Skin Cancer Lesion Image Classification

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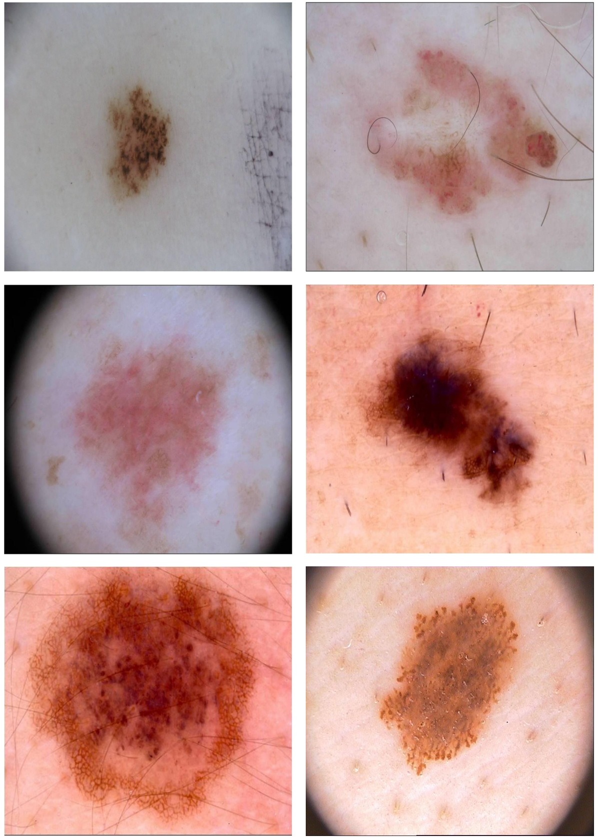
Introduction

- Skin cancer is among the most common cancers globally, early detection is crucial for effective treatment.
- We leverage computer vision and Machine Learning techniques to support dermatological assessment and diagnosis.



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Dataset: ISIC 2019 Challenge dataset

Class Name	Class Label	Training Dataset	Resampled Training
Melanocytic Nevus	NV	12876	1000
Melanoma	MEL	4522	1000
Basal Cell Carcinoma	BCC	3323	1000
Benign Keratosis	BKL	2624	1000
Actinic Keratosis	AK	867	1000
Squamous Cell Carcinoma	SCC	628	1000
Vascular Lesion	VASC	253	1000
Dermatofibroma	DF	239	1000

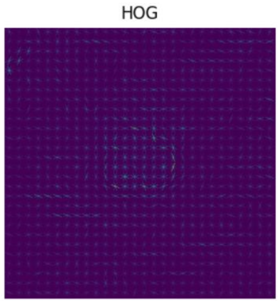
- **25,331** images for **training**
- **6,091** images for **testing**,
- **8 diagnostic categories**.
- Resolution: **450×450** to **6000×4000** pixels
- Channels: **RGB**
- Compression: **JPEG**
- Variations:
  - Lighting,
  - Skin tone,
  - Vignettes,
  - Artifacts (hairs, rulers)

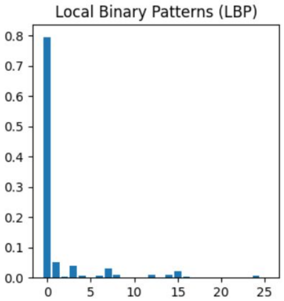
Feature Selection

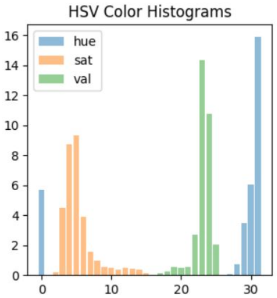
Feature	Melanoma	Carcinoma	Vascular Lesion	Nevus
Asymmetry	✔️ High	✔️ Moderate	❌ Rare	❌ Absent
Border Irregularity	✔️ High	✔️ Possible	❌ Usually smooth	❌ Absent
Color Variation	✔️ Significant	❌ Minimal	✔️ Distinct (red/purple)	❌ Minimal
Texture Variation	✔️ Significant	✔️ Possible	❌ Homogeneous	❌ Absent
Specific Dermoscopic Signs	✔️ Pigment network, veil, streaks	✔️ Telangiectasia, keratin)	✔️ (Lacunae, vessels)	✔️ (Regular patterns)
Growth Pattern	✔️ Rapid	✔️ Variable	✔️ Can be fast	❌ Stable

