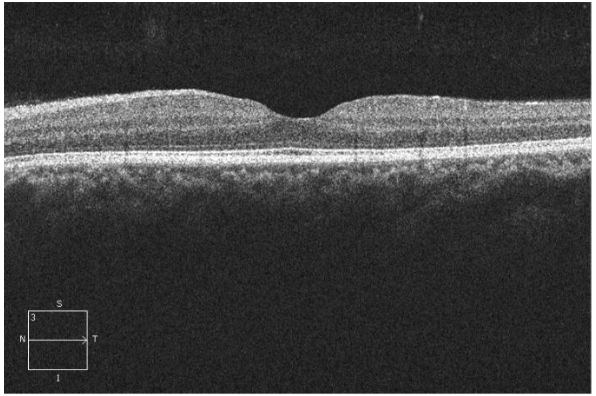
Identification of Age-related Macular Degeneration among Retinal Images obtained via Optical Coherence Tomography

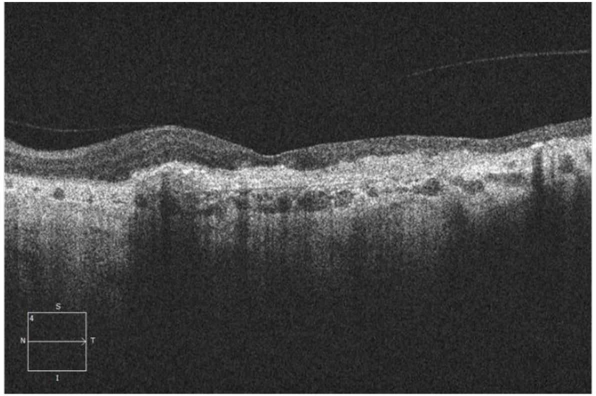
By Rami Dabit and Terry Wang

Background

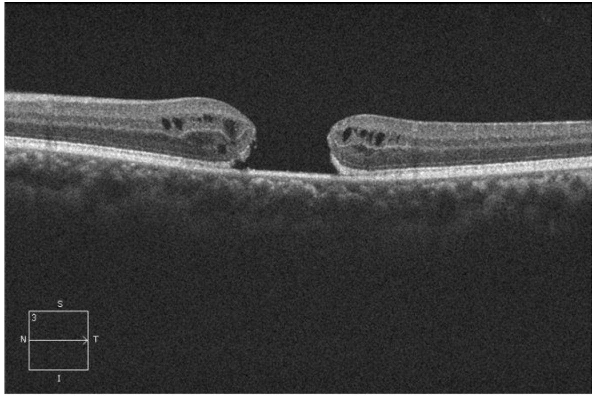
- Age-related macular degeneration (AMD) is an eye disease and leading cause of vision loss for older adults
- AMD affects approximately 1-in-10 Americans aged 50+



(i) Healthy Retina



(ii) Retina with AMD



(iii) Retina with Macular Hole

Image credits: Bionic Vision Lab @ UCSB

Background

- Optical Coherence Tomography introduced in 1991
  - Widely used imaging modality which bounces light waves at different depths within the eye to reconstruct a profile or slice
- Limited literature available on AMD identification given retinal OCT image slices: one paper on Google Scholar
  - "Identification of age-related macular degeneration using oct images." by Arabi et al. (2018)

Literature for Landmark Extraction

Arabi et al. (2018)

- Apply Gaussian filter to grayscale OCT images
- Enhance via contrast stretching
- Threshold retinal foreground from darker background
- Divide image into 8 sub-images or quadrants, and classify based on the mean pixel value in each

