CSE 237D: Digital Stethoscope Project Specification

Amrita Moturi, Shayan Boghani, Shelby Myrman, Siya Rajpal

UC San Diego Computer Science & Engineering Dept.

Project Charter

Project Overview

Despite significant technological advancements, most healthcare professionals still rely on traditional stethoscope designs that have remained mostly unchanged for over 200 years. Common practitioner complaints include not being able to hear sounds clearly due to ambient noise, frequent misplacement, and high costs associated with digital alternatives. Although digital stethoscopes are available on the market, they have not seen widespread adoption, largely due to their costs often exceeding $300.

Our objective is to design and build an affordable, digital smart stethoscope that enhances the user experience for healthcare professionals while addressing the limitations of traditional models. The system will include both the hardware device and a companion mobile application that enables real-time visualization and playback of heart and lung sounds.

Project Approach

The final goal of building a digital stethoscope can be divided into three parts: hardware development, data acquisition and communication, and interface development.

Hardware Development will entail designing the embedded system that will acquire the heart and lung sounds and transmit them to the user interface. This will first require choosing a microcontroller that is able to communicate via Bluetooth or WiFi, process incoming audio signal data, and is well documented to enable efficient setup. This will be done by researching a set of popular microcontrollers and evaluating these key requirements via a selection matrix. Once a microcontroller is selected, a microphone is needed to acquire heart and lung sounds. The requirements for the microphone are related to the frequency range of the sounds the product must acquire, which range between 20-4000 Hz. Additionally, the microphone must be able to interface with the selected microcontroller. Once some options are identified, they will be tested and compared for quality and ability to capture heart and lung sounds. To further improve the acquisition of audio signals, noise insulating materials will be used in conjunction with the microphone. Several foam and noise insulating materials will be tested to determine the best method to improve the audio acquired. Once these components are finalized, the final casing of the product will be designed and printed. The ergonomics and ruggedness of the casing will be tested to withstand the wear and tear expected in an urgent care setting.

Data Acquisition and Communication will require interfacing with the microphone directly from the microcontroller to record audio data. The first step will be to pull basic audio from the microphone and read it through the Serial Monitor interface of the microcontroller. Once this can be done reliably, the quality of the audio will be improved by testing different filtering approaches along with testing different acquisition settings including sample rate. The next step will be to set up a reliable method to communicate a fixed-length audio file. This will be tested on both WiFi and Bluetooth to determine the best approach to communicating the data.

Interface development is related to the user interface and experience. A test application with basic functionality will be deployed as a first step. From here, features will be added in an iterative fashion to allow users to playback audio, attach audio to patients, and seamlessly navigate the interface to find previous recordings. These features will be tested using unit and integration testing. A backend will be set up to store audio data received from the hardware device in an efficient manner to serve users when requested.

Minimum Viable Product

The goal of our Minimum Viable Product (MVP) is to develop a fully functional and portable digital stethoscope that captures, amplifies, records, and visualizes heart and lung sounds. This MVP serves as a proof-of-concept, providing the foundational system architecture for our broader vision while allowing us to gather early user feedback and iterate over time. Our emphasis is on deliverability: each core function is selected for high feasibility and clear alignment with the project's long-term clinical goals.

Core MVP Components

1. **Acoustic Signal Acquisition:** The MVP will use a digital microphone with sensitivity in the appropriate frequency bands for heart and lung sounds. The system will be integrated into a robust enclosure modeled after existing stethoscope chest pieces to facilitate familiarity and ergonomics.

2. **Recording and Playback:** The MVP must reliably capture sound data for local storage and enable playback through either a speaker or through the front end software interface. Data will be stored securely and labeled with timestamps, creating a foundation for potential clinical documentation or further diagnostic analysis.

3. **Portable and Durable Hardware Design:** The stethoscope will be encased in a 3D-printed shell that is both lightweight and resilient. It will house the microcontroller, power supply (battery), and microphone. The prototype will prioritize modularity to support future iterations, such as integration of custom PCBs or embedded ML components.

4. **Visualization via Companion Interface:** The MVP will include a simple user interface (UI) that visualizes the sound waveform and increases the sound captured by the device. This UI will be implemented either as a mobile app based on preliminary user research and will focus on clarity and usability. The visualization and audio allows real-time signal monitoring, enabling both users and potential clinical testers to assess stethoscope performance.