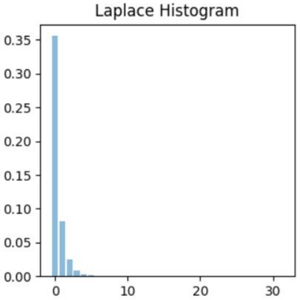
- **Edges & Gradients:**
  - HOG
  - Laplacian
- **Texture and Patterns:**
  - Local Binary Pattern (LBP)
  - GLCM
  - Wavelet decomposition
- **Color Features:**
  - HSV color histograms
  - HSV metrics (mean, std, entropy)
  - HSV contrast
- **Shape Features:**
  - Circularity
  - Eccentricity
  - Convexity

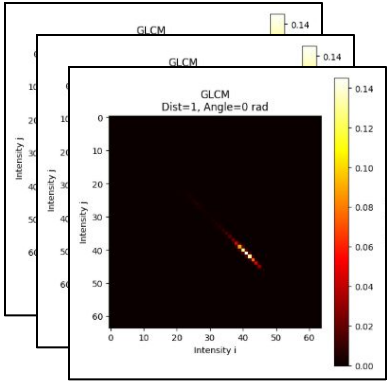
Feature Examples











GLCM Metrics

	contrast	dissimilarity	homogeneity	energy	correlation	ASM
0	0.660124	0.386805	0.823111	0.241315	0.993136	0.058233

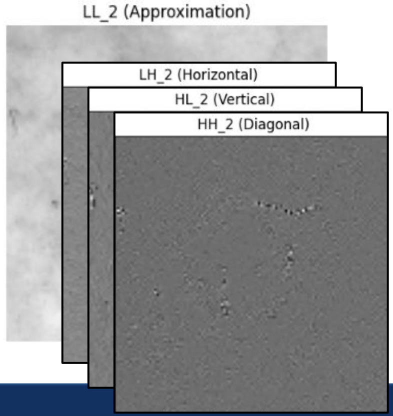
Shape Metrics

	circularity	eccentricity	convexity
6154	0.623895	0.475786	0.83546

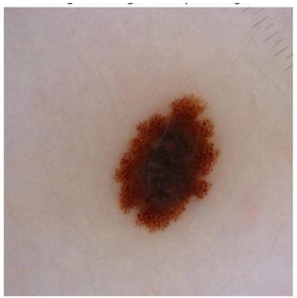
HSV Metrics

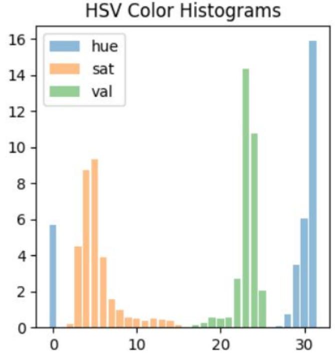
	Mean	Std	Entropy	Contrast
h	168.756804	1.860798	0.489277	4.661649
s	196.234163	24.350305	0.785036	77.135967
v	164.716464	12.689486	0.713761	25.926955