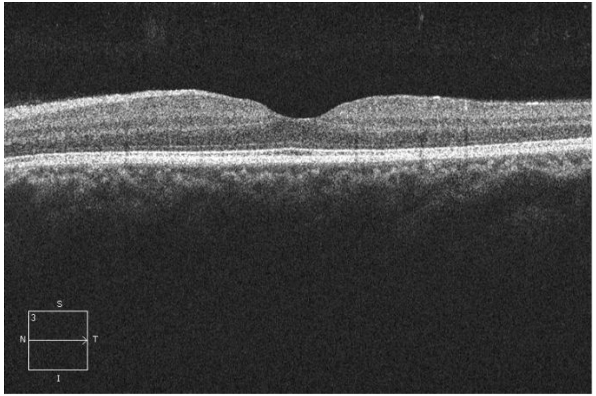
Ghesu et al. (2016)

- "An artificial agent for anatomical landmark detection in medical images."
- Reinforcement learning for image parsing with feature extraction via deep learning
- Not well suited for retinal scans such as macular hole, which include discontinuities

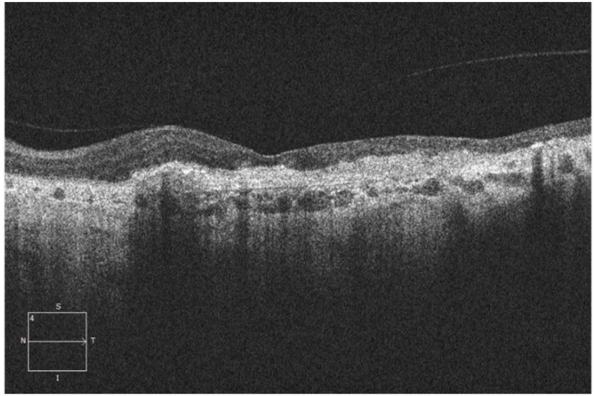
Question and Approach

- Given some sets of **retinal OCT image data**, is it possible to computationally aid ophthalmologists in tasks such as identification of age-related macular degeneration using anatomical **landmark detection** and **shape analysis**?
- Our approach: extract and analyze the inner and outer segment junction or IS/OS line for each retinal image to characterize unhealthy scans

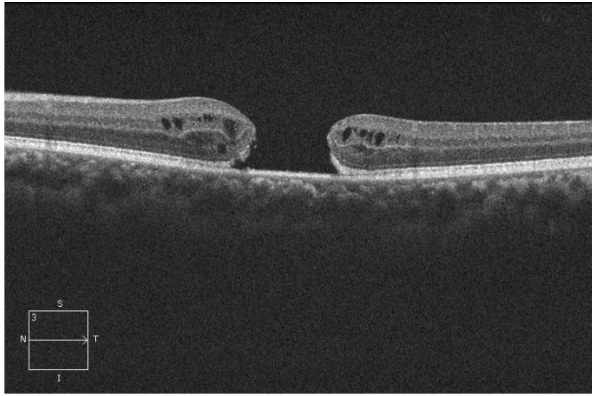
Inner and Outer Segment Junction



(i) Healthy Retina



(ii) Retina with AMD



(iii) Retina with Macular Hole

Image credits: Bionic Vision Lab @ UCSB

I. Preprocessing

- Read in 3 datasets from OCTID corresponding to healthy adult retinas (206), retinas with AMD (55), and retinas with a macular hole (102).
  - Total dataset size of 363 images

- Resize images from the AMD dataset to 750x500
- Remove dark background from images to enhance visibility of the retina shape and convert from BGR to RGB

II. IS/OS Line Extraction

- Inner/outer segment of photoreceptors may be disturbed, indicating AMD or presence of a macular hole
  - Extract as an anatomical landmark using OpenCV

- Convert RGB images to grayscale and use a binary threshold to detect any “hyper-reflective” bands
- Iterate through the detected contours and compute the area of the band, extracting only the contour with maximum area