The MVP is intentionally narrow in scope but complete in functionality. Each feature is selected to highlight a critical part of the user experience and overall system integrity. The emphasis is not on completeness or polish but on creating an end-to-end experience that can be tested, validated, and iterated upon. By grounding the MVP in core biomedical functionality (amplification, recording, and visualization), we create a minimum usable product that is meaningful to stakeholders and can evolve based on feedback.

The MVP enables us to evaluate core assumptions about hardware compatibility, UI requirements, and clinical relevance before committing to more complex features such as headphone integration, HIPAA compliance, edge ML deployment, or custom PCB creation. It also provides an anchor for testing usability, sound quality, and data handling practices early in the development lifecycle. Ultimately, our MVP will demonstrate that a portable, secure, and intelligible digital stethoscope can serve as a launchpad for more advanced diagnostic tools and integration with health information systems.

Constraints, Risk, Feasibility

Developing a fully functional and portable digital stethoscope within a single quarter poses several technical constraints and risks that may deliver or prevent delivery. The most critical are summarized below:

1. **Signal clarity and audio quality:** Heart and lung sounds are low-amplitude and easily obscured by background noise, or mechanical interference. Given the limited time available for analog circuit tuning, we may encounter issues with poor amplification or noise recordings that render the audio useless to the target user. To mitigate this, we will prioritize selecting a high-sensitivity, low-frequency microphone early in our development. We may also incorporate lightweight digital filters, if necessary. We will also conduct early testing under realistic noise conditions to evaluate system performance, and give us time to iterate on the design if needed.

2. **Audio compression and audio processing:** Microcontrollers have limited compute resources. Real-time digital signal processing or compression may exceed CPU or memory limits on them, resulting in latency, or degraded playback quality. Furthermore, lossy compression formats, like MP3, may eliminate subtle audio cues that are important to clinicians. To reduce these risks, we will store audio in a lossless format, such as WAV. Heavier signal processing and compression will be offloaded to the mobile application or deferred until after recording.

3. **Hardware design complexity:** The system must combine components such as a microphone, power supply, and microcontroller in a portable form. Therefore, integration issues, like signal degradation,

power instability, or physical interference are possible, and can be time-consuming to find and resolve. To minimize this risk, we will adopt a modular design approach that enables us to test individual components before full integration. We will also allocate buffer time for debugging and ensure proper shielding,grounding and circuit layout in the hardware design.

4. **Data Transmission from Device to iOS App:** Data transmission is likely the biggest risk, as there are both hardware and software constraints involved. iOS imposes strict limits on supported Bluetooth profiles, so we are limited to Bluetooth Low Energy (BLE), which has a low data throughput and limited real-time transmission capabilities. This poses a challenge for transmitting high-fidelity audio. To address this issue, we can segment audio into BLE-compatible chunks with proper sequencing and buffering. Another option to keep recording intact, would be to use Wi-Fi transmission via a microcontroller-hosted local server.