Wavelet



Feature Extraction - Color & Shape Metrics

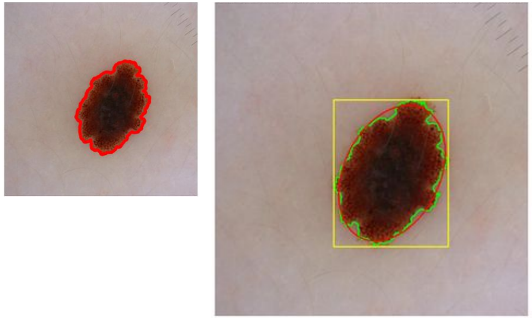




Mean	STD
h: 53.5	h: 80.63
s: 95.52	s: 15.64
v: 165.16	v: 13.4

Entropy	Contrast
h: 0.49	h: 39.27
s: 0.74	s: 31.44
v: 0.71	v: 19.85

Contrast Magnitude: 54.08



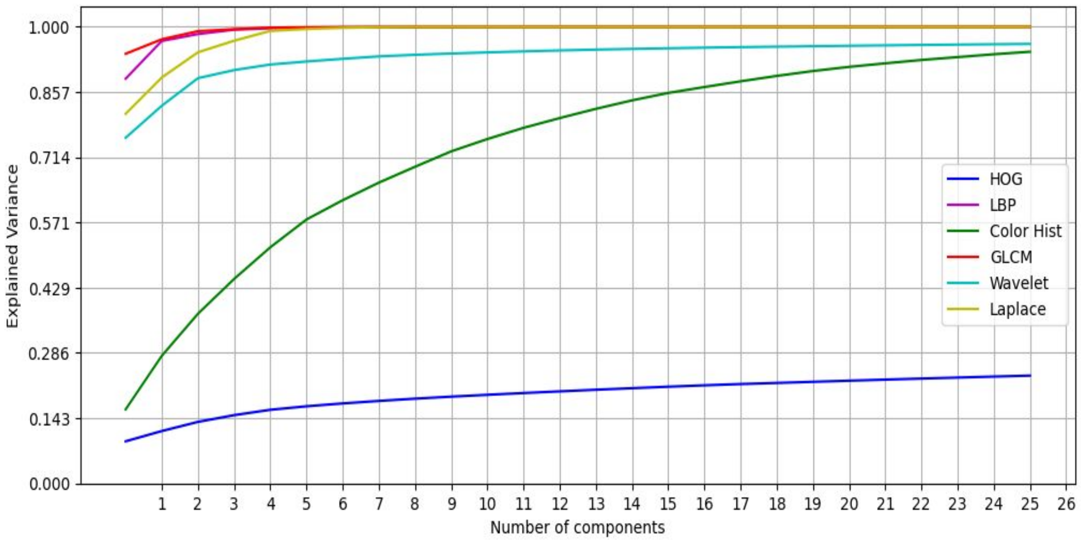
Shape Metrics

	circularity	eccentricity	convexity
2634	0.426892	0.343492	0.707103

Dimensionality Reduction

For each feature, we identified the optimal number of components by two methods.

- **Cumulative Variance:** The number of components is the one that reaches a cumulative variance of 95% of the total variance.
- **Cross Validation:** The number of components that returns the best cross-validation score when fitting a logistic regression to the data.