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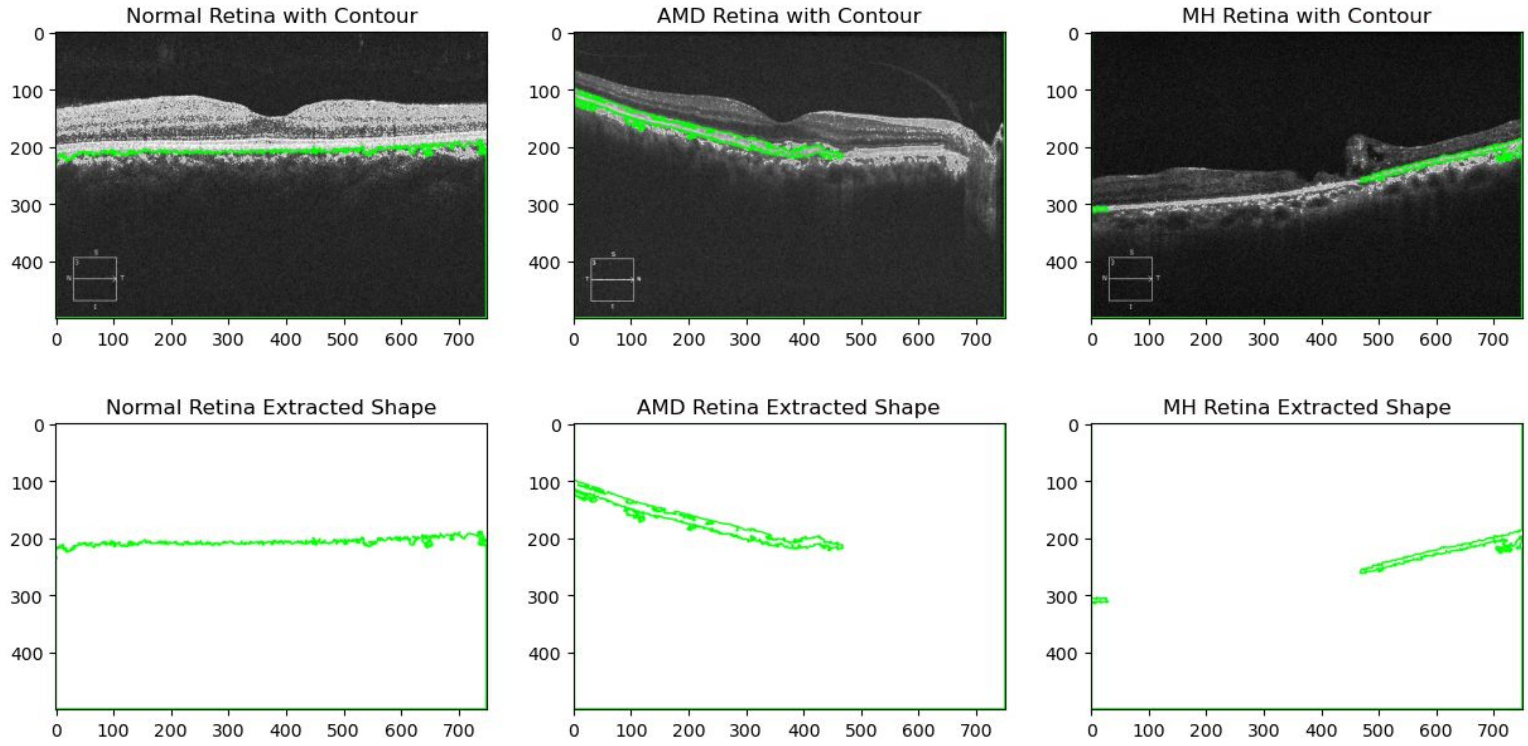
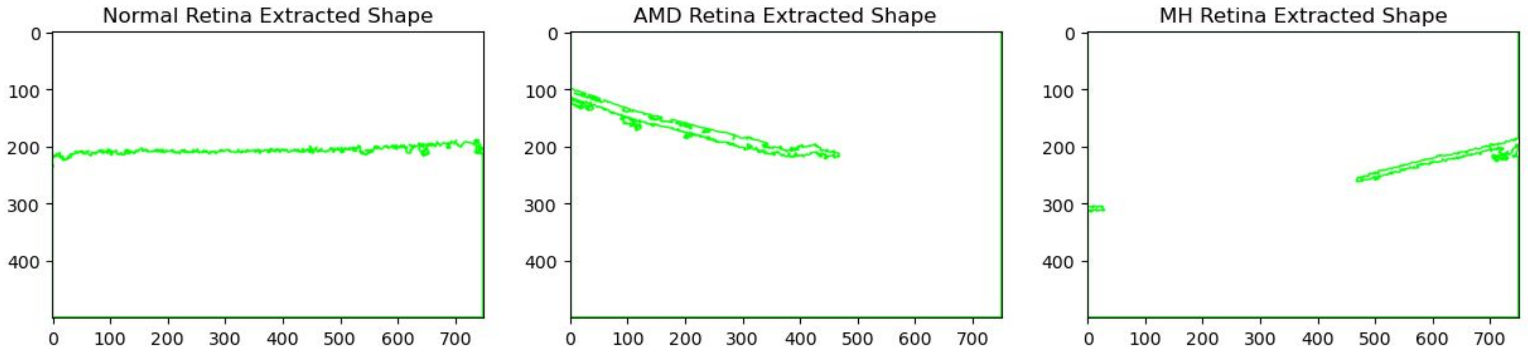
II. IS/OS Line Extraction