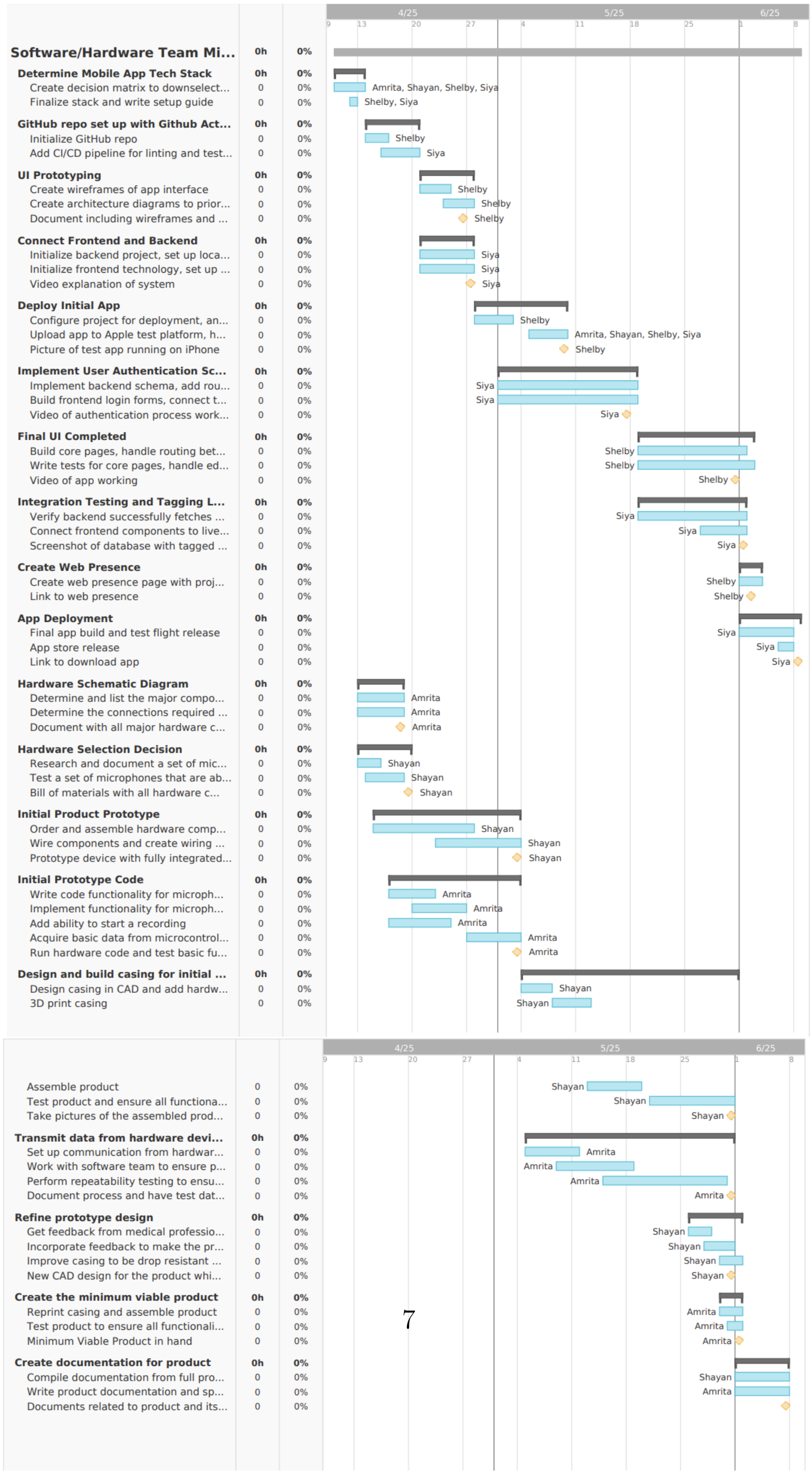
Group Management

To help divide up the work, we will be splitting the hardware and software aspects of the project into two teams, in which each team of two will work closely with one another to make progress toward each weekly milestone. Specific decisions about project direction and implementation details will be decided by group consensus.

We will primarily be communicating over text messaging to plan meetings and to get quick feedback from other members. We will be meeting in person on Tuesdays and Thursdays in-class, and additionally on Thursdays after class for a stand-up to communicate current progress and next steps. Some milestones that we have defined require that the teams work together, which we will plan for during our in-person Thursday meetings. Each team will coordinate to meet with each other outside of these times in-person or over Zoom. We will know if we are off-schedule if we do not meet the weekly milestone goals we have set. If we find ourselves in this position, we will identify the root of what is causing the delays and plan to catch up the following week.

We will reach out to class TAs and more experienced individuals like the

Makerspace to get past issues that are causing us to slow down our progress. This also may require us to prioritize certain features over others if they are not necessary for our MVP, which we will decide on as a group. The Gantt chart below provides a detailed breakdown of who is responsible for each milestone. Shelby and Siya will be working on the software side of the project, while Amrita and Shayan will work on the hardware side.


