Section III: Results

Finding the Optimal Frequency for Testing

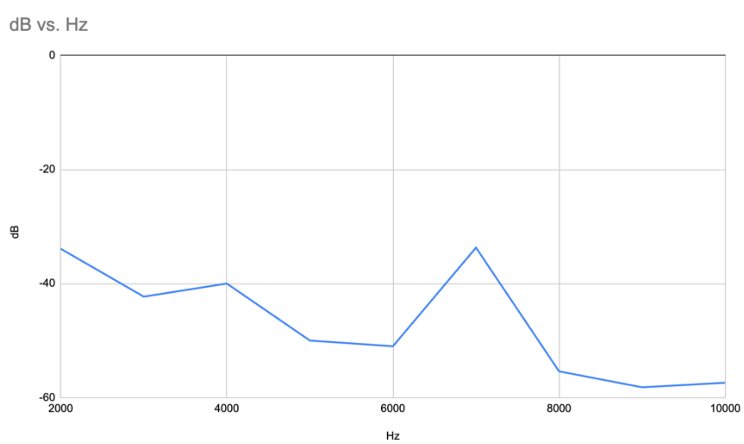
This table measures the decibels returned in the reflection wave at different hertz levels to find the optimal frequency (the frequency that produces the most decibels) to test with. The optimal frequency was 7000Hz.

4000	-40.0
5000	-50.0
6000	-51.0
7000	-33.7
8000	-55.4
9000	-58.2
10000	-57.4

Figure 7: The number of decibels returned in the reflection wave at different hertz levels.

T

This graph is a visual representation of the data from Table 1. It highlights the optimal frequency to test at, which is 7000 Hz.



Testing the Novel Instrument's Ability to Measure IOP

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Avg
Medium IOP	-35.8	-35.6	-35.2	-36.1	-36.9	-36.7	-36.2	-35.7	-35.9	-36.6	-36.07
High IOP	-34.5	-35.1	-33.5	-35.6	-36.2	-36.3	-35.9	-35.5	-35.8	-36.0	-35.44

Table 2: Measuring the number of decibels returned in the reflection wave to observe if there is a relationship between high internal pressure and the reflection wave magnitude.

Table 2 is data taken from ten different rounds in which a latex glove with a high internal pressure is placed in front of the created IOP instrument and the reflection decibels are measured, and then a latex glove with slightly less pressure is also placed in front and reflection decibels were also measured.

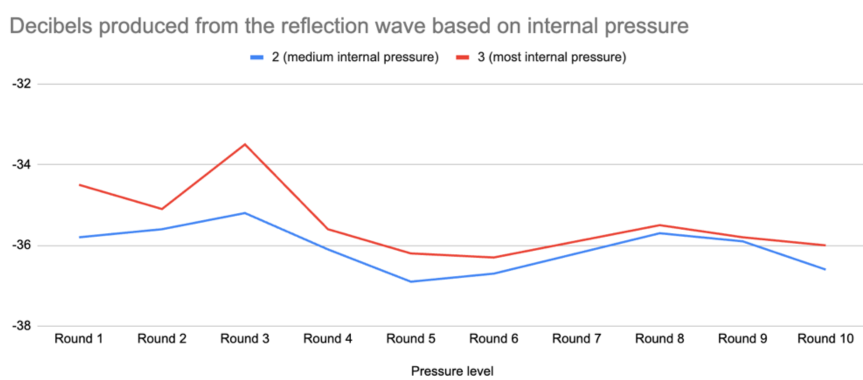


Figure 8: The number of decibels produced by the reflection wave for different internal pressures.

Figure 8 visualizes the data generated from Table 2. The blue line represents the returned decibels from a latex glove with high internal pressure and the red line represents the returned decibels from a latex glove with a lower amount of pressure.

