DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
THE UNIVERSITY OF TEXAS AT ARLINGTON

PROJECT CHARTER
CSE 4316: SENIOR DESIGN I
FALL 2023

SIM BREATHE REPEAT
BREATHE EASY SIM

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Revision History

Revision	Date	Author(s)	Description
0.1	09.15.2023	MZ	document creation
0.2	09.22.2023	DG, EH, KH, ES, MZ	complete draft
0.3	09.24.2023	DG, EH, KH, ES, MZ	release candidate 1
1.0	09.25.2023	KH, ES, MZ	official release
1.1	03.16.2024	ES	contents updated based on adjustments to project
1.2	04.14.2024	MZ	project hardware adaptations
1.3	04.28.2024	ES	final document adjustments to align with project turn in

Contents

List of Figures

1 Problem Statement

The ventilators currently in use at UTA's SMART Hospital are not compatible with the "lungs" (bladders) of the mannequins. Due to the amount of air provided by the current ventilators, the bladders are prone to popping due to too much airflow into the bladders. If the amount of air that the ventilator pumps into the mannequin was reduced, this would prevent the bladders from rupturing.

2 Methodology

In order to preserve the bladders in the mannequins while maintaining a suitable training environment for medical students, our solution is to create a simulation ventilator that will simulate a medical ventilator, similar to the ones currently used in the SMART Hospital. The airflow rate would be reduced so as to prevent the bladders from popping, while continuing to provide software and readouts similar to that of a real medical ventilator.

3 Value Proposition

The simulation ventilator would allow UTA's nursing students to continue to gain experience using a hospital-grade ventilator without the concern of popping the bladders, thus keeping the real-world aspect of the ventilator while protecting the bladders. This alleviates the financial risk of using the ventilators on the mannequins because popping the bladders will no longer be a concern.

4 Development Milestones

The following list contains the core project milestones related to the major documents and demonstration of major project features.

- Project Charter first draft - September 2023
- System Requirements Specification - October 2023
- Architectural Design Specification - November 2023
- Demonstration of Graphical User Interface (GUI) detached from ventilator screen - December 2023
- Detailed Design Specification - February 2024
- Demonstration of GUI attached to ventilator screen - February 2024
- Demonstration of all GUI components working on ventilator - March 2024
- Demonstration of ventilator delivering precise airflow - April 2024
- Demonstration of ventilator on mannequin in SMART Hospital - April 2024
- CoE Innovation Day poster presentation - April 2024
- Final Project Demonstration - May 2024

5 BACKGROUND

The SMART Hospital at UTA currently uses the AVEA Ventilator in simulations for the nursing students to gain experience and prepare them for real-life scenarios in a hospital where they may need to use equipment like a ventilator. The ventilators used in the SMART Hospital are the same ventilators used in real hospitals on real patients. This gives the nursing students a chance to use equipment they may encounter in a true hospital setting. However, in the SMART Hospital, the ventilator is used on mannequins, not real patients, which poses a problem with the amount of air pumped into the mannequin's bladders. The bladders in the mannequins are not similar in size to a real patient's lungs. In fact, the bladders are much smaller than a real patient's lungs. However, the ventilator is designed for the size of a real patient's lungs, so when the ventilator is used on the bladders in the mannequins, it pops the bladders because it releases more air than what the bladders can hold.

Currently, the SMART Hospital is using washers from Home Depot to weigh down the bladders to keep them from filling up too much, but our sponsor would like a more permanent and convenient solution that can be used on current and future mannequins the SMART Hospital acquires without the need to add anything to the mannequins. It is also important to the sponsor that the nursing students continue to gain experience with real-world equipment that would be used in a true hospital, thus most aspects of the ventilator must remain the same in order to ensure the students are prepared for using a ventilator in a real hospital setting. Because of this, our sponsor would like our team to create a simulation ventilator that acts as the current ventilators used in the SMART Hospital, but with more control of the air that goes into the bladders to prevent the bladders from popping. Before this project, our team had no previous relationship with our sponsor; but since the beginning of this project, we have had the opportunity to meet with our sponsor to learn more about the current issue with the ventilators in the SMART Hospital and to better understand how we can go about finding and developing a solution to this issue.