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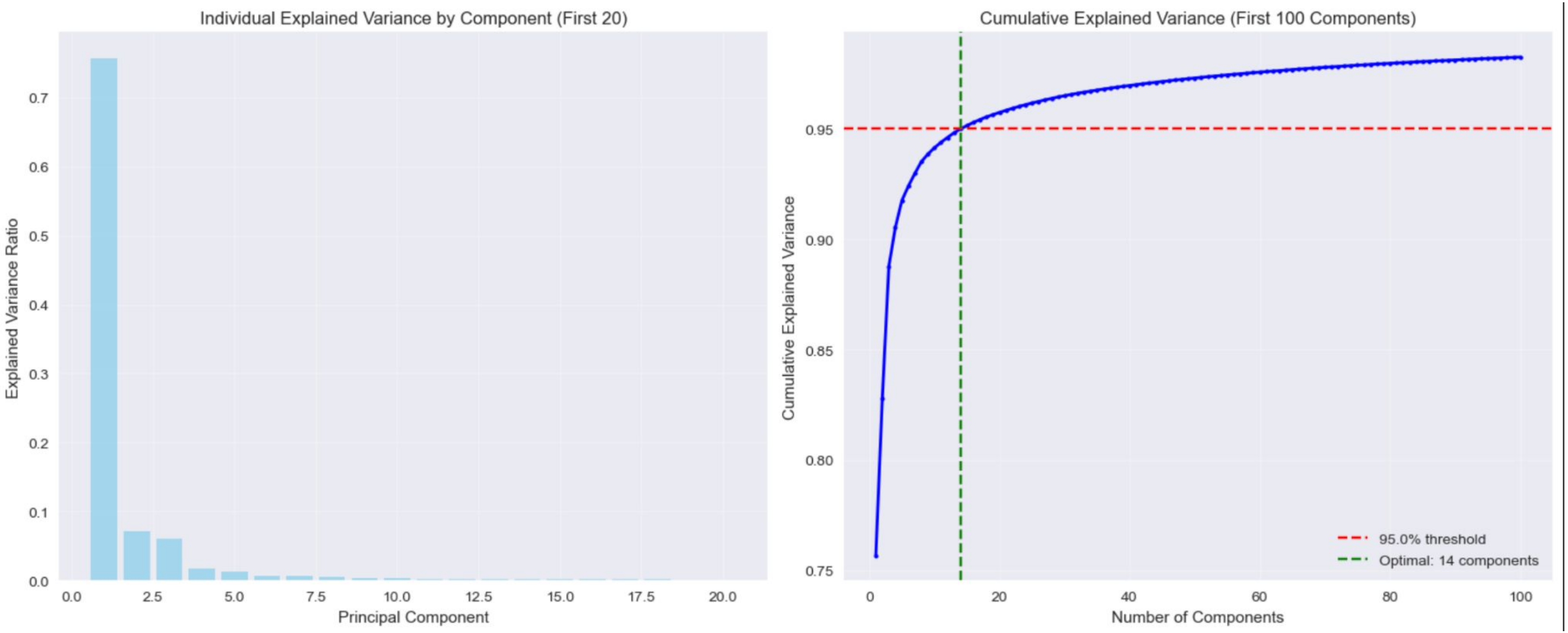
