Portable Retina Eye Scanning Device

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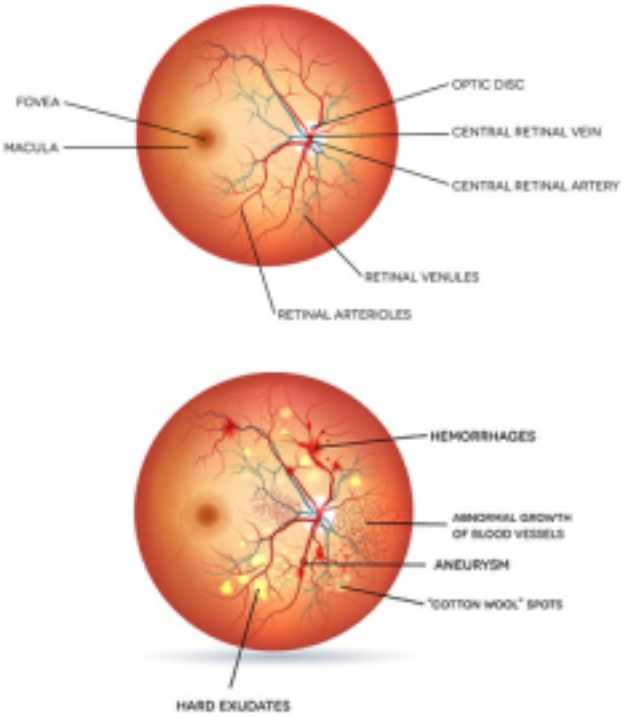
Problem

- Millions of people in the world are diagnosed with diabetes every year.
- Leading to diabetic retinopathy, a disease found in the retina of the individual.
- Often leading to blindness if left untreated.
- This disease is not easily detected, and normally not reversible when found in the patient.



Previous Works and our Solution

Peek Vision:

- Created cameras and software applications on smartphones to scan patients' retinas, but does not utilize machine learning so runs slowly.

Epipole:

- Handheld retinal fundus camera, must be connected to Windows or Android and the Internet.

Our Solution:

- A standalone product that is able to give instant results by utilizing Machine Learning and Image Processing.
- No Internet connection necessary.

Our device is a diagnostic tool, and results given from device should be taken to a licensed medical professional