6 RELATED WORK

The field of Medical Simulation Equipment is being focused mainly on Virtual Reality simulation. While its potential is impressive, physical simulation devices can be more practical for students to have the best learning experience. However, the field of Simulation Medical Devices is not very competitive. and very few companies are investing research and resources on it.

Laerdal Medical manufacture the most advanced Patient Simulation Mannequins, called SimMan [3]. The Breathe Easy Sim ventilator was mainly designed to pair with the SimMan mannequin and avoid damaging the mannequin. No previous work has been done towards this specific problem. As mentioned in the *Background* section, although most ventilators are compatible with the SimMan, they have the risk of damaging the interiors of the mannequin with excess air pressure. As explained by the Simulation Technology Manager of UTA's SMART Hospital, a professional medical ventilator will blow too much air, causing the bladder lungs of the mannequin to explode. These bladders can be purchased in retail for approximately $ 36 dollars [4], heavily affecting the hospital’s availability and finances.

The current solution used by the SMART Hospital is to purchase small washers that can obstruct the airflow and protect the mannequin's lungs. This solution is unreliable and does not provide any certainty of function in a long term environment. Additionally, the washers can end up damaging the ventilator equipment, and requires constant maintenance.

A similar product available in the market, but not specifically a solution to the SMART Hospital’s problem, is the ASL 5000 Breathing Simulator. This is considered the state-of-the-art device for respiration simulation for SimMan products [5]. The ASL 5000 allows the mannequin to sustain a spontaneous breathe and hold PEEP at virtually any level [2]. Positive end-expiratory Pressure (PEEP) is the pressure that remains in the airways at the end of the respiratory cycle [1]. However, the major limitation to this product is that it does not provide any simulation software for the nursing students.

Another study conducted provided a mechanism to reduce the air pressure going into the mannequin and improve the mechanical ventilation fidelity of the system [6]. While it is not a solution for the problem, it provides a great amount of information about the overall functionality between a SimMan and a Ventilator.

7 System Overview

7.1 Overall Picture

The Breathe Easy Sim system is a simulated medical ventilator designed to provide students with hands-on experience for treating respiratory failure in a patient. The main difference between a common medical ventilator and the Breathe Easy Sim is its simplification and complementary functions. The system is intended to be used alongside a SimMan mannequin, instead of a human patient. SimMan mannequins are advanced patient simulators designed to replicate human respiration, pulse, reactions, and other human faculties.

The development of this product is based on the necessity to provide students with a practical medical ventilator compatible with Simulation Mannequins like SimMan. Commonly, these mannequins come with a complete respiration system that allows them to replicate that of a human. However, its internal components can fail drastically if the proper equipment is not used. For example, the small bladders within the SimMan that retain the air and make the function of lungs have a high risk of bursting due to administering too much air pressure. The Breathe Easy Sim will be specifically calibrated to protect the components of the SimMan mannequins by scaling down the magnitude of the pressure.

A fully functioning system consists of three main parts: a Breathe Easy Sim, a SimMan and the user. The ventilator will take input parameters set by the developer/owner to adjust airflow values. The input into the mannequin will be provided by the internal pump mechanism, and readouts on the ventilator will be simulated based on the mannequin's response.

The key Input and Output relationships are shown in Figure 1.