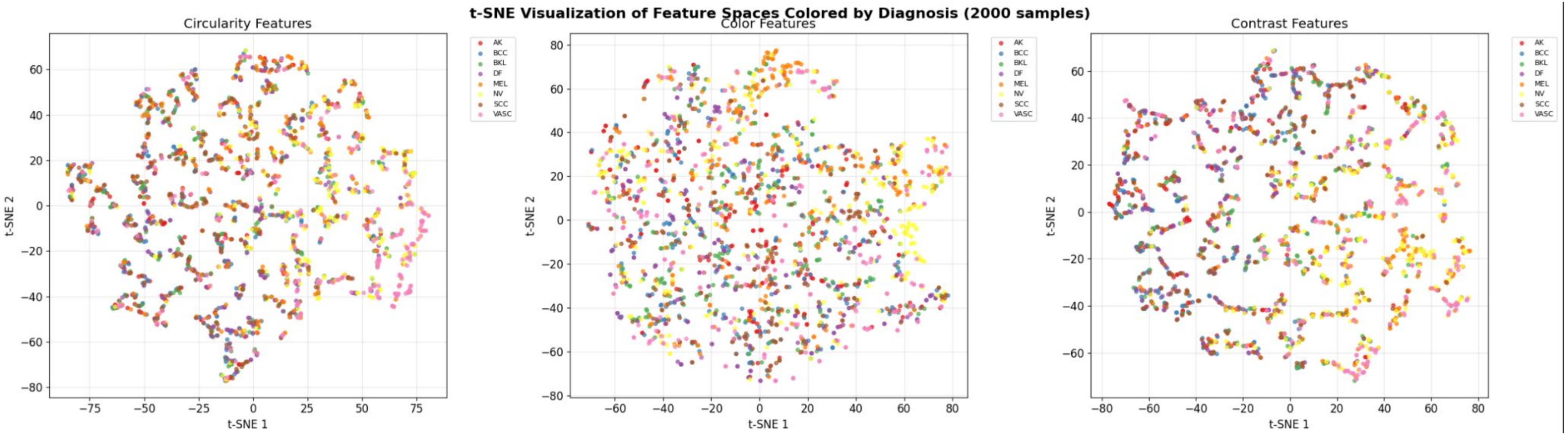
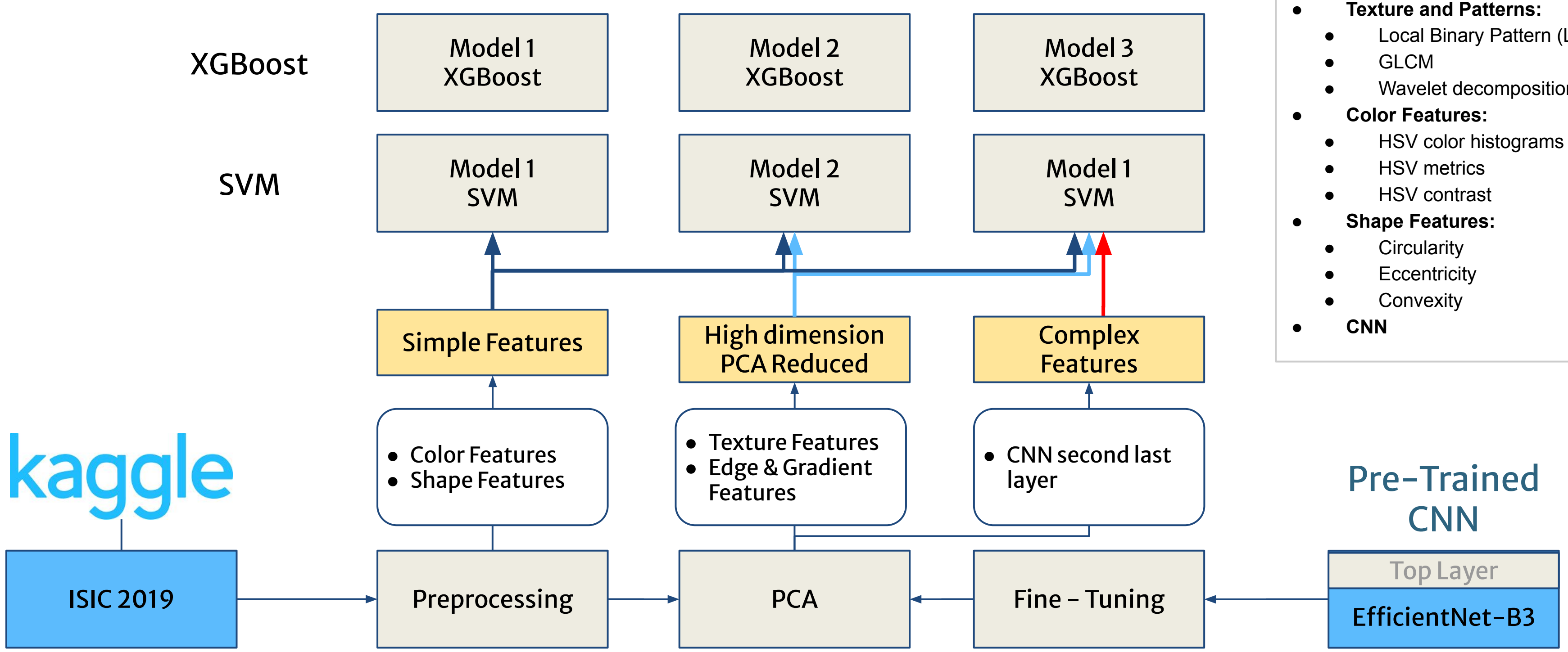
PCA Reduction - Wavelet (from 1,000 to 14)