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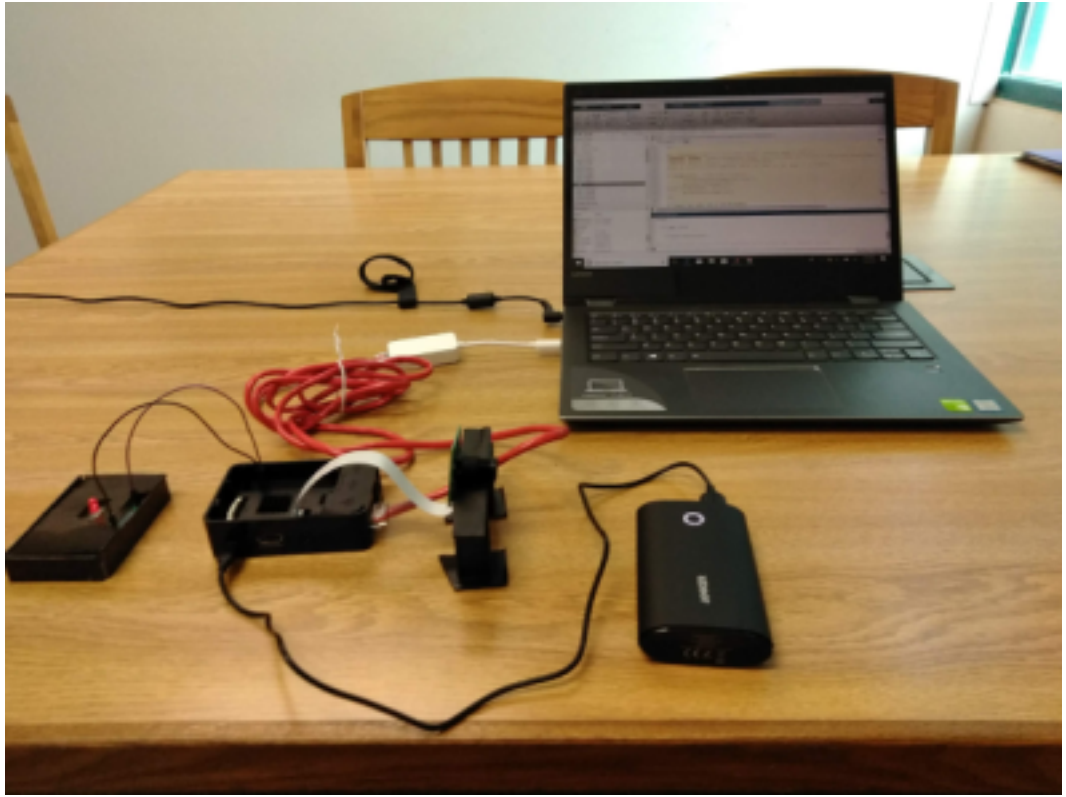
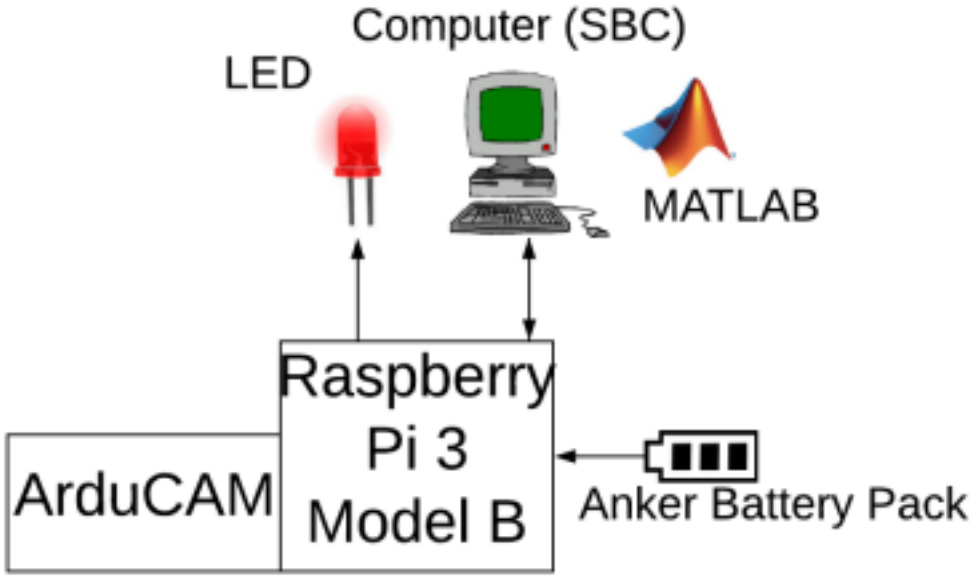
Final Product



- Image of our final product.
- How computer, raspberry pi, camera, LED and battery are all connected.

System Overview

- System overview that looks over entire device and shows how each piece is connected.
- Basic overview of how our system works and can be implemented.



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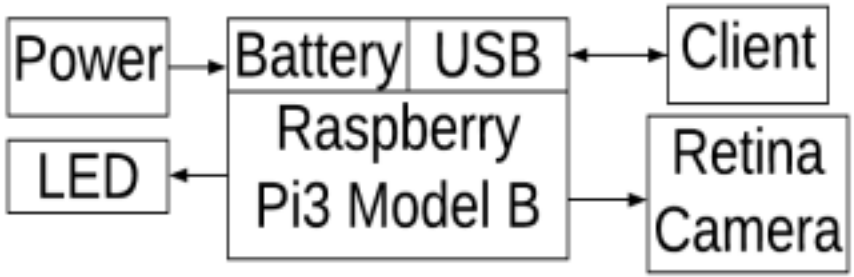
Hardware Design

- Visual representation of all of the hardware components we utilized.
- Raspberry Pi is the central unit.
- Demonstrates how all components interact with each other.