Machine Learning Models

The Cataracts Image Classification Model

```
16/16 [==============================] - 0s 5ms/step
              precision    recall  f1-score   support

           0       0.92      0.95      0.93       243
           1       0.95      0.91      0.93       246

    accuracy                           0.93       489
   macro avg       0.93      0.93      0.93       489
weighted avg       0.93      0.93      0.93       489

4/4 [==============================] - 0s 5ms/step
              precision    recall  f1-score   support

           0       0.87      0.87      0.87        61
           1       0.87      0.87      0.87        60

    accuracy                           0.87       121
   macro avg       0.87      0.87      0.87       121
weighted avg       0.87      0.87      0.87       121
```

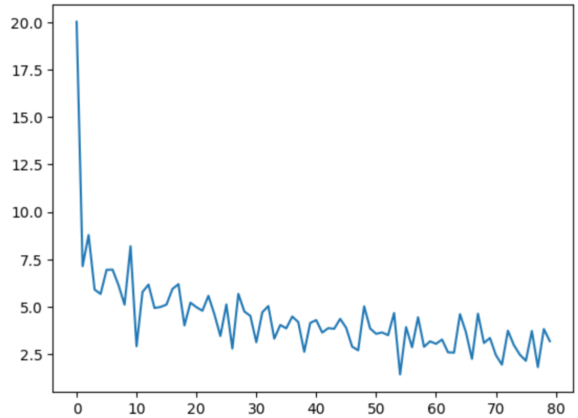


Table 3 represents the classification report of the cataracts model. An accuracy of 93% was achieved on the testing set and an accuracy of 87% was achieved on the validation set. Figure 9 represents the binary cross entropy error as the number of epochs is increased while training the cataracts classification model. The total number of epochs run was 80.

The Glaucoma Left Eye Image Classification Model

```
24/24 [==============================] - 0s 14ms/step
              precision    recall  f1-score   support

           0       0.93      0.87      0.90       377
           1       0.88      0.94      0.91       373

    accuracy                           0.90       750
   macro avg       0.90      0.90      0.90       750
weighted avg       0.90      0.90      0.90       750

8/8 [==============================] - 0s 10ms/step
              precision    recall  f1-score   support

           0       0.89      0.82      0.85       123
           1       0.84      0.90      0.87       127

    accuracy                           0.86       250
   macro avg       0.86      0.86      0.86       250
weighted avg       0.86      0.86      0.86       250
```

Table 4: The classification report produced for the cataracts image classification model.

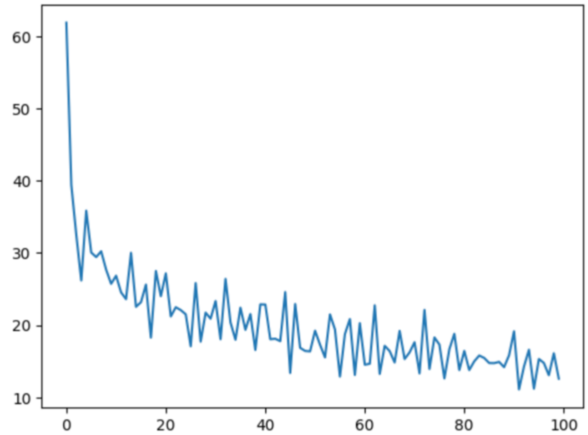


Figure 10: The binary cross entropy error as the number of epochs increases.

Table 4 represents the classification report of the left eye glaucoma model. An accuracy of 90% was achieved on the testing set and an accuracy of 86% was achieved on the validation set. Figure 10 represents the binary cross entropy error as the number of epochs is increased while training the glaucoma classification model. The total number of epochs run was 100.

The Glaucoma Right Eye Image Classification Model

```
24/24 [==============================] - 0s 14ms/step
              precision    recall  f1-score   support

           0       0.98      0.67      0.80       377
           1       0.75      0.99      0.85       373

    accuracy                           0.83       750
   macro avg       0.87      0.83      0.83       750
weighted avg       0.87      0.83      0.83       750

8/8 [==============================] - 0s 13ms/step
              precision    recall  f1-score   support

           0       0.91      0.65      0.76       123
           1       0.73      0.94      0.82       127

    accuracy                           0.80       250
   macro avg       0.82      0.79      0.79       250
weighted avg       0.82      0.80      0.79       250
```

Table 5: The classification report produced for the glaucoma left eye image classification model.