t-SNE Visualization



Modeling

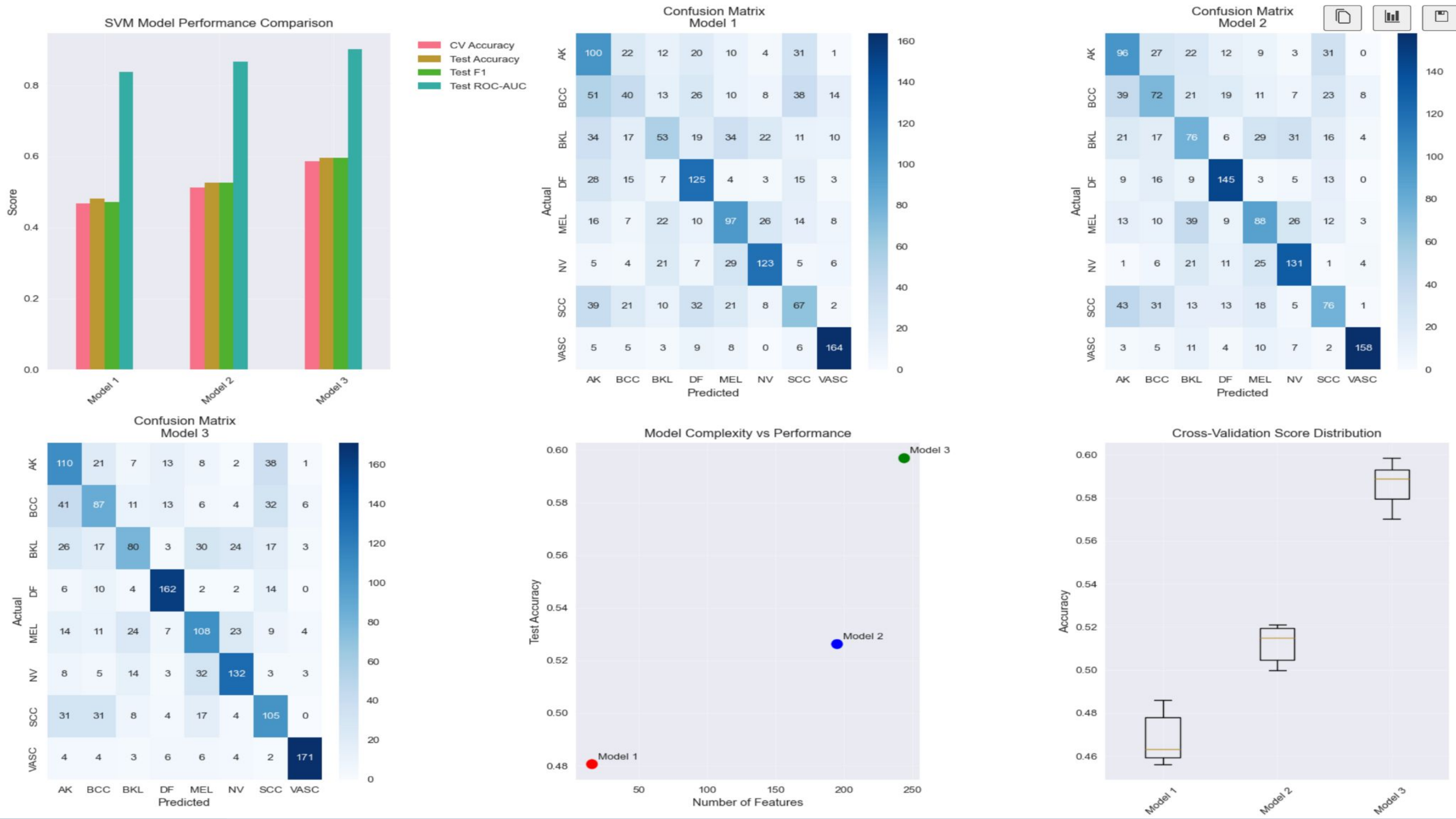


Features Summary

- **Edges & Gradients:**
  - HOG
  - Laplacian
- **Texture and Patterns:**
  - Local Binary Pattern (LBP)
  - GLCM
  - Wavelet decomposition
- **Color Features:**
  - HSV color histograms
  - HSV metrics
  - HSV contrast
- **Shape Features:**
  - Circularity
  - Eccentricity
  - Convexity
- **CNN**