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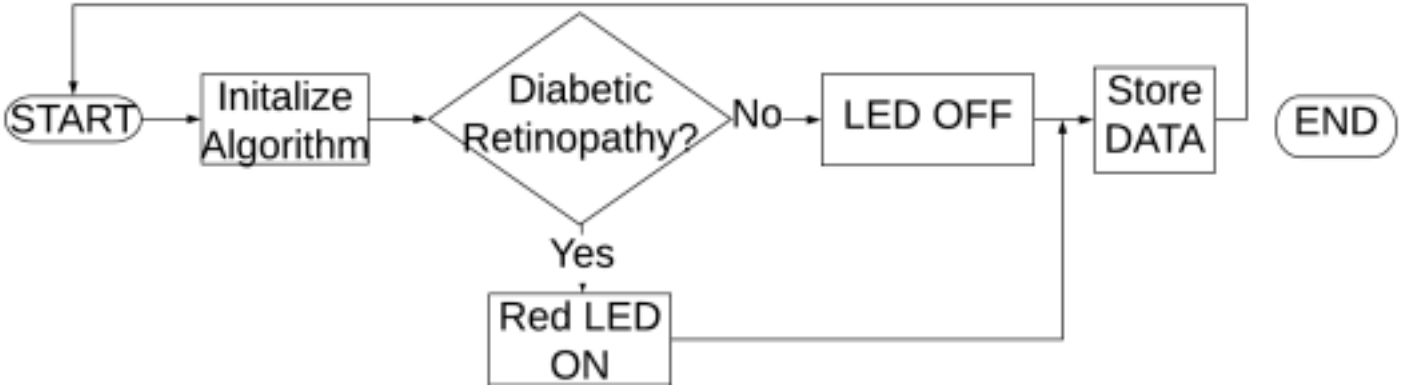
Software Design



- This flowchart gives a general description of what our program does.
- Initializes, takes a picture, determines whether or not the retina is healthy and displays the result via LED.
- This program utilizes the machine learning toolbox in MATLAB, Raspberry Pi 3 Model B, and LED to give accurate results.

Requirements

Marketing Requirements

- The device will be reliable in determining the health status of a picture of a patient's retina.
- The device will not be fully automated, but will be simple to use.
- The device will capture pictures of a retina fundus images with high resolution.
- The device will be marketed toward trained physicians and health practitioners involved in treating patients in rural regions with limited access to ophthalmology testing technology throughout the world.

Engineering Requirements

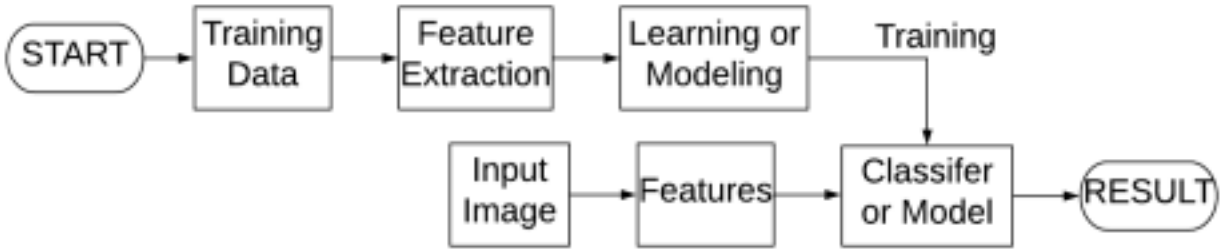
- The accuracy of the scanning must be over 90% in order for the device to be reliable in determining the status of the picture.
- The device will consist of four components: Raspberry Pi 3 Model B, ArduCAM (camera), Battery Pack, and LED box light.
- The project requires interfacing MATLAB with the device but, minimal commands are used to execute the device.
- Functionality of the device will be a precursor to taking a scan of a patient's retina, a practice done by licensed individuals.

For a complete list of our requirements visit our website:
http://diabeticretinopathyssu.weebly.com

Machine Learning and the Confusion Matrix

What is Machine Learning?

- It is a type of computer programming which uses data to perform a task.
- The more data, or images you add to a program, the better it performs.



What is the Confusion Matrix?

- It is a table that is used to describe the performance of a classifier (method used to classify data) on a set of test data where the true values are known.
- In our project the most important part of the matrix looked at the false negative rate and true positive rate to determine the overall accuracy of our algorithm.

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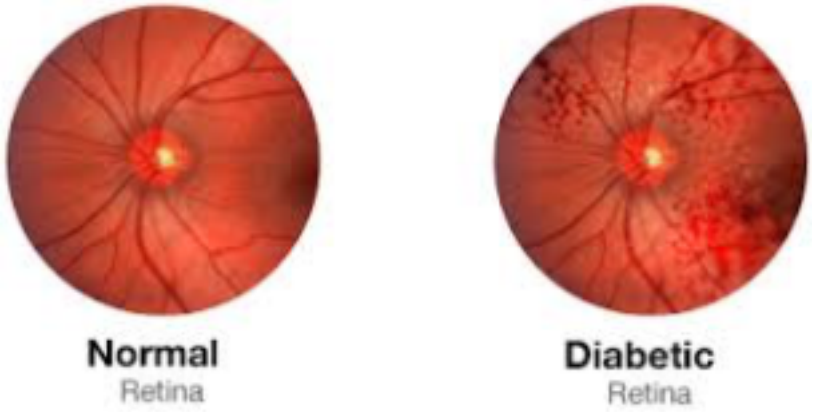
Machine Learning and our Project