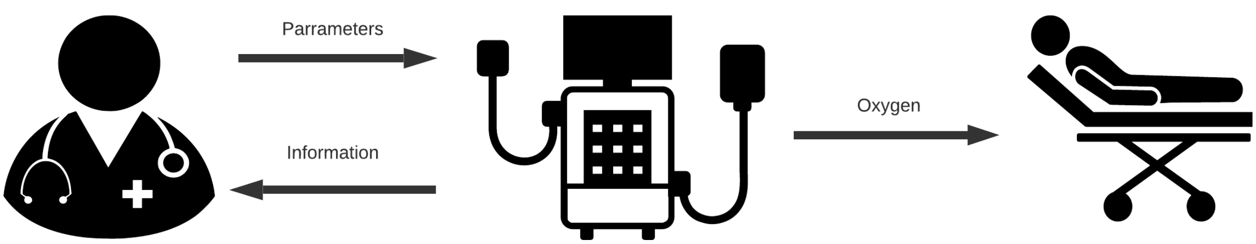

Figure 1: System Input and Output Design

7.2 System Specification

First and foremost, the physical appearance of the system should replicate that of a common medical ventilator, in order to provide students with a feeling of using a 'real' ventilator. The Graphical User Interface will facilitate the use of the system and show the user critical information regarding the patient. The system will consist of two processing units. A main processing unit in charge of handling the Graphical User Interface, and a second smaller unit in charge of controlling the inputs to the system.

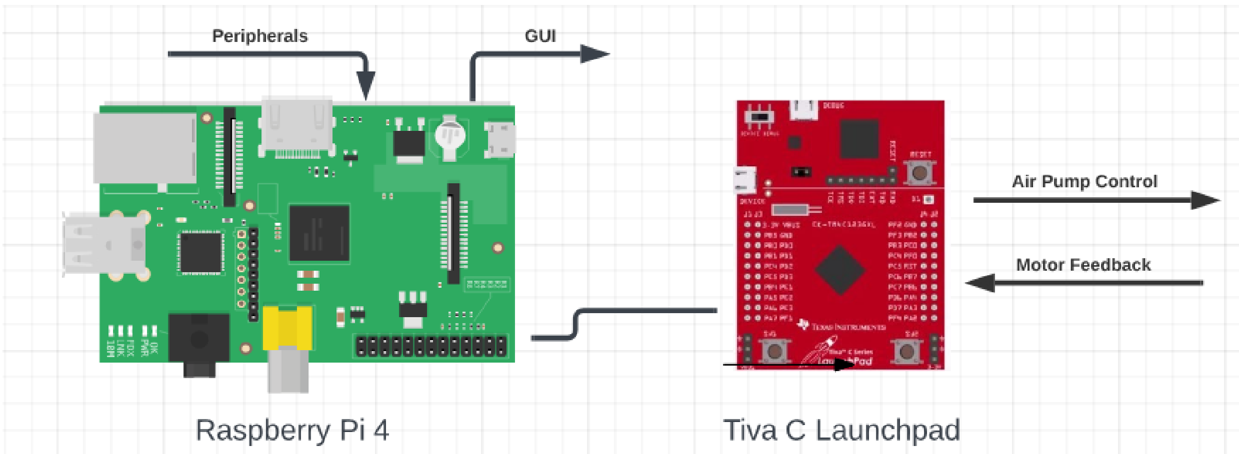

Figure 2: Processing Unit Design

8 Roles & Responsibilities

8.1 Stakeholders:

1. SMART Hospital at UTA: The primary sponsor and end-user of the simulation Ventilator. They have a vested interest in the successful development and implementation of the project to enhance medical education.

2. Design Team: The group responsible for creating the simulation Ventilator. They are accountable for meeting the project requirements, timelines, and quality standards.

3. Students: The intended users of the simulation Ventilator. Their experience and feedback are essential to ensure that the product aligns with educational needs.

8.2 Points of Contact:

- Sponsor/Customer: Erica Hinojosa from SMART Hospital at UTA. Erica will serve as the primary contact person representing the sponsor's interests, providing project guidance, and ensuring alignment with SMART Hospital's objectives.

- Project Team: Elisabeth Harris, who will be the point of contact from the design team. Elisabeth will facilitate communication between the design team and the sponsor, ensuring that project objectives are met.

