Team Project: Developing and testing a software-based prototype of an AED

Textual explanation

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Explanation:

The document provides a comprehensive explanation of a team project focused on developing and testing a software-based prototype of an Automated External Defibrillator (AED).

To accommodate the design of the software for a graphical user interface (GUI) that resembles the AED Plus's display, our team’s design documentation and ideas are the following:

The design includes User Interface Design, Cardiac Arrhythmia Detection, Real-Time CPR Feedback, Visual Prompts, User Interaction and Simulated Scenarios.

The document details the design and functionality of a software-based prototype Automated External Defibrillator (AED).

Powered Off State: The AED is turned off.

Self-Test State: The AED performs a self-test to ensure its functioning correctly with device status indicators

(e.g., battery, electrode placement).

Check Responsiveness State: Instruct the operator to check if the patient is responsive.

Call For Help State: Instruct the user to call for emergency assistance.

Attach Defibrillator Pads State: This state indicates the need to attach defibrillator pads to the patient's chest.

Analyzing State: The AED analyzes the patient's heart rhythm to determine if a shock is needed with Cardiac arrhythmia diagnosis results (shockable-non-shockable).

Include a display panel to show the simulated ECG diagram and device status.

Perform CPR State: Guiding the operator to perform CPR on the patient with Real-time CPR feedback.

Also, simulate the measurement and assessment of chest compressions

And loop back to Analyzing State until the end program cases are active to power off the program.

Powered Off State: The AED is turned off.

The demo video can be found here.

**State Pattern**

The state pattern was used because the program’s behaviour changed depending on which step of the process the AED was in. We used the approach of creating separate classes for each of the states and having them inherit a single abstract state class. State-specific logic is moved into their corresponding classes to keep the code organized. The current state is kept track of in the MainWindow class and the state is changed by calling changeState() on an instance of MainWindow and passing a new instance of a state.

The state classes have two special methods called execute() and initialize(). execute() is the main method that’s called by the mainWindow when the state changes. When used with the IntermediateState class, the method can change behaviour depending on its current step. initialize() is similar to a constructor method and is called right after the state instance is initialized. The main purpose for the initialize method is to call the execute() method (if used). The reason as to why the method exists is because problems arise when calling execute() on one state while in another state.

**Observer Pattern**

The observer pattern is incorporated using Qt’s signals and slots. We used it to subscribe events emitted by buttons, combo boxes, spin boxes, etc. We’ve also defined new signals inside of the MainWindow to notify subscribers of changes to its state.

Use Cases:

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| UC-01 | AED Deployment in Cardiac Emergency Use Case |
| Description | The base use case for administering an AED. |
| Primary Actor | AED Operator |
| Pre-condition | 1. An AED should only be utilized under the condition that the patient exhibits signs of a suspected cardiac arrest, which include unconsciousness, absence of normal breathing, and lack of a pulse or other signs of circulation. Furthermore, the device must be operated by individuals who have received training in basic life support/AED, advanced life support, or a similar physician-authorized emergency medical response program. |
| Post-condition | The AED performs all intended actions properly. |
| Main Sequence | 1. Turn the AED unit on by pressing the power button. The AED unit performs an automatic self-test to ensure that the battery usage indicator shows adequate battery capacity for usage and that the defibrillation electrodes are properly connected. 2. Check to see if the self-test unit goes from an “X” to a checkmark and the AED will say “Automatic Defibrillator Unit OK”. 3. AED will output a message saying, “Stay calm”. 4. The indicator light on the “check responsiveness” picture flashes. 5. AED outputs a message saying, “Check responsiveness”. 6. AED operator Shouts, “Are you OK”. They should be shaking the person while doing this. 7. The indicator light on the “call for emergency” starts flashing. 8. AED outputs a message saying, “Call for help”. 9. AED operator calls or sends someone else to call for help. 10. The indicator light on the “attach electrode pads” picture starts flashing. 11. AED outputs a message saying, “Attach defib pads to patient’s bare chest”. 12. AED operator attaches adult or infant/child electrode pads to the patient's bare chest. Follow electrode pad package instructions. 13. The indicator light on the “analyzing patient” picture starts flashing. 14. AED outputs a message saying, “Don’t touch the patient. Analyzing”. 15. The indicator light on the “perform CPR” picture starts flashing. 16. AED Administrator administers CPR. Give two breaths for every thirty compressions. 17. The AED will output feedback messages 18. 18. Keep repeating steps 15-16 until emergency services arrive.[3] |
| Extensions | 2a. The AED self-test unit stays as an “X” because there is not enough battery life, go to UC-02.  2b. When the victim is less than 8 years of age or weighs less than 55 lbs (25 kg), the Fully Automatic AED Plus should be used with ZOLL AED Plus Pediatric Electrodes.  2c. The AED self-test unit stays as an “X” because the defibrillation electrodes are not properly attached. The AED will output a message saying “Fully Attach Defibrillation electrodes to the device”.  2d. At any step if the user presses the power off button go to UC-04.  14a. AED detects a shockable rhythm. Go to UC-03. This shockable rhythm could either be the patient has ventricular fibrillation or pulseless ventricular tachycardia.  14b. AED outputs a message saying, “No shock advised.”. |
| Variation | 16. When giving compressions the AED will output either one of these 3 messages:   1. The compression is too deep. Reduce force." 2. Compression is too shallow. Press harder. 3. Good compression depth. Keep going. |