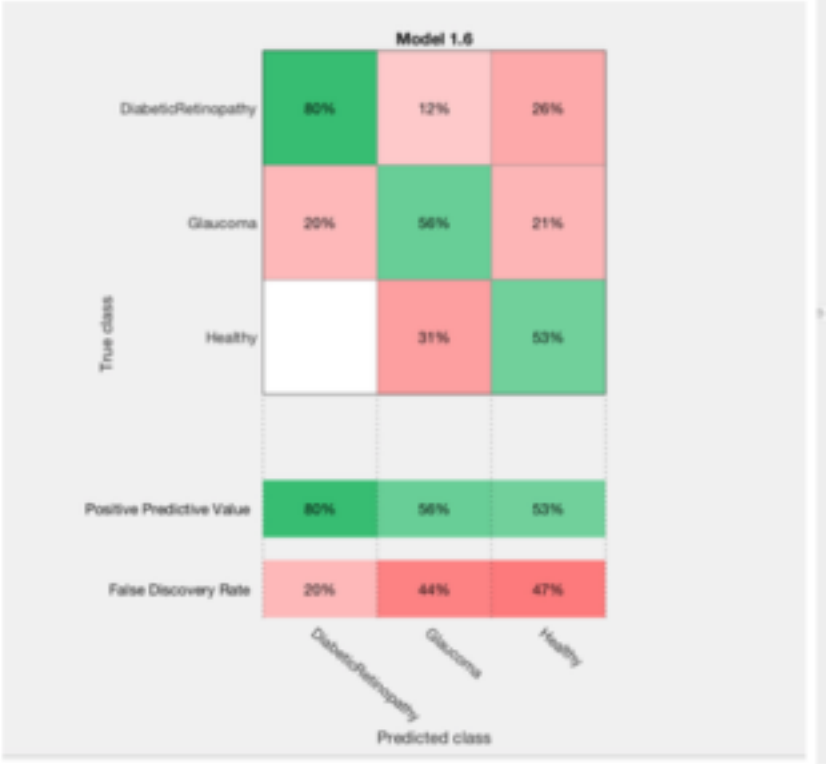
- Our project utilizes machine learning and image processing in order to run the algorithm, and differentiate between images.

- In order to check between healthy retina images and diabetic retina images our algorithm looks at blood vessels, dark spots, damage to the retina shape to understand the differences between the two categories.



Classifier Test

- Test used to determine which type of classifier would be best suited to test our algorithm most accurately.
- Tested 21 different classifiers and found that 8 had same best accuracy of 60%.
- This test was completed before we improved the average accuracy of our algorithm.
- Looked at confusion matrices and concluded that Linear Support Vector Machine (SVM) would give us the best result.



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Accuracy Improvement Test

- Initially the best accuracy for the Linear Support Vector Model was 60% which was 30% lower than our minimum goal accuracy of 90%.
- To increase our accuracy first we eliminated our Glaucoma group from our code, this increased our average accuracy to 83%.
- Increased the number of images in Diabetic Retinopathy from 15 to 45, this action increased our average accuracy to 91.7%.
- Our False discovery rate for Diabetic Retinopathy is 2% and is 22% for healthy retinas.

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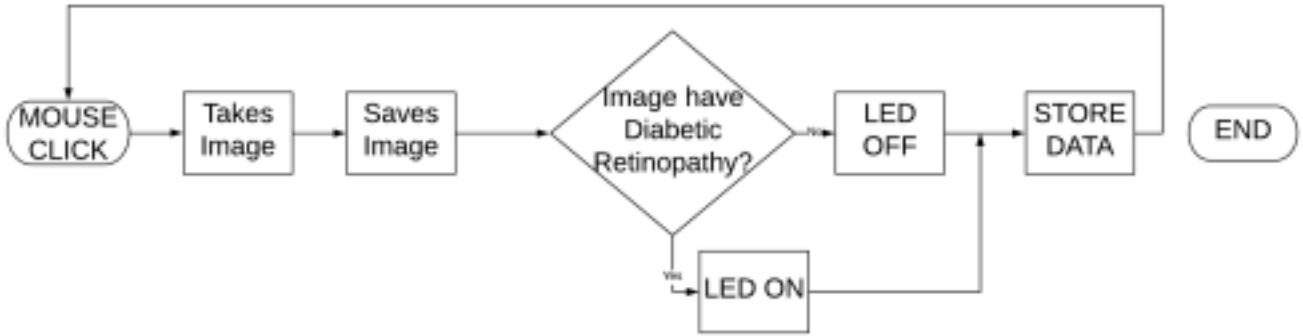
Algorithm Accuracy Test