8.3 Team Members and Areas of Responsibility:

1. Kyle Henry (Scrum Master and Software Expert):
   - Responsible for facilitating Agile development processes, managing the team's workflow, and

ensuring the project stays on track.
- Provides expertise in software development, ensuring alignment with project goals.

2. Elisabeth Harris (Point of Contact and Software Expert):
   - Serves as the primary liaison between the design team and the sponsor.
   - Contributes to software development efforts, working to meet software-related goals.

3. Maicol Zayas (Hardware and Software Expert):
   - Specializes as a bridge between hardware and software components of the project, facilitating integration.
   - Contributes in hardware development, focusing on the physical components of the simulation Ventilator.

4. Ethan Sprinkle (Hardware Expert):
   - Specializes in hardware development, focusing on the physical components of the simulation Ventilator.

5. David Gomez (Software Expert):
   - Specializes in software development, ensuring that the simulation software meets the required functionality and quality standards.

The Scrum Master role will be consistently held by Kyle Henry throughout the project. This ensures consistent project management and adherence to Agile principles. Elisabeth Harris will maintain her role as the point of contact between the design team and the sponsor throughout the project to facilitate effective communication and alignment with SMART Hospital at UTA's objectives.

9 Cost Proposal

In the context of our Simulated Ventilator (Sim Vent) project, it's crucial to outline and justify the major expenses that will be incurred during the project. Below, we provide a discussion and justification of these key expenses:

1. Final PCB (Printed Circuit Board):
   - Justification: The Final PCB is a critical component of the Sim Vent, serving as the central platform for connecting and integrating various electronic components. It provides the electrical connections necessary for the Sim Vent to function as intended. The PCB needs to be professionally designed and manufactured to ensure reliability and performance.

2. Computer (Main Brain):
   - Justification: The computer, often referred to as the "Main Brain," is the core processing unit of the Sim Vent. It controls the simulation, data collection, and user interface. A robust computer is essential to handle complex calculations, user interactions, and real-time feedback, ensuring the Sim Vent operates smoothly and accurately.

3. Product Housing (Prototype Enclosure):
   - Justification: The product housing serves both functional and aesthetic purposes. It provides a protective and professional-looking enclosure for the Sim Vent, making it user-friendly and visually representative of a real ventilator. The housing enhances the educational experience and ensures safety during use.

4. Air Pumps (Ventilation Function):
   - Justification: Air pumps are the core functional components of the Sim Vent, responsible for

generating and controlling airflow. The quality and performance of these pumps directly impact the realism and effectiveness of the simulation. High-quality air pumps are essential for achieving the project's educational goals.

5. Hardware Circuitry (User Interface):
   - Justification: Hardware circuitry includes components such as screens, push buttons, knobs, and more, which form the user interface of the Sim Vent. These components enable users to interact with the simulator and adjust settings as needed. Reliable and responsive hardware circuitry is essential for user engagement and learning.

9.1 Preliminary Budget

Final PCB	$50
Computer	$150
Sensors	$75
Product Housing	$150
Air Pumps	$200
Hardware Circuitry	$175

9.2 Current & Pending Support

CSE Department	$800
Individual Team Support	$50 x5

10 Facilities & Equipment

For the completion of our project, we will primarily rely on the following lab space, equipment, and resources available at the University of Texas at Arlington (UTA) in the Engineering Research Building (ERB):

Lab Space:
- Senior Design Lab: We will utilize the senior design lab facilities within the ERB. This space is well-equipped for project development, offering ample workspace and a conducive environment for collaborative work.
- MakerSpace Lab: Utilized for 3D Printers, power tools, and access to electronics testing equipment.

Equipment:
- Soldering Station: We will make use of the soldering station available in the senior design lab. This equipment is essential for soldering and assembling electronic components in our project.

Computers:
- Personal Computers: Our team members will utilize their personal computers to develop the Graphical User Interface (GUI) required for the project. These computers are readily available and equipped with the necessary software for software development and simulation.

