## Section II: Methodology

**Role of Student vs Mentor**

The student research in this project completed all coding and methods on their own. The mentor provided weekly/bi-weekly feedback on the project in the form of tips and suggestions.

**Equipment and Material**

For this project, instrument designs were utilized and modified from the oDocs Fundus Imager open-source 3D model files. All images of 3D CAD model files used from oDocs can be seen in Appendix 1. To print this material, a 3D printer is also required. In addition to this, the software program OnShape is required to develop the 3D CAD models. Also, a wired mini microphone and mini speaker are required for the novel instrument measuring IOP. To test the instrument, three latex gloves are also necessary. The programming part of this project, a MacBook Pro, and numerous online tutorials will be utilized. Specific software used includes the integrated development environments XCode and Google Colab, and the programming languages Python and Swift.

**Technique #1: Testing, modifying, and creating instruments for diagnosis.**

The first procedure for this project is testing and modifying the current instrument produced by oDocs. oDocs is an ophthalmology company that provides open-source CAD models for 3D printing fundus for point-of-care use. However, these CAD models have been developed for earlier iPhone models in which only one small camera is present. As a result, these designs are outdated and need to be modified to ensure ease of use for the patient and the production of accurate results. The current oDocs imagers will be tested on newer phone models and new CAD designs will be sketched according to any modifications that need to be made. In addition to this, a new CAD model and instrument for the novel method of diagnosing IOP through sound waves will be built. This instrument will implement a mini microphone and speaker sitting on opposite sides of the phone at the 60º angle. By doing so, the sound waves produced by the speaker will be emitted at a 60º angle, and then reflect off the eye model that will be positioned at the same 60º angle on the opposite side and be recorded by the microphone. The optimal sound wave frequency will be tested for by observing the number of decibels returned in the reflection wave for sound waves ranging from 2000-10000 Hz. The sound range that produces the greatest number of decibels in the reflection wave be used for testing. The eye model used in this experiment will be three latex gloves containing different amount of air to simulate different internal pressure of eyes. Latex gloves in specific were used for experimentation because of the little rigidity of the material, and the ability to increase the amount of air in the glove without changing its surface area, effectively increasing internal pressure. The experimental setup can be seen in Appendix 2. Finally, for the diagnosis of cataracts, since this can be done simply through a zoomed in picture of the eye, the iPhone's camera will be utilized, and no instruments need to be created or tested.

**Summary of Preliminary Data.** A preliminary 3D CAD model was designed to measure IOP using sound waves as seen in Figure 2 and explained previously. One arm will hold a small speaker emitting the sound waves and the other arm will hold a small microphone to measure the decibels emitted by the reflection wave as mentioned above. The decibels returned in the reflection wave are directly proportional to internal pressure as explained in past research.

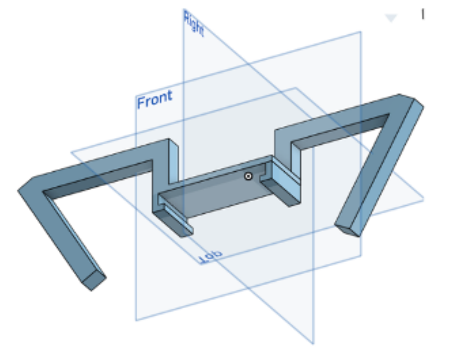


***Figure 2: Preliminary Design for the 3D CAD Model to Measure IOP.*** *This model is an initial design that uses sound waves to measure IOP for the diagnosis of glaucoma.*

**Technique #2: Creating Diagnostic Models**

The second technique for this project is related to creating machine-learning models for the diagnosis of cataracts and glaucoma. The public fundus images were taken from a smartphone dataset in a previous study and cataracts images data set from a Kaggle dataset will be utilized to test and train the models. A model will be made for each disease using Neural Networks.

**Summary of Preliminary Data.** As preliminary data, a neural network model for cataracts using cataracts images was created. As seen in Figure 3, the model

```
              precision    recall  f1-score   support

           0       0.99      0.65      0.79       243
           1       0.74      1.00      0.85       246

    accuracy                           0.82       489
   macro avg       0.87      0.82      0.82       489
weighted avg       0.87      0.82      0.82       489

4/4 [==============================] - 0s 4ms/step
              precision    recall  f1-score   support

           0       0.87      0.54      0.67        61
           1       0.66      0.92      0.77        60

    accuracy                           0.73       121
   macro avg       0.77      0.73      0.72       121
weighted avg       0.77      0.73      0.72       121
```

performed well with an accuracy of 82% on the training set and 73% on the validation set. Higher model accuracies were achievable after the number of epochs run is experimented with.

**Technique #3: Creating the Mobile Application**

The third technique is related to building the final mobile application implementing the diagnostic models, novel instrument readings, and potential next steps/severity measurement. This was done using XCode and Swift, as well as the technologies Firebase, Core ML, and Core Data.

**Summary of Preliminary Data.** After all the models were created, the models that performed the best for each task (diagnosing cataracts and diagnosing glaucoma) were implemented into a final mobile application. A portion of the preliminary design for this mobile application can be seen in Figure 3. The entire preliminary design is available in Appendix 3.

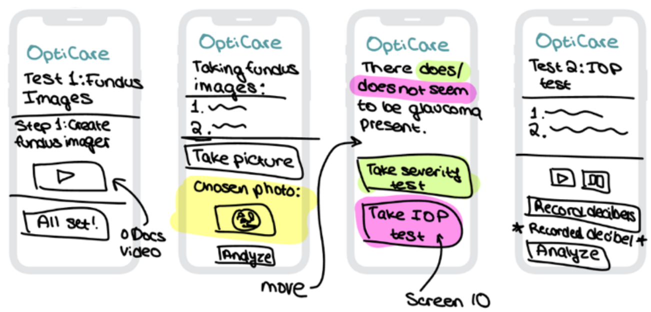


***Figure 4: Preliminary Design of the Mobile Application****. This is a portion of the entire design. This design will be built upon and encompass the diagnostic testing interface in the future.*

**Statistical Test**

A one-tailed one proportion t-test will be performed on the machine learning model accuracy and other metrics to ensure the models' predictions are statistically significant. Also, a two-tailed two proportion t-test will be performed on the ability of the novel instrument to capture changes in IOP.