- Tested the accuracy of the algorithm, by testing 60 images, 30 with diabetic retinopathy and 30 healthy retinal images.
- Images tested were not included in our testing algorithm, were taken by our camera, and had not been previously seen by our algorithm.
- We were able to conclude 5 healthy images were given an inaccurate result, and only a single image with diabetic retinopathy was given an inaccurate result.
- Given an average accuracy of 90%, diabetic retinopathy accuracy of 97%, and healthy accuracy of 83%.
- Diabetic retinopathy had a false discovery rate of 3% and healthy had a false discovery rate of 17%.

Automation Test

- Automated taking pictures, saving them, and testing them.
- It automatically take images with an external camera, saves them to a specific location, and tests them with our algorithm.
- This program works with a single click of a mouse.



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Health Indicator Test

- Tested to confirm that the LED was compatible with MATLAB and would give us the correct result.
- If the LED turns on it means the image has diabetic retinopathy, if not the image is healthy.

- Tested Image result is Diabetic Retinopathy.

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Materials and Costs

- Special Thanks to SOURCE who gave us $400 to complete our project.
- Special thanks to Sharahm Marivani for providing components.

Portable Retina Eye Scanning Device

Part/Service	Quantity	Source	Description	Price
Raspberry Pi3 Model B	2	Amazon	Main processing and control unit of device	$35.73x2
Anker Battery Pack	1	eBay	Rechargeable battery pack, to power the device	$18.99
ArduCAM	1	getpfv.com	Camera to scan retina image of an eye	$18.99
MATLAB Student Edition	1	Mathworks	Programming language used to control our project.	$49.99
Electrical Components	N/A	EE Department	Components to connect our device together.	$0
16 GB SD Card	1	Best Buy	Store Raspian Operating System.	$9.99
Ethernet Cable	1	EE Department	Connect Raspberry Pi to computer.	$0
Ethernet Adapter	1	Office Depot	Connect Computer with Crossover Ethernet Cable.	$35.99
Raspberry Pi Heat Sink	5	Amazon	Prevent Raspberry Pi from overheating	$7.99
Total				$213.40

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Timeline

Portable Retina Scanning Device

▾ **Project Update 1**	**100%**		**Start**	**Due**	**Assigned**
Improve Algorithm Accuracy	100%		Jan 26, 2018	Mar 2, 2018	...
Train & Test Classifiers	100%		Jan 26, 2018	Mar 2, 2018	...
Record Results & Samples	100%		Jan 26, 2018	Mar 2, 2018	...
Design Device Model	100%		Jan 26, 2018	Mar 2, 2018	D...
Update Website	100%		Jan 26, 2018	Mar 2, 2018	...
▾ **Project 2 Update**	**100%**		**Start**	**Due**	**Assigned**
Utilize Camera	100%		Mar 3, 2018	Apr 7, 2018	D...
Connect Camera with SBC	100%		Mar 3, 2018	Apr 7, 2018	D...
Program LED as indicator	100%		Mar 3, 2018	Apr 7, 2018	D...
Update Documentation	100%		Mar 3, 2018	Apr 7, 2018	...
▾ **Project 3 Update**	**95%**		**Start**	**Due**	**Assigned**
Test and Debug Project	75%		Apr 6, 2018	Apr 20, 2018	...
Review Engineering Requirements	100%		Apr 6, 2018	Apr 20, 2018	D...
Review Marketing Requirements	100%		Apr 6, 2018	Apr 20, 2018	...
Update Website	100%		Apr 6, 2018	Apr 20, 2018	...
Update Documentation	100%		Apr 6, 2018	Apr 20, 2018	...
▾ **Final Project Presentation**	**0%**		**Start**	**Due**	**Assigned**
Turn in Draft of Final Project	0%		Apr 20, 2018	Friday	...
Finalize Webpage	0%		Apr 20, 2018	Friday	...
Finalize Documentation	0%		Apr 20, 2018	Friday	...
Poster Presentation	0%		Apr 20, 2018	Friday	...
Final Project Presentation	0%		Apr 20, 2018	May 20, 2018	...