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| UC-02 | AED Battery Change Use Case |
| Description | This use case describes a situation where the AED does not have enough battery power to turn on, so a battery change is performed. |
| Primary Actor | AED operator, Battery |
| Pre-condition | AED does not have enough battery power to turn on. |
| Post-condition | AED has a full battery. |
| Main Sequence | 1. Ensure that the Fully Automatic AED Plus is turned off. Open the battery compartment by removing the battery cover from the back of the unit. 2. Insert 10 new batteries into the Fully Automatic AED Plus unit. 3. Connect electrode cable to Fully Automatic AED Plus unit and pack sealed    1. electrodes inside unit cover. Close cover. 4. Turn the unit on and wait for the “Unit OK” audio message. Verify that the unit issues appropriate “Adult Pads” or “Pediatric Pads” audio messages. 5. Turn the unit off. 6. Wait 2 minutes. Verify that the green check symbol appears in the status indicator window (located on the left side of the handle) and that the unit does not emit a beeping tone. 7. Place a Fully Automatic AED Plus unit in service.   8. Check the Fully Automatic AED Plus unit periodically to ensure that the green check symbol appears in the status indicator window |

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| UC-03 | AED Advises Shock Use Case |
| Description | This use case describes the situation where the AED determines that a shock is advisable. |
| Primary Actor | AED Operator |
| Pre-condition | AED operator has completed use case 1 steps 1-11 properly. |
| Post-condition |  |
| Main Sequence | 1. The button in the middle starts flashing. 2. The AED operator presses the button in the middle which contains a heart. 3. AED outputs a message saying, “Don’t touch the patient. Analyzing”. 4. AED Operator gives a warning to other bystanders “Stand clear”. 5. AED outputs a message saying, “Shock will be delivered”.   6. AED shock tone beeps and a shock to the patient is delivered. |
| Extensions | 1a. The AED does not have enough power to administer a shock. Go to UC-02 |

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| UC-04 | Power Off Use Case |
| Description | The concrete use case for power off of the device. |
| Primary Actor | AED Operator, Battery |
| Pre-condition | AED has been powered on. |
| Post-condition | AED has been powered off. |
| Main Sequence | 1. The user presses the power button. 2. AED timer resets and the machine powers off. |

图示

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UML Class Diagram:

图示, 工程绘图

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Normal Sequence Diagram:

This follows Use Case - 01

Safety feature sequence diagrams - Install Electrodes:

This AED detects the electrode pads are not attached properly during the self-test.

So AED software detects this and warns the AED operator to Install Electrodes.

图形用户界面, 应用程序

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Safety feature sequence diagrams - Low Battery:

This shows AED detects a non-functional battery during self-test.

So AED operator recognizes the need for a battery change and follows the battery replacement process.

图形用户界面, 应用程序, Teams

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State Diagram:

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Traceability matrix:

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| ID | Requirement | Related Use Case | Fulfilled By | Test By | Description |
| 1 | Simulate AED's ability to diagnose cardiac arrhythmias (AED-AdminGuide Page.5) | N/A | MainWindow.ui,  Patient status widget | Perform a test simulation where the GUI is presented with diagrams representing ventricular fibrillation and tachycardia. | Develop a module to simulate the AED's capability to diagnose cardiac arrhythmias, specifically ventricular fibrillation and ventricular tachycardia. |
| 2 | Real-time CPR Feedback (AED-AdminGuide Page.14) | N/A | MainWindow.ui,  performcprstate | Confirm the AED provides real-time feedback on compression depth, and that visual feedback is clear and corresponds to the user's actions. | Create a system that emulates the real-time CPR feedback feature of the AED Plus, providing visual and textual feedback to guide the user. |
| 3 | Visual prompts for a simulated cardiac emergency (AED-AdminGuide Page.4, 15) | N/A | MainWindow.ui,  graphs | Check that visual prompts appear as specified in the guide the user correctly through the procedure. | Specify scenarios of a simulated cardiac emergency with visual prompts and their timing to guide the user through a rescue situation. |
| 4 | The battery depletes when a shock is delivered. (AED-AdminGuide Page.20) | N/A | MainWindow.ui,  batterieswidget | Give a shock and observe the battery display, the battery level will lower as the treatment progresses. | The AED keeps a consistent record of the power level of the device, which the MainWindowcan then use to update its display. After the shock, the battery level will consistently decrease (the rate of decrease is affected by the power level). |
| 5 | AED displays elapsed time. (AED-AdminGuide Page.4, 5 and 9) | N/A | MainWindow.ui, | Monitor the time from AED power on until power off to observe its allotted time. | MainWindow contains a QTimer attribute, which will display the elapsed time that the AED has been running. |
| 6 | The application user interaction with AED operation (AED-AdminGuide Page.5) | N/A | MainWindow.ui | Run the simulator in Qt to observe the GUI. | Implement an interactive system that allows users to perform actions mimicking real-world AED operations, including electrode placement, shock delivery, and CPR initiation. |
| 7 | AED Deployment in Cardiac Emergency (AED-AdminGuide Page. vii) | UC-01 | MainWindow.ui, | Test AED in a mock cardiac emergency, verifying that the deployment process aligns with the base use case steps and everything is clear without confusion. | The base use case for administering an AED in a cardiac emergency. |
| 8 | AED detects a non-functional battery during self-test (AED-AdminGuide Page.16) | UC-02 | MainWindow.ui,  selfteststate | The system should detect the non-functional battery during the self-test and indicate it to the user. | AED detects a non-functional battery during self-test |
| 9 | AED Needs Battery Change (AED-AdminGuide Page.18) | UC-02 | MainWindow.ui,  batterieswidget | Simulate a low battery situation and the battery replacement process. | Verify that the AED operator recognizes the need for a battery change and follows the battery replacement process. |
| 10 | AED detects the electrode pads are attached during self-test (AED-AdminGuide Page.11) | UC-01 | MainWindow.ui,  Install electrodes widget | Run a test where the electrode pads are not properly attached. Verify that the AED software detects this and warns the AED operator. | AED detects the electrode pads are not attached properly during the self-test |
| 11 | AED performs self-test successfully  (AED-AdminGuide Page.16, 18) | UC-01 | MainWindow.ui,  selfteststate | Execute a self-test and ensure that the AED completes it without errors. | Ensure the AED performs a self-test successfully. |
| 12 | AED outputs an "Automatic Defibrillator Unit OK" message (AED-OperatorGuide Page.2) | UC-01 | MainWindow.ui,  Attached fibrillatory pads state | Check that the AED system performs a self-check and, if all checks pass, displays the "Automatic Defibrillator Unit OK" | Ensure the AED provides the correct status message during the initial steps. |
| 13 | AED indicator light flashes for "call for emergency" (AED-OperatorGuide Page.2) | UC-01 | MainWindow.ui,  callforhelpstate | Verify the indicator light for "call for emergency" flashes and give the user to do so according to the specifications. | Verify that the AED signals the need to call for emergency help. |
| 14 | AED outputs "Attach defib pads to patient's bare chest" (AED-OperatorGuide Page.2) | UC-01 | MainWindow.ui,  Attached fibrillatory pads state,  patientstatuswidget | Confirm that the message is clear, the indicator light flashes and occurs at the correct point in the process. | Ensure the AED instructs the operator to attach electrode pads correctly. |
| 15 | AED starts analyzing and provides the "Don't touch the patient. Analyzing" message (AED-OperatorGuide Page.2) | UC-01, UC-03 | MainWindow.ui,  analyzingstate | Initiate the AED's analysis phase and confirm that it correctly instructs the operator not to touch the patient during this critical time. | AED starts to analyze. Ensure the AED instructs the operator not to touch the patient during analysis. |
| 16 | AED advises "No shock advised" (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  patientstatuswidget | Verify that the AED correctly advises "No shock advised". Check that this message is unambiguous to the operator. | Ensure the AED provides the correct message when a shock is not advised. |
| 17 | AED detects a shockable rhythm (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  patientstatuswidget | Showing the shockable rhythm ensures that it identifies the rhythm correctly and advises the operator to prepare for shock delivery. | Ensure the AED detects a shockable rhythm and advises the operator accordingly. |
| 18 | AED advises Shock (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  analyzingstate | Confirm the AED identifies it correctly and provides clear instructions to the operator to deliver a shock. | Use case for AED advising a shock based on detected heart rhythm. |
| 19 | AED Operator performs "Stand clear" warning (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  analyzingstate | Ensure that the "Stand clear" message is noticeable with the indicator light flashes. | Ensure the AED operator provides a warning to bystanders before shock delivery. |
| 20 | AED provides a "Shock will be delivered in three, two, one ..." message (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  analyzingstate | Ensure that it provides a clear countdown message. | Ensure AED outputs a countdown to shock. |
| 21 | AED shock tone beeps and delivers a shock, providing a "Shock delivered." message (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  analyzingstate | Verify that the AED delivers the shock, and clearly indicates to the operator that the shock has been delivered. | Verify that the AED operator follows instructions to deliver a shock when advised. |
| 22 | AED provides a "Start CPR." message (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  performcprstate | The AED should prompt the operator to begin CPR. Confirm that the message is delivered promptly and is clear. | Ensure the AED operator knows the shock is finished and continues following the procedure. |
| 23 | AED started analyzing the procedure again and repeated ID 13-21 until emergency services arrived (AED-OperatorGuide Page.2) | UC-03 | MainWindow.ui,  performcprstate | Verify that the AED repeats the process as outlined in IDs 13-21, and maintains the protocol until the simulation is manually ended to emergency services are arrived. | AED started to analyze again to check did the patient needed more shock. |