Equipment Procurement:
- Soldering Materials: Consumables such as solder wire and soldering tips for the soldering station will be procured as needed, either through the university's supplies or by purchasing them externally.
- Software Tools: We will utilize software tools for GUI development, simulation, and programming. Licensing for these tools may be obtained through the university's resources or, if necessary, by purchasing

licenses.

11 Assumptions

The following list contains critical assumptions related to the implementation and testing of the project.

- The ventilator will only be used in a simulated environment created by the customer
- The ventilator will be designed to be used on the currently owned high fidelity mannequins
- The ventilator will be loosely based on the AVEA Ventilator Model Number 16448
- The ventilator will provide only one pressure setting using atmospheric air
- The customer will provide ample power connections at the SMART hospital

12 Constraints

The following list contains key constraints related to the implementation and testing of the project.

- Final prototype demonstration must be completed by May 3rd, 2024
- Customer installation site will only be accessible by development team during normal business hours
- No live classroom simulations will be available for observation and testing of ventilator.
- Technical documentation for the ventilator and high fidelity mannequins are unavailable for use of design due to cost requirements.

13 Risks

The following high-level risk census contains identified project risks with the highest exposure. Mitigation strategies will be discussed in future planning sessions.

Risk description	**Probability**	**Loss (days)**	**Exposure (days)**
Availability of Raspberry Pi Sensors due to parts shortages	0.40	21	8.40
Unable to access SMART Hospital resources for testing and parts	0.15	7	1.05
Shipping Delays due to poor weather conditions	0.50	14	7.0
Delays in shipping from overseas vendors	0.10	20	2.0
Major design change specifications from customer	0.05	45	2.25

Table 1: Overview of highest exposure project risks

14 Documentation & Reporting

14.1 Major Documentation Deliverables

14.1.1 Project Charter

The Project Charter will not be updated often. Unless there is a description that is no longer true due to project requirements, the document will remain static during most of the project's development. The final version of the Project Charter will be delivered in May.

14.1.2 System Requirements Specification

The System Requirements Specification will be changed based off the feedback of the customer or based off the progress of the development team. The goal is to make the least amount of changes to this document as possible, but it's likely the customer will have feedback that affects the original development plan outlined in this document. The final version of the System Requirements Specification will be delivered by May.

14.1.3 Architectural Design Specification

The Architectural Design Specification will be updated through the course of development of the project. Though this document is not technical, we will most likely have most changes be towards the beginning of the product assembly as we learn more and more of what is required to get the architecture to completely implement the needed requirements. The final version of the Architectural Design Specification will be delivered by May.

14.1.4 Detailed Design Specification

The Detailed Design Specification will be updated semi-frequently as the developers explore and test which methods of implementation best fulfill specific requirements. The final version of the Detailed Design Specification will be delivered by May.

14.2 Recurring Sprint Items

14.2.1 Product Backlog

The product backlog will be updated to include everything required to fulfill the next upcoming demo (The schedule for the project demos and their specific tested features can be found in Section 4 of this document). This will involve a collaborative discussion between the computer engineers and computer scientists, who will decide what features are needed to present the demo. The scrum master will have the final say on everything that goes into the backlog if there any major disagreements among team members. The backlog will be managed using a shared spreadsheet. The stakeholders will have a modified version of the product backlog spreadsheet that will be updated at the beginning of every sprint.

14.2.2 Sprint Planning

Between each sprint, the team will meet to discuss the sprint. There will be 8 sprints during the course of this project. The engineers will come together and discuss the requirements needing to be fulfilled, as well as the needs of the customer and any proposed changes to the course of development.

14.2.3 Sprint Goal

The sprint goal is primarily decided by the next upcoming demo project milestone. Please view Section 4 for more information.

14.2.4 Sprint Backlog

The sprint backlog will be discussed the meeting before the sprint start. The team will discuss which features are needed to have a functional demo by the beginning of the next sprint. Trello will be used to manage the team's sprint backlog.