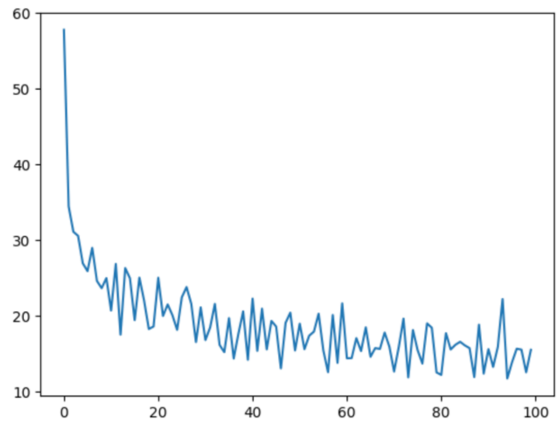
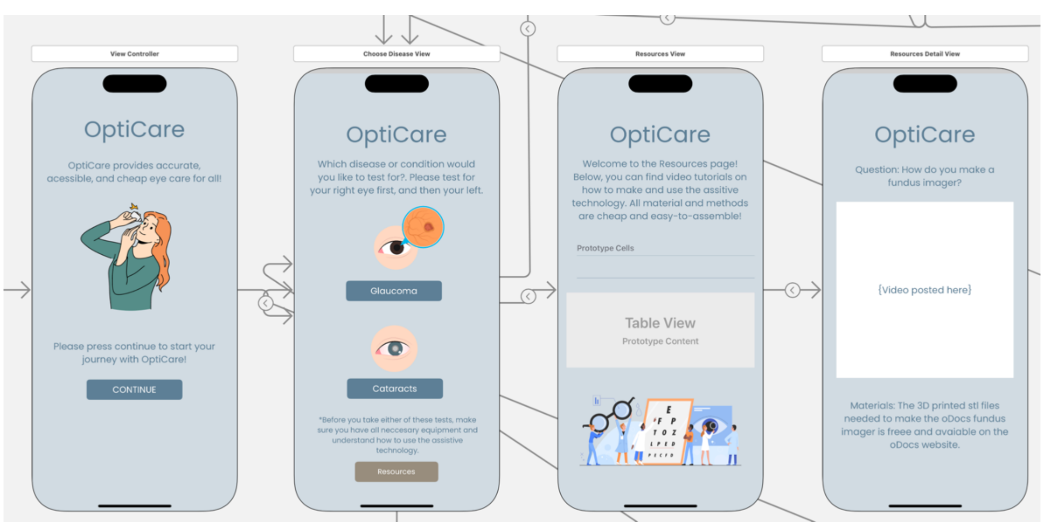


Figure 11: The binary cross entropy error as the number of epochs increases.

Table 5 represents the classification report of the right eye glaucoma model. An accuracy of 83% was achieved on the testing set and an accuracy of 80% was achieved on the validation set. Figure 11 represents the binary cross entropy error as the number of epochs is increased while training the glaucoma classification model. The total number of epochs run was 100.