III. Shape Characteristics

- Using our own implemented algorithms, we then measure two properties of the extracted IS/OS band:
  - Average contour thickness along the line
  - Average largest length of discontinuity in contour line



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IV. Machine Learning

- Modified support vector classifier from scikit-learn library
- Two variations of SVC:
  - Classification using linear kernel
    - Find a best-fit line using normal OCT data and classify points deviating from the straight line as disturbed
  - Classification using radial basis function (RBF)
    - Point-to-point distance method using Euclidean or L_2-norm between point pairs, classifying distant points as belonging to different classes: $K(X_1, X_2) = exp(-\frac{||X_1 - X_2||^2}{2\sigma^2})$

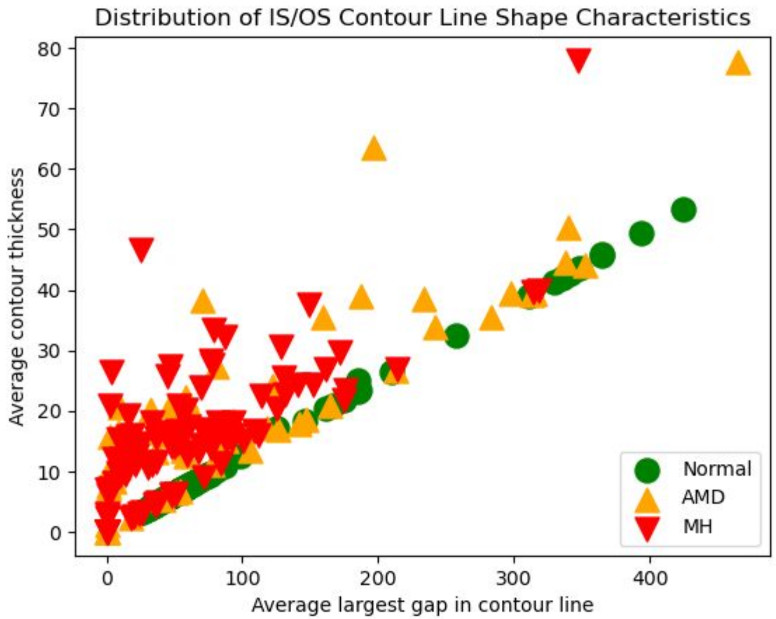
IV. Machine Learning: Input Data, Metrics

```python
# Pack our desired tolerance values into a tuple
tolerance = (tol_top, tol_bot, tol_left, tol_right)

# Perform the aforementioned steps across the entire dataset
coords_normal, coords_amd, coords_mh = metrics.get_metrics(images_normal, images_amd, images_mh, tolerance)

print('Number of normal points: ' + str(len(coords_normal)))
print('Number of AMD points: ' + str(len(coords_amd)))
print('Number of MH points: ' + str(len(coords_mh)))
```