- Testing and Debugging our project took longer due to camera and Raspberry Pi issues.
- Communication led to some drawbacks and time constraints.
- Getting MATLAB to communicate correctly with Raspberry Pi caused delays.
- Even with these issues we were still able to make a completed project.

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Challenges

- We had to change the idea of our project from NVIDIA to Raspberry Pi due to lack of NVIDIA support.
- Utilizing machine learning and image processing.
- Getting MATLAB on Raspberry Pi.
- Testing and updating our algorithm to get it to over 90% accuracy.

Lessons Learned

- Progress is not a straight path, especially when you have a project that is mainly software based.
- Things go wrong, and by things we mean everything.
- Teamwork, and dedication are vital when taking on a new project.

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Future Work

- The next phase of our project will be to attach a retinal fundus camera to our device in order to take an image of a patient's retina.

- Introducing, the product to doctors and health practitioners in regions that to do not have access to this technology, and make it so patients in these different regions have access to better medical care and are able to get treated faster.

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Special Thanks

- We would like to thank our Professor Dr. Farid Farahamand, Faculty Advisor Dr. Sudhir Shrestha, Industry Advisor Ben Valvodinos, and Client North Bay Vision Center for giving us feedback, and helping us with the completion of our project.

- We would also like to thank our family and friends, for their encouragement and support throughout our senior design project, those actions and kind words did not go unnoticed.

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References

- https://www.aoa.org/patients-and-public/eye-and-vision-problems/glossary-of-eye-and-vision-conditions/diabetic-retinopathy
- http://www.diabetes.co.uk/news/2014/may/portable-eye-scanner-to-revolutionise-detection-of-diabetic-retinopathy-96133928.html
- http://www.who.int/mediacentre/news/releases/2003/pr86/en/
- https://www.mathworks.com/discovery/machine-learning.html
- https://www.sas.com/en_us/insights/analytics/machine-learning.html#
- https://www.engineersgarage.com/articles/image-processing-tutorial-applications
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4463765/
- http://onlinelibrary.wiley.com/doi/10.1046/j.1464-5491.2000.00333.x/full

Questions/Comments

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Classifier Test Table 1

Classifier Type	Accuracy
Fine Tree	60%
Medium Tree	60%
Linear Discriminant	57.8%
Quadratic Discriminant	Failed
Linear SVM	60%
Quadratic SVM	53.3%
Cubic SVM	53.3%
Fine Gaussian	33.3%
Medium Gaussian	55.6%
Coarse Gaussian	60%
Fine KNN	42.2%
Medium KNN	57.8%
Coarse KNN	33.3%
Cosine KNN	60%
Cubic KNN	60%
Weighted KNN	55.6%
Boosted Tree	33.3%
Bagged Tree	55.6%
Subspace Discriminate	60%
Subspace KNN	48.9%
RUSBoost	33.3%

- Took 21 classifiers and looked at the average accuracy using the confusion matrix.
- Found that 8 different classifiers had same initial accuracy of 60%.
- These accuracies were our initial accuracies before adding anything to our algorithm.

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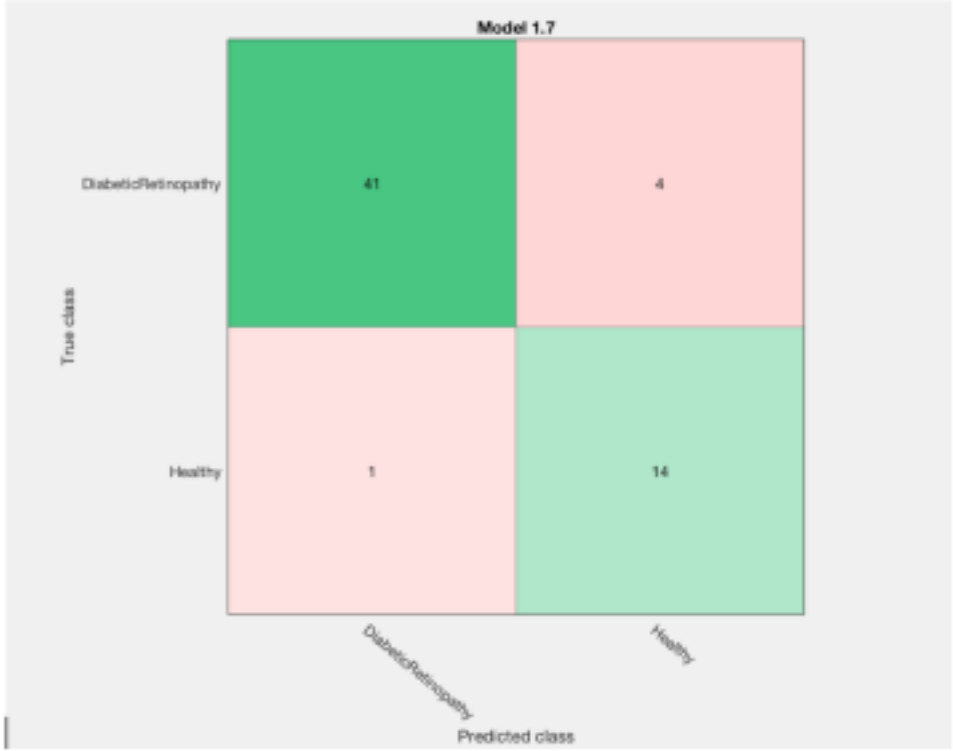
Classifier Test Table 2