4/25
5/25
6/25
9 13 20 27 4 11 18 25 1 8
Software/Hardware Team Mi... 0h 0%
Determine Mobile App Tech Stack 0h 0%
Create decision matrix to downselect... 0 0%
Finalize stack and write setup guide 0 0%
GitHub repo set up with Github Act... 0h 0%
Initialize GitHub repo 0 0%
Add CI/CD pipeline for linting and test... 0 0%
UI Prototyping 0h 0%
Create wireframes of app interface 0 0%
Create architecture diagrams to prior... 0 0%
Document including wireframes and ... 0 0%
Connect Frontend and Backend 0h 0%
Initialize backend project, set up loca... 0 0%
Initialize frontend technology, set up ... 0 0%
Video explanation of system 0 0%
Deploy Initial App 0h 0%
Configure project for deployment, an... 0 0%
Upload app to Apple test platform, h... 0 0%
Picture of test app running on iPhone 0 0%
Implement User Authentication Sc... 0h 0%
Implement backend schema, add rou... 0 0%
Build frontend login forms, connect t... 0 0%
Video of authentication process work... 0 0%
Final UI Completed 0h 0%
Build core pages, handle routing bet... 0 0%
Write tests for core pages, handle ed... 0 0%
Video of app working 0 0%
Integration Testing and Tagging L... 0h 0%
Verify backend successfully fetches ... 0 0%
Connect frontend components to live... 0 0%
Screenshot of database with tagged ... 0 0%
Create Web Presence 0h 0%
Create web presence page with proj... 0 0%
Link to web presence 0 0%
App Deployment 0h 0%
Final app build and test flight release 0 0%
App store release 0 0%
Link to download app 0 0%
Hardware Schematic Diagram 0h 0%
Determine and list the major compo... 0 0%
Determine the connections required ... 0 0%
Document with all major hardware c... 0 0%
Hardware Selection Decision 0h 0%
Research and document a set of mic... 0 0%
Test a set of microphones that are ab... 0 0%
Bill of materials with all hardware c... 0 0%
Initial Product Prototype 0h 0%
Order and assemble hardware comp... 0 0%
Wire components and create wiring ... 0 0%
Prototype device with fully integrated... 0 0%
Initial Prototype Code 0h 0%
Write code functionality for microph... 0 0%
Implement functionality for microph... 0 0%
Add ability to start a recording 0 0%
Acquire basic data from microcontrol... 0 0%
Run hardware code and test basic fu... 0 0%
Design and build casing for initial ... 0h 0%
Design casing in CAD and add hardw... 0 0%
3D print casing 0 0%
Assemble product 0 0%
Test product and ensure all functiona... 0 0%
Take pictures of the assembled prod... 0 0%
Transmit data from hardware devi... 0h 0%
Set up communication from hardwar... 0 0%
Work with software team to ensure p... 0 0%
Perform repeatability testing to ensu... 0 0%
Document process and have test dat... 0 0%
Refine prototype design 0h 0%
Get feedback from medical professio... 0 0%
Incorporate feedback to make the pr... 0 0%
Improve casing to be drop resistant ... 0 0%
New CAD design for the product whi... 0 0%
Create the minimum viable product 0h 0%
Reprint casing and assemble product 0 0%
Test product to ensure all functionali... 0 0%
Minimum Viable Product in hand 0 0%
Create documentation for product 0h 0%
Compile documentation from full pro... 0 0%
Write product documentation and sp... 0 0%
Documents related to product and its... 0 0%

Project Development

The team will be split into hardware and software, with some overlap as the nature of the project requires all members to be fluid in their roles. The hardware team will primarily be Shayan and Amrita and the software team will be Shelby and Siya. Each team will work towards deliverables which will be assigned to specific individuals on the team.

The hardware needed for the project is likely a microcontroller like an ESP32, a digital MEMS microphone, various electrical components (resistors, capacitors, buttons, etc), and 3D printing materials. The team has most of this already ordered and available and can source the remaining parts from places like the UCSD Makerspace. The software used will be a backend database and Swift for the mobile application.

The hardware chosen are mostly commonly available components that are standard in hobby projects. These parts will be sourced from Amazon and some specialized electronics sites. The arrival time will likely be within a week. Software costs will likely relate to storage using a database service which is required given a data-centric project.

Hardware testing will be done through benchmarking and requirements testing. On the software side, unit and integration testing will be used to ensure a strong pipeline from the hardware all the way to the user facing application.

Documentation will be a priority that is done throughout the course of the project. Each week, the team will meet to summarize progress, setbacks, and lessons learned. Additionally, through the use of milestones and deliverables the team will have a meticulous record of each stage of the project from start to finish.