Final Application Interface and Workflow



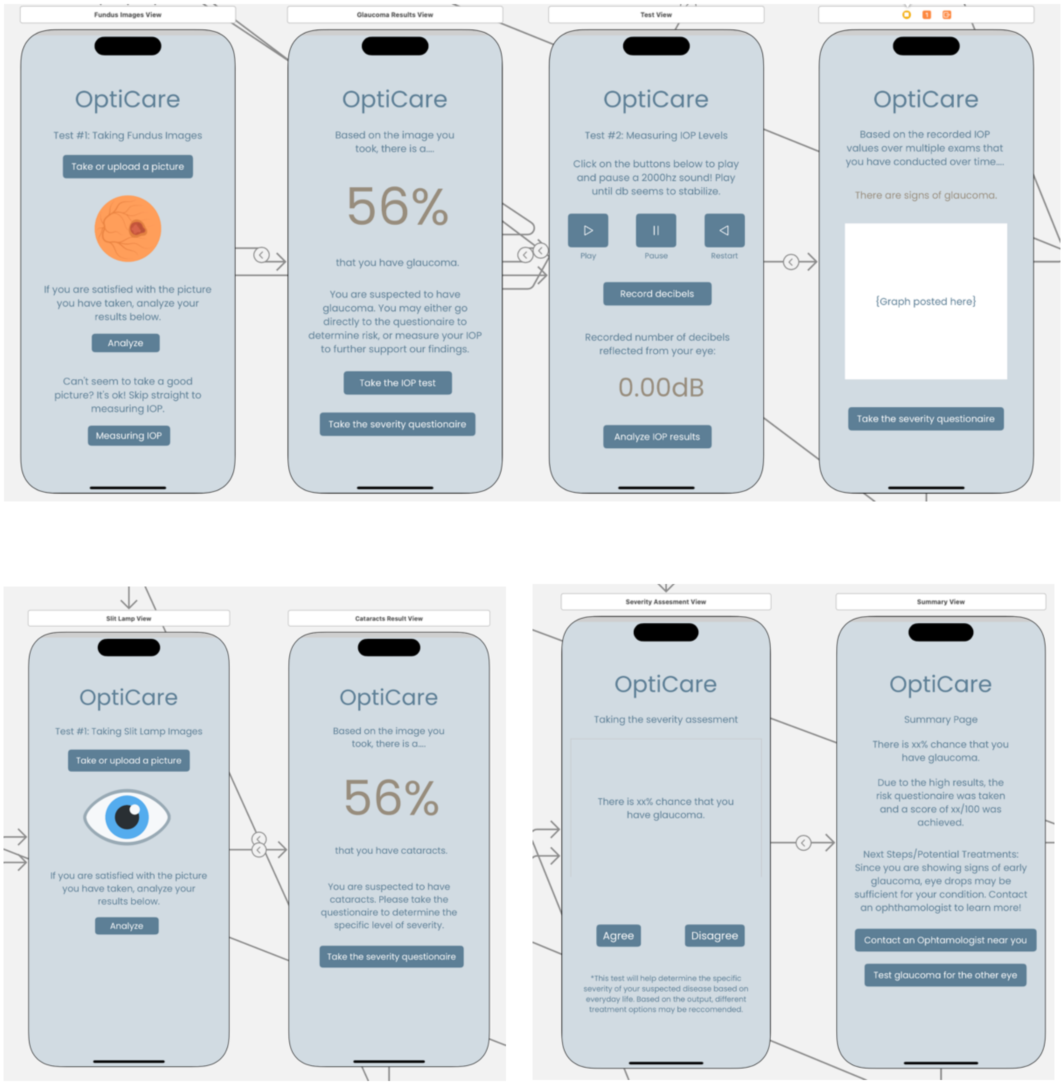


Figure 12: This figure represents the final mobile application workflow and design for OptiCare.

Figure 12 represents the final workflow and design for the mobile application that was built. The first set of images represent the home and resources page, the second set represents the glaucoma diagnosis pages, the third set represents the cataracts diagnosis pages and the severity questionnaire.

Section IV: Discussion

As seen in the data analysis, the machine learning models performed well, with all models achieving an accuracy greater than or equal to 80%, In addition to this, precision and recall values were also very high, indicating that the number of false positives and false negatives were also limited. As for the novel IOP measurement instrument, as seen in the data, the latex glove with the lower internal pressure returned a lower number of decibels in the reflection wave than the number of decibels returned by the latex glove with higher internal pressure. This experimentation took place at 7000 hertz because this was tested to be the optimal resonance frequency as it returns the greatest number of decibels back in the reflection wave. Overall, the sound waves testing proves the relationship between the reflection wave value and IOP and makes the novel instrument a success. In the final mobile application, the user was alerted if the reflection wave returned from their eye was greater than 0.63 in magnitude, because this was the difference between the average reflection wave decibel values returned from the experimentation (seen in Table 2) and represents a serious increase in IOP. For the fundus imager produced by oDocs, this was 3D printed as well and tested on the iPhone 14, a phone with different camera dimensions. Contrary to what was expected no modifications needed to be made to the design as the instrument was still able to take fundus images even with the new camera dimensions.

For statistical testing the two-proportion t-test performed on the reflection decibels returned for the novel instrument testing had a p-value of 0.03327138154. As a result, this data was statistically significant. As for the machine learning models, the p-value produced from a one proportion t-test was 0.002014342757, therefore also being statistically significant.

For future steps of this project and improvements, the main course of action will be to further solidify the relationship between IOP and sound waves because even though a relationship was confirmed, the scale at which the reflection wave changes in correspondence with the IOP is small. As a result, experimenting with a larger microphone and speaker has the potential of catching a more accurate and potentially larger direct relationship between IOP and the returned decibels of the reflection wave. In addition to this, one point of error in experimentation was the geometry of the model eye. Latex balloons were simulated as model eyes for this experiment as the focus was testing how the model performed for different internal pressures. However, a latex balloon is not like the geometry of a human eye and therefore specific reflation levels may have been skewed. While the relationship of the geometry of an eye and this form of measuring IOP through sound waves has not been established, this is a potential variable that should be taken into consideration in the future.