14.2.5 Task Breakdown

Tasks will be assigned based off the story needs and which developer fits the role of the story the best. So if it's a purely hardware requirement, it will be assigned to a team member who purely does hardware. Same tactic goes for purely software requirements. When it's a combination of software and hardware, it will be passed back and fourth between the software engineer and the computer engineer who is reserved to speak what the needs of the hardware-software interaction are. Time worked on a story will be documented in Trello and transferred over to the team's man hour spreadsheet.

14.2.6 Sprint Burn Down Charts

The scrum master will have the responsibility of generating the burn down chart. He will use the information in Jira regarding story completion and hours spent on a story to get the effort given by each user. The burn down chart will be a line chart spanning the days of the sprint and will show the rate of the amount of stories being done.

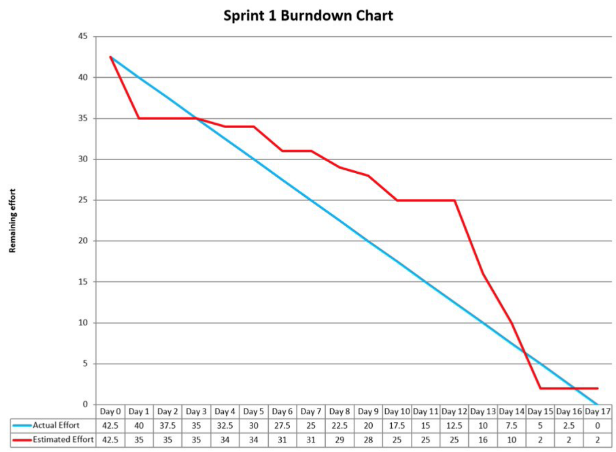

Figure 3: Example Sprint Burn Down Chart

14.2.7 Sprint Retrospective

The sprint retrospective meeting will happen every Friday after a sprint has completed. It will be about 30 minutes of discussion about what can be improved or kept the same to lead to a more successful sprint. The scrum master will document the responses and suggestions of the meeting. The documentation will be available before the Monday the next sprint starts.

14.2.8 Individual Status Reports

Individuals will document any personal successes or struggles that happened during the sprint and how improvements can be made on a personal level. The individual will also grade their team mates on the basis on them being dependable and efficient at what they are expected to complete during a sprint.

14.3 Closeout Materials

14.3.1 System Prototype

The final system prototype will be comprised of custom made AVEA-inspired ventilator. It will be demonstrated on a mannequin provided by the SMART Hospital in April. We will have some Prototype Acceptance Test (PAT) with our customers. Every demo will be at the SMART Hospital.

14.3.2 Project Poster

The poster will an executive summary of the project, background of the problem being solved, how we set up our experiment for testing the product, the experiment plan & results, conclusions from the experiment, and any references we used in the making of the poster. Its dimensions will be 32"x40".

14.3.3 Web Page

We will have a blog detailing the details of the project. It will have an abstract, background of the project, some project requirements, a system overview, results of the project, the future work this project may receive, project files, and the references used in the making of the blog. It will be accessible to the public and be part of the closing out of the project.

14.3.4 Demo Video

The demo video will show off the product being demonstrated working separately from the SMART Hospital mannequins. It will just show the process of using the product and have a high-level explanation on how everything works.

14.3.5 Source Code

The main source code will be stored on GitHub.com. We will adopt the git versioning control system. The customer will have access to the source code and will be closed source. They will need to have a GitHub account to access the source code.

14.3.6 Source Code Documentation

The source code will be documented using comments in the code to describe the purpose and uses of methods or classes.

14.3.7 Hardware Schematics

The final product will contain a wiring schematic of the redboard and associated connections. The main board will interface between the computer being used to run the GUI software and the hardware sensors and components. The wiring diagram will be included in the Service Manual deliverable.

14.3.8 CAD files

CAD parts and assembly files will be provided for all parts designed in CAD software.

14.3.9 User Manual

We will provide the customer with a digital version of the manual in the PDF standard.

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