Project Milestones and Schedule

Hardware

- **Deliverable 1 (Week 3): Hardware Schematic Diagram (Amrita)**
  Proof: Document with all major hardware components mapped out
  Milestones:

  - Determine and list major components needed based on final product requirements
  - Determine connections and additional interfacing components

- **Deliverable 2 (Week 3): Hardware Selection Decision (Shayan)**
  Proof: Bill of materials based on hardware schematic diagram
  Milestones:
  - Research and downselect microcontrollers
  - Test microphones for heart and lung sound frequencies
  - Decide on filtering approach (analog and/or digital) to isolate target frequency bands for heart (typically 20–150 Hz) and lung (100–1000 Hz) sounds

- **Deliverable 3 (Week 5): Initial Product Prototype (Shayan)**
  Proof: Prototype with fully integrated hardware components
  Milestones:
  - Order and assemble hardware
  - Wire components, create documentation and diagram

- **Deliverable 4 (Week 5): Initial Prototype Code (Amrita)**
  Proof: Run and test hardware code, graphs showing frequency response before and after filtering, video demonstration
  Milestones:
  - Microphone data acquisition and processing
  - Recording functionality
  - Implement digital filtering to isolate relevant sound frequencies
  - Transmit data from microcontroller to device

- **Deliverable 5 (Week 7): Design and Build Casing (Shayan)**
  Proof: Pictures of assembled product, tested with casing
  Milestones:
  - CAD design, dimensioning and tolerancing
  - 3D print and assemble casing

- Test full product functionality

- **Deliverable 6 (Week 7): Transmit Data to Database (Amrita)**
  Proof: Documented process with test data samples in database
  Milestones:
  - Communication from device to external gateway
  - Route data from gateway to database
  - Repeatability testing to ensure consistency and quality
- **Deliverable 7 (Week 9): Refine Prototype Design (Shayan)**
  Proof: New CAD design focused on ruggedness and ergonomics
  Milestones:
  - Feedback from medical professionals
  - Improve usability, add drop and water resistance
- **Deliverable 8 (Week 9): Create MVP (Amrita)**
  Proof: MVP in hand
  Milestones:
  - Reprint casing, assemble product
  - Full functionality testing
- **Deliverable 9 (Week 10): Product Documentation (Shayan and Amrita)**
  Proof: Full documentation, specifications, and use cases
  Milestones:
  - Compile and write product documentation
  - Specifications sheet with safety and use case info

Software

- **Deliverable 1 (Week 2): Tech Stack Decision (Shelby)**
  Proof: Tech stack list and rationale
  Milestones:
  - Compare options and finalize stack

- Write setup guide

- **Deliverable 2 (Week 2): GitHub Setup (Siya)**
  Proof: Screenshot of repo and CI/CD pipeline
  Milestones:
  - Initialize repo
  - Add CI/CD for linting and testing
- **Deliverable 3 (Week 4): UI Prototyping (Shelby)**
  Proof: Wireframes and architecture document
  Milestones:
  - Create Figma wireframes
  - Diagram architecture for modularity
- **Deliverable 4 (Week 4): Frontend and Backend Setup (Siya)**
  Proof: Video explanation of system
  Milestones:
  - Backend init, sample route, local DB
  - Frontend init and routing
- **Deliverable 5 (Week 5): Deploying Test App (Shelby)**
  Proof: Picture of test app on iPhone
  Milestones:
  - Configure deployment and fix permission issues
  - Upload to Apple test platform and test usability
- **Deliverable 6 (Week 5): Add Authentication (Siya)**
  Proof: Video of working auth flow
  Milestones:
  - Backend schema and session logic
  - Frontend login and API integration
- **Deliverable 7 (Week 8): UI Complete (Shelby)**
  Proof: App walkthrough video
  Milestones:

- Build and route core pages
- Write tests and handle edge cases

- **Deliverable 8 (Week 8): Integration Test + Tagging (Siya)**
  Proof: Screenshot of database with tags
  Milestones:
  - Backend fetching and tagging
  - Integrate simple waveform display for audio recordings
  - Connect live frontend-backend and verify E2E
- **Deliverable 9 (Week 10): Web Presence (Shelby)**
  Proof: Link to website
  Milestones:
  - Create and deploy webpage
- **Deliverable 10 (Week 10): App Deployment (Siya)**
  Proof: Link to download app
  Milestones:
  - Final app build, TestFlight and App Store release