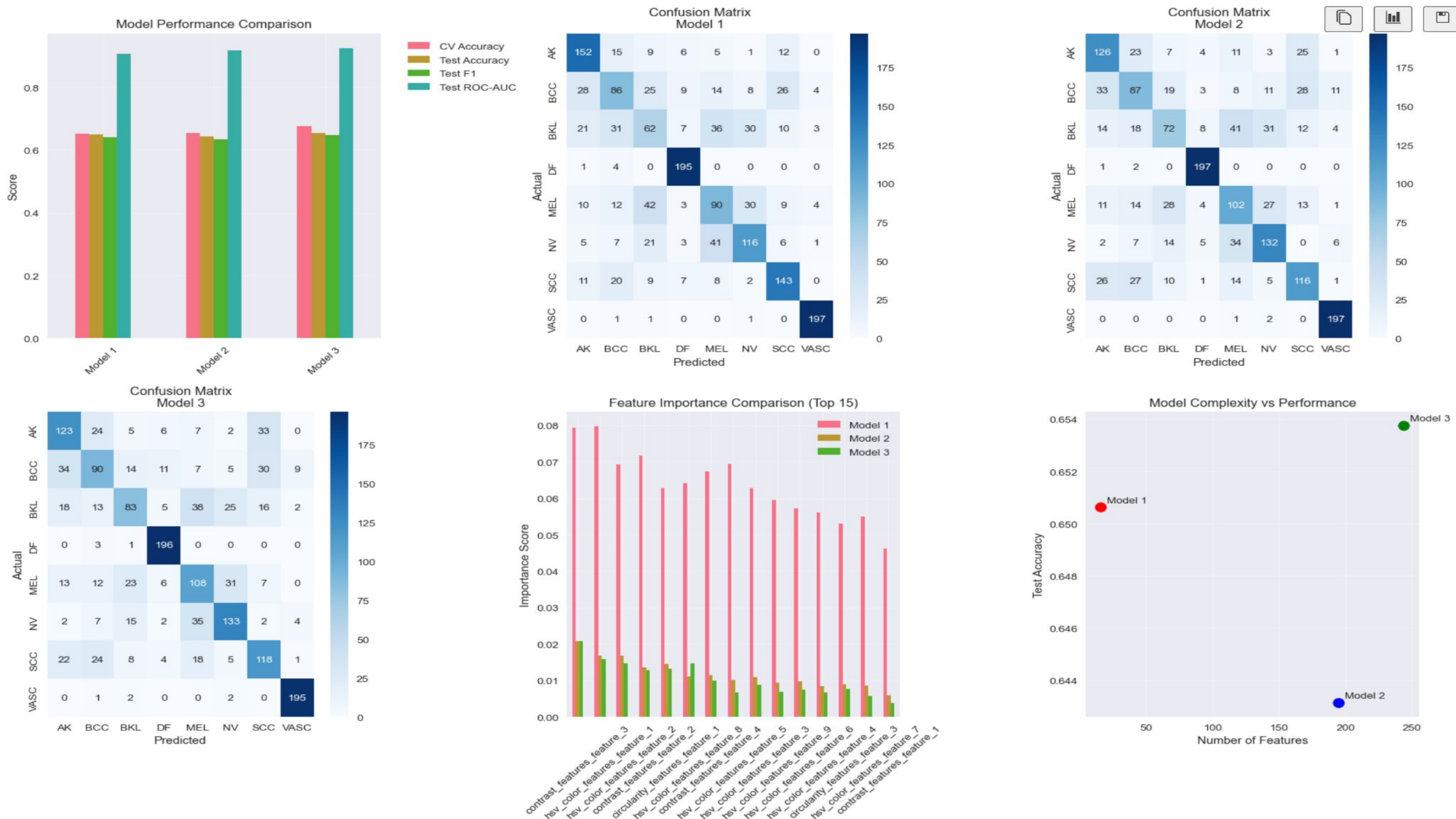
Model Performance - SVM

```
================================================================================
DETAILED SVM MODEL COMPARISON
================================================================================
  Model   Features      CV Accuracy Test Accuracy Test F1 Test ROC-AUC
Model 1         16 0.4686 ± 0.0115        0.4806  0.4717       0.8371
Model 2        195 0.5120 ± 0.0083        0.5262  0.5262       0.8659
Model 3        244 0.5861 ± 0.0100        0.5969  0.5966       0.9018

Best performing SVM model: Model 3 (All features)
Test accuracy: 0.5969
```