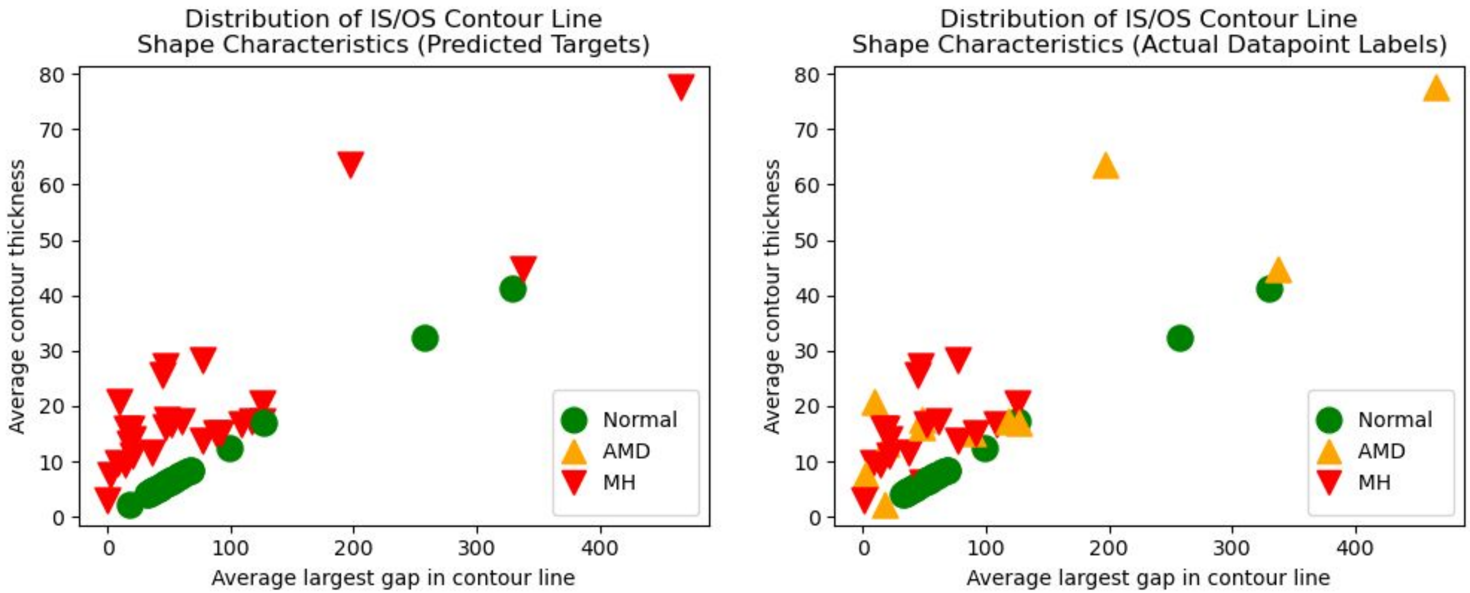
```
Number of normal points: 206
Number of AMD points: 55
Number of MH points: 102
```



