Smartphone Based Nano-device for Human Breath Sensing
DESIGN DOCUMENT

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1 Introduction

1.1 PROJECT STATEMENT

The goal of this project is to provide a non-invasive test for diagnosing diseases in a portable, cheap, user friendly package. Our project utilizes the capabilities of an optical spectrometer developed by our mentor to intake a patient's breathe and determine the bacteria or virus causing a patient's illness using spectral analysis. Our goal is to attach the spectrometer to a smartphone and develop an app to allow the capabilities of the spectrometer to be utilized in a portable, cheap, user friendly package.

1.2 PURPOSE

This project will benefit society because it could replace more invasive forms of medical diagnostic testing such as blood tests. This means lower cost to diagnose, greater portability, greater patient comfort, more efficient use of doctor's time, and puts greater information into the hands of patients by allowing for self-diagnosis. All these factors give patients a better option for diagnosis than is widely used now. It could also allow third world countries with poor health care access to accurate diagnoses that had previously been too expensive or logistically impossible to achieve. This could save countless lives.

1.3 GOALS

Our goals for this project include becoming better at teamwork as well as improving our technical skills in several areas. Additionally, we have goals for the performance of the product of our project. Below is a listing of specific things we would like to learn and product capabilities we would like to achieve:
-learning to use 3D printer and develop 3D cad designs
-learn how to plan software (Android app) project to make sure all components work together at the end
-determine best places to research android code implementation
-learn how to build a user interface that is user-friendly and can be understood by people with very little technological experience
-learn how to give presentation in a convincing manner and effectively explain project
-learn how to effectively work in a team, delegate tasks, develop schedule, and bring product pieces together in working unit
-learn how to ensure whole team is understanding the project and how their tasks fit into the project
-develop a product that is much easier to use to diagnose diseases than is currently available
-build a product that is cheaper than current testing methods and durable enough to be used in third world countries
-build a product that always diagnoses correctly

2 Deliverables

-3D Design for spectrometer housing phone case
-3D printed spectrometer housing phone case for spectrometer that our mentor will develop: should be durable, portable, fairly cheap to build
-Android app that can determine frequencies and intensities of light that is focused on the camera by the spectrometer
-App must determine which diseases emit these light frequencies
-App must have easy to use user interface
-App must communicate with user steps to use the app and clearly display what disease is present

3 Design

3.1 SYSTEM SPECIFICATIONS

3.1.1 Non-functional
List and explain the non-functional requirements of the project.
-An app that can run on any Android capable device
-A 3D model and case for the spectrometer to fit over a phone
-An adjustment on the case to allow reflected spectrum to fill full size of camera on different phones by changing distance from lens to camera

-Associated 3D CAD model and app design documentation

3.1.2 Functional
-Android application capable of in taking image for analysis
-Android application must include capability to determine all frequencies of light entering camera
-Android application must include capability to determine the intensity of each of these frequencies
-Android application must include capability to graph frequency vs intensity spectra
-Android application must include capability to determine what bacteria or virus would make that intensity spectra

3.2 PROPOSED DESIGN/METHOD
For the app portion of our project, our team has decided to build an android app rather than an iOS app due to the fact that we have more experience with Android and because Android is more prevalent worldwide.

Our app will have several different capabilities. First the app will have a calibration section that allows you to utilize the app on any Android phone regardless of camera size and resolution. This section will obtain a video feed from the camera and instruct the user to adjust the spectrometer until the spectrum fills the whole screen. This will ensure that the spectrum fills the whole camera and gives the phone the ability to calculate frequency of the image based on the distance from the edge of the camera each pixel is. The spectrometer will have a dial measuring the distance to the camera and this distance will be input to the calibration portion of the app to form the frequency calculations which are described in greater detail later.

The next activity in the app will instruct the user to point the spectrometer at a patient's mouth and click a button to take an image when ready. This image will be retrieved from the camera and stored. The image will be displayed on screen and another button will appear to calculate the frequency vs intensity spectra. The intensity will be graphed for each pixel in a cross-section of the image by adapting Matlab code to Java. The app will find Intensity by calculating a weighted average of the RGB pixels using the following equation: Intensity = `0.2989 * R + 0.5870 * G + 0.1140 * Fr`equency can be graphed by calculating how many pixels/distance from the edge of the camera you are analyzing and plugging it into the equation:

$$n\lambda = d(\sin \alpha - \sin \beta) \qquad\qquad (2)$$

with

n	diffraction order (integer)
λ	wavelength (nm)
d	grating groove space (nm)
α	incidence angle of light on grating, measured counter-clockwise from grating normal
β	exit angle of observed, constructively-interfering light, measured counter-clockwise from grating normal

After obtaining a frequency vs spectrum graph, the app will then compare the graph to saved graphs representing the spectrum of known viruses and bacteria. It will find a match if there is one and display the virus or disease on screen that the patient has.

We have decided to put all the calculations on the phone in case there is no cellular access. We may need to reassess if we can't store enough spectrums to match against to make the device capable of finding most diseases.