Classifier	True Positive Rate Diabetic Retinopathy	True Positive Rate Glaucoma	True Positive Rate Healthy	False Negative Rate Diabetic Retinopathy	False Negative Rate Glaucoma	False Negative Rate Healthy
Fine Tree	67%	67%	47%	33%	33%	53%
Medium Tree	67%	67%	47%	33%	33%	53%
Coarse Tree	67%	67%	47%	33%	33%	53%
Linear SVM	53%	60%	67%	47%	40%	33%
Coarse Gaussian	40%	53%	87%	60%	47%	13%
Cosine KNN	53%	67%	60%	47%	33%	40%
Cubic KNN	47%	53%	80%	53%	47%	20%
Subspace Discriminant	60%	60%	60%	40%	40%	40%

- Looked at the True Positive Rate and False Negative Rate of top 8 classifiers.
- Was able to conclude from the test that Linear SVM gave us the best overall accuracy rating in each category.
- False Negative Rate was lower in all three categories and gave us a more well-rounded accuracy.

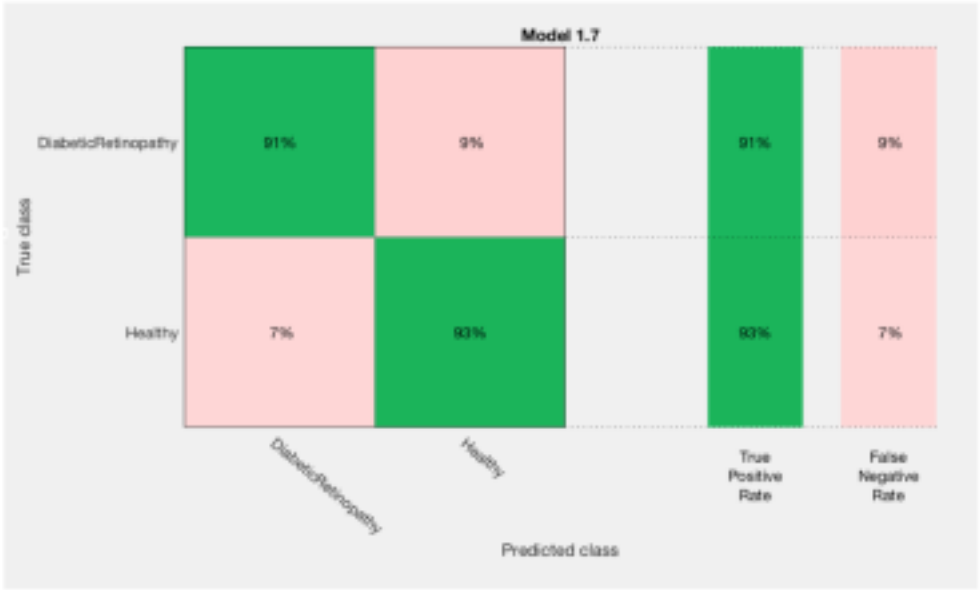
Algorithm Improvement Test Matrix 1

- Single confusion matrix for Linear Support Vector Model.
- The top row specifies Diabetic Retinopathy, where 41 out of 45 images were correctly categorized, with an accuracy rating of 91%.
- Bottom row specifies the healthy category where 14 out of 15 were categorized correctly with an accuracy rating of 93%.
- Which gave an average accuracy of 92%.



