Boston University
Electrical & Computer Engineering
EC464 Capstone Senior Design Project

Customer Installation Report

LungDetect:
Acoustic Imaging Device for Diagnosing Pneumonia

by

Team 21

Team Members:

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I. Overview

The customer installation occurred at 1:30 pm on April 24th, 2025, at the PHO113 lab bench.

The members present:

1. Shadin Almaiman
2. Thinh Nguyen
3. Hilario Gonzalez
4. Matthew Pipko
5. Astrid Mihalopoulos

Customers present:

1. LungDetect Project Client: Dr. Andrey Vyshedskiy

II. Requirements

Hardware Requirements:

1. The design is required to be able to record 12 independent audio data channels from microphones with minimized interference between each other. (**Modified)**
    - The initial design had 12 microphones mapped out. After realizing the sensitivity of the piezoelectric microphones and the likelihood of noise corrupting any recordings, the number of input devices went down to 8 microphones before eventually landing on 6 as the final, most efficient number of microphones after many iterations. Multi-channel recording is made possible by the USB-C splitter and the client's preferred third-party interface. Delay is sorted by software calibration.

2. The device must use a high enough sample frequency so the data can be analyzed at millisecond granularity. (**Original)**
    - Sample frequency: 48 KHz (48,000 samples per second, 48 samples per millisecond)

3. The device must be safe for the user; no sharp or loose wires. (**Original)**
4. Data to be passed without interference or corruption to a laptop for processing. (**Original)**
    - Microphones are embedded into the foam, with only ~3-4 inches of insulated, protected wires protruding out and into the USB-C splitter. This decreases data loss as well as the chances of any safety risk.

5. The device must be durable enough to withstand constant, heavy usage. (**Original**)
    - Three layers of thick polyethylene foam stacked together (66 cm x 47.5 cm x 7.6 cm). This is meant for product durability and patient comfort.

6. The device must be able to be easily cleaned and maintained. (**Final Product**)
    - The product will come with a plastic cover for use between patients to prevent contamination and spread of germs due to the skin-to-microphone nature of the product.

Software Requirements:

1. The app is accessible via any web browser in the form of a web application. It should be accessible from all devices on the network. (**Modified**)
    a. Originally, a downloadable application was considered, but it pivoted to a web-app because it was less than ideal to have the app be unique to a single operating system.
2. The app is capable of receiving and processing an audio file. The user can upload one multi-channel file or multiple single-channel files. (**Modified**)
    a. This requirement changed as there were different hardware iterations. Initially, the app was to have two modes; one was to be able to receive pre-recorded files, and the other was to connect to the device and natively record a file into the application. Upon the client's request to use the digital audio software, n-Track, the focus was pivoted on the app being able to receive files that had been recorded with n-Track.
3. The app must work cross-platform on both Windows and macOS. (**Original**)
    a. The application is accessible on a device with any operating system that is capable of installing and opening a web browser and connecting to the internet.
4. The visualization results must be returned with no manual input or manual command from the user. (**Original**)
    a. Once the device is calibrated, the user only needs to upload and submit their file to see their results.
5. The visualization consists of a lung diagram that correctly displays the location of the sound detected, as well as a data table that shows relevant metrics for every crackle family identified. (**Original**)
    a. The visualization achieves this, and the data table shows timestamp, delay, and transmission for every channel for every crackle family.
6. The app can perform audio playback of sounds detected at different locations, in any crackle family through the user interface. (**Final Product**)
    a. A short audio clip is played from each peak location in the crackle family per channel. If multiple single-channel .wav files were uploaded, the playback on a channel corresponds to its numbered channel. If a single multi-channel file is uploaded, the audio playback plays audio only from the requested channel.
7. The app has a robust mechanism to handle cases where an invalid file input is submitted. (**Original**)

    a. If an invalid file input is submitted, the application reports the error accordingly and prevents forwarding any corrupt or empty data down the pipeline.
8. The results are synchronized so that they represent an accurate measure of travel time for detected sounds without artificial delay added. (**Final Product**)
    a. The calibrate script successfully adjusts the results to be reflective of the real world data. After adjusting for desynchronization, the amount of reported delay on each channel is consistent with the transmission metrics and with a visual analysis of the audio waveforms.
9. The total time taken from file upload to displaying the results is less than 1 minute. (**Original**)

III. Overall Assessment and Follow-up Plans

Overall, the client seemed satisfied with the presented project. It fulfilled the hardware criteria of being a safe, comfortable device that could record sound from multiple channels. The software criteria was fulfilled by having the custom web-app be accessible on a web browser and capable of receiving and processing audio files.

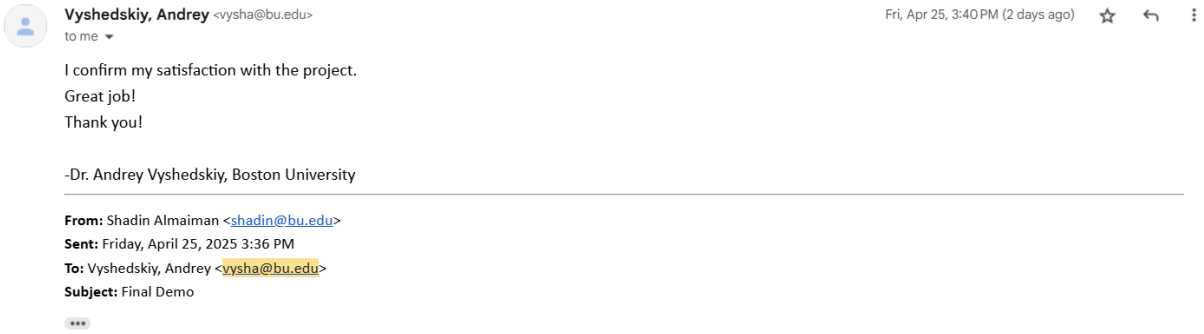
Based on the most current version of the project, there are a few directions that are worth following up on.

First, fast fourier transforms (FFTs) should be used for signal processing, as it converts signals in the time domain to signals in the frequency domain. The project's main goal is to process and analyze noise in the recorded audio files, so converting the .wav file files with FFTs would allow for easier frequency analysis (due to having the .wav file segmented into different, individual, frequency points.)

Secondly, the wiring of the microphones could be improved. Having each microphone lead to a separate wire that would then conjoin with the other wires in the USB-C splitter is very inefficient and could lead to false positives in the crackle detection system due to interference from the user applying pressure to the wires under the top two foam layers.

Finally, this iteration of the device will be passed on to the client, Dr. Vyshedskiy, to hand over to the next senior design group. This time, they will have a much stronger foundation to build upon since the multi-channel recording issue has been resolved. Hopefully, the next group of students will be able to spend more time on the software and the signal processing aspects of the device.

IV. Customer Acceptance Email



Vyshedskiy, Andrey <vysha@bu.edu> Fri, Apr 25, 3:40 PM (2 days ago)
to me

I confirm my satisfaction with the project.
Great job!
Thank you!

-Dr. Andrey Vyshedskiy, Boston University

From: Shadin Almaiman <shadin@bu.edu>
Sent: Friday, April 25, 2025 3:36 PM
To: Vyshedskiy, Andrey <vysha@bu.edu>
Subject: Final Demo