future. In order to comply with ethics regulations, the server and the app must share no data that can be used to identify the user.

4. Non-Functional Requirements

	Non-Functional Requirement Summary
NF1	Fast decision time for CA detection algorithm
NF2	Fast, accurate, and anonymous cardiovascular data streaming
NF3	Easy to use and navigate

Table 4.1 - List of non-functional requirements

NF1 - Fast decision time

Decision time for whether or not to call EMS should be fast to ensure EMS reaches the patient in a timely manner. Specifically, EMS needs to be alerted within one minute of CA happening. This means our algorithm needs to be able to output a positive decision within 30 seconds of receiving CA cardiovascular data considering the other 30 seconds are reserved for the user to cancel the 911 call in case of a false positive detection.

NF2 - Fast and accurate data streaming

CodeBlue should stream time series data at a frequency of at least 1 Hz to be able to support NF1. The CA detection algorithm also relies on accurate cardiovascular data from sensors, namely only wearable devices with data accuracy of 90% or higher should be integrated with CodeBlue [6].

NF3 - Ease of use

CodeBlue should be easy to use and navigate considering the elderly population audience. This involves using a large and easy to read font, choosing a colour-blind friendly colour scheme, and creating a user guide video tutorial. Easy navigation can be ensured by providing clear wayfinding, breadcrumbs, and persistent navigation hubs on top of avoiding multilevel hierarchical dropdown menus [5].

5. Stretch Goals

5.1 Summary

After completion of MVP, the following four features will be prioritised and implemented in the order listed:

	Stretch Goal Summary
SG1	Calculate confidence rating CA detection decision based on confidence level from source of data
SG2	Integrate CodeBlue with hardware prototype from JY-16 or from client team
SG3	Warn user if improper sensor attachment is detected, if garbage data is received or if wireless connection is lost
SG4	Pass the user's medical information to EMS
SG5	Allow user to save an emergency contact's information that will be automatically notified upon CA detection

Table 5.1 - List of stretch goals

5.2 Stretch Goals Details

SG1 - Confidence rating calculation algorithm

CodeBlue calculates a confidence rating for each CA detection decision based on factors relating to the attached hardware sensor(s), including:

- accuracy labels of the sensor, if available
- the type of sensor (PPG vs ECG)
- The location of the attached sensor
- Trends in data that imply garbage values (Eg, patterns in data match data from sensor sitting on a desk, not being worn properly)

If multiple sensors are attached, the algorithm will aggregate calculated accuracies for each attached sensor to output a final quantitative confidence rating for CA detection decisions. For example, if data from sensor 1 which has an accuracy of 10% implies CA detected, while data from sensor 2 with

accuracy of 90% shows normal heart activity, the confidence rating of a positive CA detection will be low. If only a single sensor is attached, the calculated accuracy for the attached sensor will be output as the confidence rating for any CA decisions made.

SG2 - Hardware integration

CodeBlue can connect to at least one wearable device and receive cardiovascular data from devices wirelessly. Wearable devices may be the client's custom developed prototype device or the finished product developed by the capstone team JY-16: Wearable Device for Automated Cardiac Arrest Detection. Devices available on the market are not considered for integration due to limitations outlined in section 5.2.

SG3 - Improper sensor attachment warning

CodeBlue will monitor wireless connections and detect patterns in data that suggest improper sensor attachment to prevent false positive CA detection that may arise from analysing garbage data. CodeBlue will also warn users if faulty sensor attachment or unstable wireless connections are detected to prompt users to fix the connection.

SG4 - Pass medical information to EMS

The users' medical information including age, sex, birthday, medications, and history of heart diseases will also be relayed to Emergency Medical Dispatchers (EMD) through the phone call to facilitate faster first aid.

SG5 - Emergency contact

CodeBlue prompts users for an emergency contact's information, so when a CA is detected, they can be automatically alerted.

6. Constraints

This project has no known cost or legal constraints; the client does not require any NDA or IP agreements.

6.1 Storage for sensitive data

Given that we will be working with sensitive data collected from real patients, we will need to follow strict ethics guidelines. Data will need to be stored locally in the operating device.

Personal Information Protection and Electronic Documents Act (PIPEDA) is a Canadian law relating to data privacy that governs how private sector organizations collect, use and disclose personal information in the course of commercial business. PIPEDA is a federal act that applies to all organizations operating in Canada [3].

Personal Information Protection Act (PIPA) is a provincial private-sector privacy law that specifically applies to organizations within BC [4].

PIPEDA and PIPA need to be followed closely while working with patient data from the BC Cardiac Arrest Registry.

6.2 Limited acceptable wearable sensor devices

Limitations exist for types of hardware sensors that can be integrated with CodeBlue. Even though CodeBlue supports wireless connection, many wearable devices that are available on the market, such as the Apple Watch or Fitbit's are infeasible for integration for MVP due to 2 main reasons:

1. Collected cardiovascular data is often abstracted. For example, when the Apple Watch detects 0 bpm heart rate readings, it aggregates the most recent readings and outputs an average instead of sending a null output. Many other products also abstract cardiovascular data such that CodeBlue cannot receive raw data that is needed for the CA detection algorithm.
2. On top of this many sensor products that support wireless connection do not support custom API's or connecting to custom apps. Instead, the product typically comes with a pre-built app that displays received cardiovascular data and allows users to send the collected data via their app. Regardless of the medium in which cardiovascular data can be exported from market apps (Eg, email, Bluetooth, etc), the process cannot be automated efficiently to continuously track users' data in the background.

For these reasons, the integration of CodeBlue has a dependency on JY-16: Wearable Device for Automated Cardiac Arrest Detection or CanSAVE and their progress in developing hardware prototypes that are ready to integrate with CodeBlue.

7. References

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8. Appendix

A. Glossary

Acronym	Definition
BC	British Columbia
CA	Cardiac Arrest
CPR	Cardiopulmonary resuscitation
EMD	Emergency Medical Dispatcher
EMS	Emergency Medical Services
EP	Emergency Procedure
F	Functional requirement
MVP	Minimum Viable Product
NF	Non-functional requirement
OHCA	Out-of-hospital cardiac arrest
SCA	Sudden cardiac arrest
SG	Stretch goal

B. Contributions

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