Algorithm Improvement Test Matrix 2

- Confusion matrix for Linear Support Vector Model, that shows true positive and false negative rates.
- For Diabetic retinopathy the true positive rate was 91% and false negative rate was 9%.
- For Healthy the true positive rate was 93% and false negative rate was 7%.



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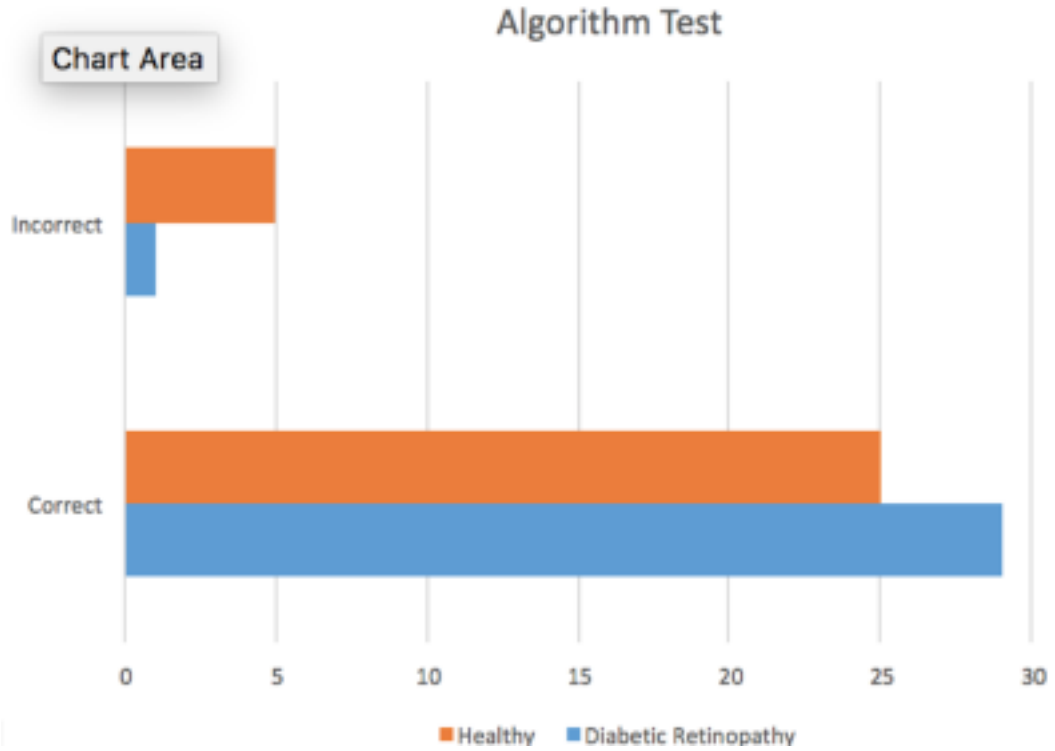
Algorithm Accuracy Test Graph

- Blue bar is Diabetic Retinopathy and orange is Healthy.
- Tested 30 images with Diabetic Retinopathy, and was given 29 correct results.
- Resulted in a 3% False negative rate.
- Tested 30 Healthy Images and was given 25 correct results.
- Resulted in a 17% False negative rate.



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Automation Test

```
%% Acquire image frame from webcam and save it to a file

webcamlist %Shows the list of webcams connected to the computer
cam = webcam('FaceTime HD Camera') %Connects it to the camera connected to device.
cam.AvailableResolutions %Displays available resolution
% This for loop is to take multiple images using the snapshot function.
count=0;
for i = 1:2

    img = snapshot(cam); %Takes a snapshot
    imshow(img);         %Shows the snapshot
    saveas(gcf,'Test.tif'); %Lets you choose where to save your image snapshots.
    count=count+1; % Addresses the counter and makes it so it adds one each time we go through the loop
    if count<2  %Makes sure the count does not grow larger than 2
        continue %If it is less than two then it continues and takes an image and chooses where to save
    else
    end %Other wise it ends the for loop
    clear cam %clears the cam  so it can be used again.
    pic = imread(fullfile('P.R.E.S.D.','Test.tif'));  %Selects image to look at.
    [labelIdx, scores] = predict(classifier, pic);  %Check the image and classify it into either Diabet
    classifier.Labels(labelIdx) %Shows the label for the image on the display.


end
```

- Code used in order to automate our program.
- Written in MATLAB and utilizes our machine learning algorithm.