- 363 total labeled images
- Train on 80% of datapoints, reserve 20% for testing

V. Results: Learning via Linear SVC

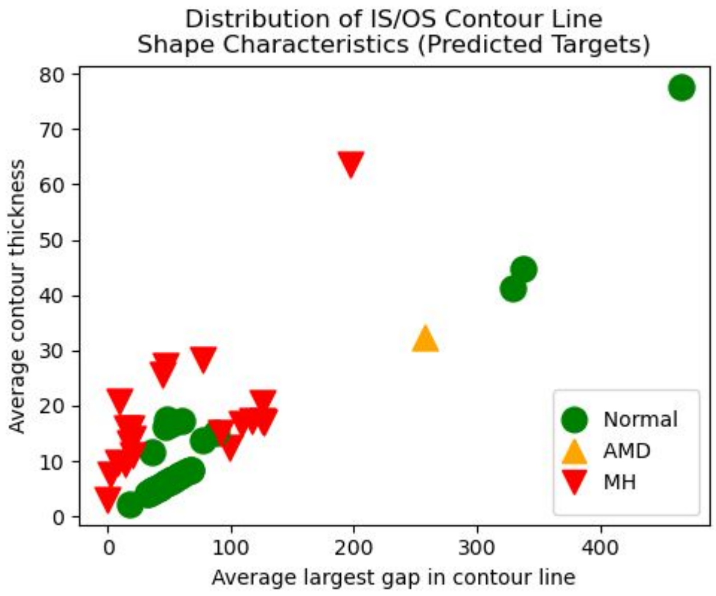
```
X_test, y_test, y_pred, accuracy = my_svc.classify_points(coords_normal, coords_amd, coords_mh, kernel='linear')
```

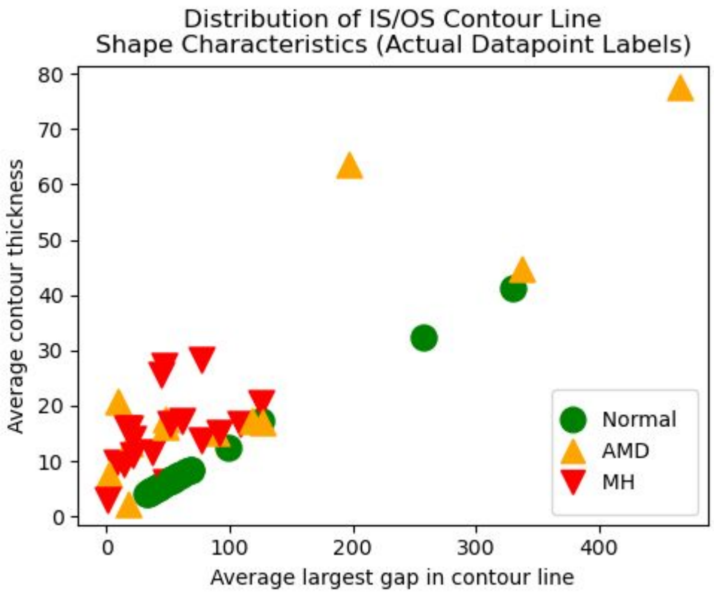



```
Accuracy of linear SVC Model: 80.82%
```

V. Results: Learning via RBF SVC

```
X_test, y_test, y_pred, accuracy = my_svc.classify_points(coords_normal, coords_amd, coords_mh, kernel='rbf')
```





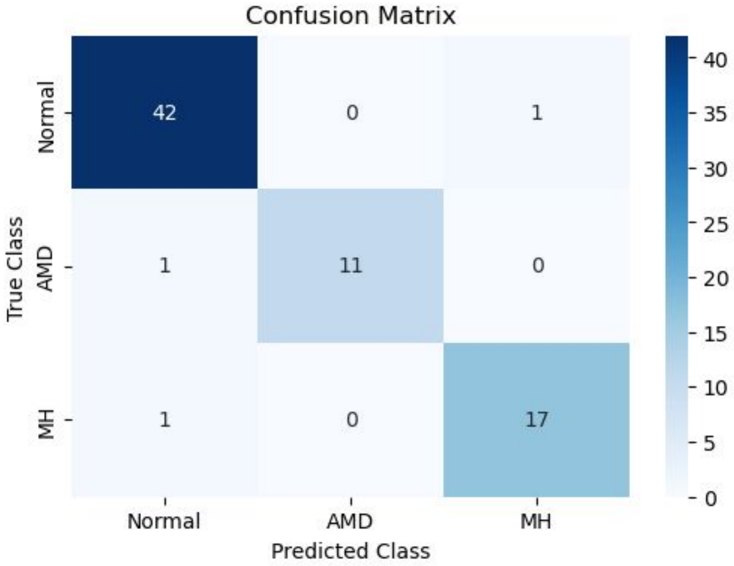

```
Accuracy of RBF SVC Model: 72.6%
```