For the spectrometer case, we will be designing the model in solid works and getting it 3D printed on campus. It can fit on different android phones.

3.3 DESIGN ANALYSIS

So far we have created Matlab code that will intake a spectrum image and determine the intensity at each pixel across the image and plotting the intensity against frequency. It can also determine what frequency corresponds to each pixel by determining how many pixels the pixel is from the left of the camera. It can then plot the frequency against intensity.

4 Testing/Development

4.1 INTERFACE SPECIFICATIONS

We will be obtaining a picture from the camera on our smartphone. This should be fairly simple given the hardware access software tools provided in Android Studio.

4.2 HARDWARE/SOFTWARE

We will be using Matlab to start with to graph our frequency vs intensity plots. We will then convert this code to its equivalent Java code. We will be using Java to build our app.

4.2 PROCESS

In order to test whether we can generate the correct frequency vs intensity graph, we can compare our results to a real spectrometer. Additionally to determine if our disease matching works, we can try our app out on microscope slides of different viruses and bacteria. Additionally we can ensure that our device works correctly on several different android devices. Lastly we can test the usability of our app by finding people to run the app and see how easy they think it is to run. Fig 1 below illustrates our testing process.
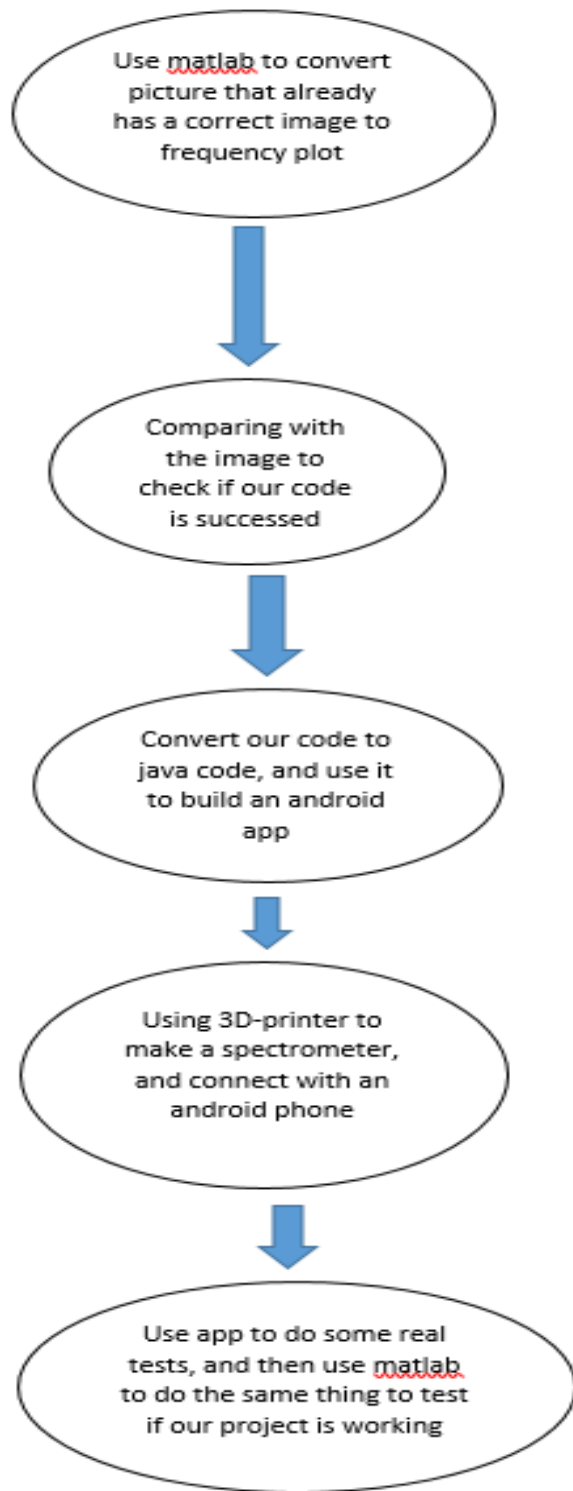
Fig. 1

5 Results

We are able to take a picture spectrum like shown below and plot the intensity vs frequency of it in matlab. Additionally we have been able to develop the java code to take a picture. Next we will need to find a way to analyze the picture within the java android app and then we need to compare our result with the commercial spectrometer to make our result more accurate.

6 Conclusions

We have been working on the basics of the code for our project. Our goal is to develop a smartphone spectrometer which can analyze different kinds of diseases. Because we need to make an android app which can analyze the image, we first choose to use the matlab to experiment on image analysis because matlab has some similar function. After we got it working, we'll rewrite the code in android studio to make the app able to analyze the image. We use matlab as a stair to reach our goal because we thought it would help us find the way to solve the problem easily and then we can go into the next step. We also started researching how to write the java code because most of us don't have a lot of experience building android apps. After we have completed the app, we will make a spectrometer with a 3D printer and connect it with the smartphone and do some real tests to make sure our project works.