VI. SVC Directly on Image Samples

- Alternative to classifying extracted IS/OS contour shapes
- Directly dealing with the image data
- Contains much more information for learning, considering that the IS/OS layer is one of 10 layers present in the retina

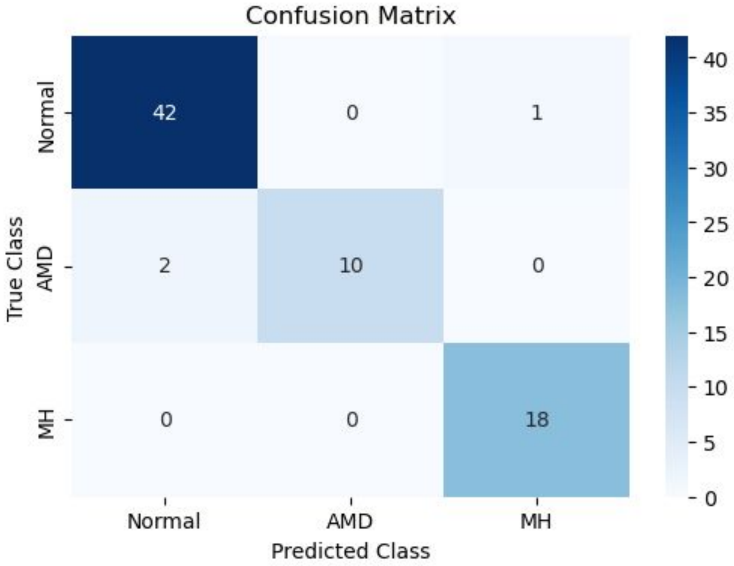
VI. Results: SVC Directly on Image Samples

Linear kernel:




```
Accuracy of linear SVC Model: 95.89%
```

RBF kernel:




```
Accuracy of RBF SVC Model: 95.89%
```

VII. Future Directions

- Try landmark extraction via reinforcement learning as proposed by Ghesu et al. (2016)
  - IS/OS contours are far from perfect, and more layers of the retina may be extracted for better classification results
- Refine our implemented algorithms which compute thickness and discontinuity in the IS/OS shape
- Explore other landmarks such as large quantities of drusen or cellular debris deposits underneath the retina
  - Indicator of high risk for macular disease

References

[1] Arabi, Punal M., Nanditha Krishna, V. Ashwini, and H. M. Prathibha. "Identification of age-related macular degeneration using oct images." In *IOP Conference Series: Materials Science and Engineering,* vol. 310, no. 1, p. 012096. IOP Publishing, 2018.

[2] Ghesu, Florin C., Bogdan Georgescu, Tommaso Mansi, Dominik Neumann, Joachim Hornegger, and Dorin Comaniciu. "An artificial agent for anatomical landmark detection in medical images." In *Medical Image Computing and Computer-Assisted Intervention-MICCAI 2016: 19th International Conference, Athens, Greece, October 17-21, 2016, Proceedings, Part III 19,* pp. 229-237. Springer International Publishing, 2016.

[3] Gholami, Peyman; Roy, Priyanka; Lakshminarayanan, Vasudevan, 2018, "Normal Retinal OCT images", https://doi.org/10.5683/SP/WLW4ZT, Borealis, V1

[4] Gholami, Peyman; Roy, Priyanka; Lakshminarayanan, Vasudevan, 2018, "Age-related Macular Degeneration Retinal OCT images", https://doi.org/10.5683/SP/YEM3RA, Borealis, V1

[5] Gholami, Peyman; Roy, Priyanka; Lakshminarayanan, Vasudevan, 2018, "Macular Hole Retinal OCT images", https://doi.org/10.5683/SP/MBMQGD, Borealis, V1

Thank you!

Questions?