SVM Model Performance Comparison
CV Accuracy
Test Accuracy
Test F1
Test ROC-AUC
Score
0.0
0.2
0.4
0.6
0.8
Model 1
Model 2
Model 3
Confusion Matrix
Model 1
Actual
Predicted
AK BCC BKL DF MEL NV SCC VASC
AK 100 22 12 20 10 4 31 1
BCC 51 40 13 26 10 8 38 14
BKL 34 17 53 19 34 22 11 10
DF 28 15 7 125 4 3 15 3
MEL 16 7 22 10 97 26 14 8
NV 5 4 21 7 29 123 5 6
SCC 39 21 10 32 21 8 67 2
VASC 5 5 3 9 8 0 6 164
0 20 40 60 80 100 120 140 160
Confusion Matrix
Model 2
Actual
Predicted
AK BCC BKL DF MEL NV SCC VASC
AK 96 27 22 12 9 3 31 0
BCC 39 72 21 19 11 7 23 8
BKL 21 17 76 6 29 31 16 4
DF 9 16 9 145 3 5 13 0
MEL 13 10 39 9 88 26 12 3
NV 1 6 21 11 25 131 1 4
SCC 43 31 13 13 18 5 76 1
VASC 3 5 11 4 10 7 2 158
0 20 40 60 80 100 120 140
Confusion Matrix
Model 3
Actual
Predicted
AK BCC BKL DF MEL NV SCC VASC
AK 110 21 7 13 8 2 38 1
BCC 41 87 11 13 6 4 32 6
BKL 26 17 80 3 30 24 17 3
DF 6 10 4 162 2 2 14 0
MEL 14 11 24 7 108 23 9 4
NV 8 5 14 3 32 132 3 3
SCC 31 31 8 4 17 4 105 0
VASC 4 4 3 6 6 4 2 171
0 20 40 60 80 100 120 140 160
Model Complexity vs Performance
Test Accuracy
Number of Features
Model 1
Model 2
Model 3
0.48 0.50 0.52 0.54 0.56 0.58 0.60
50 100 150 200 250
Cross-Validation Score Distribution
Accuracy
0.46 0.48 0.50 0.52 0.54 0.56 0.58 0.60
Model 1
Model 2
Model 3

Model Performance - XGBoost

```
================================================================================
DETAILED XGB MODEL COMPARISON
================================================================================
  Model   Features      CV Accuracy Test Accuracy Test F1 Test ROC-AUC
Model 1         16 0.6514 ± 0.0076        0.6506  0.6417       0.9067
Model 2        195 0.6539 ± 0.0100        0.6431  0.6349       0.9183
Model 3        244 0.6773 ± 0.0156        0.6538  0.6470       0.9250

Best performing model: Model 3 (All features)
Test accuracy: 0.6538
```

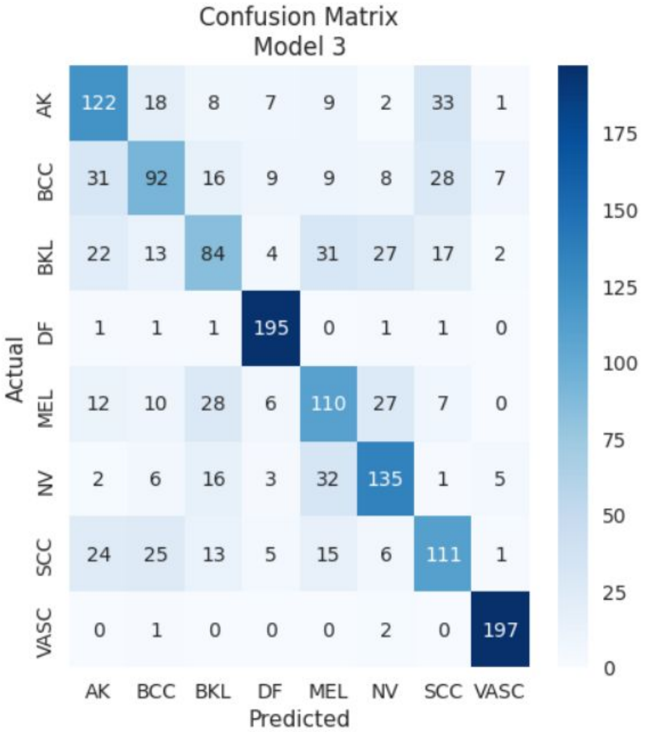


Model Performance Comparison
CV Accuracy
Test Accuracy
Test F1
Test ROC-AUC
Score
0.0
0.2
0.4
0.6
0.8
Model 1
Model 2
Model 3
Confusion Matrix
Model 1
Actual
Predicted
AK BCC BKL DF MEL NV SCC VASC
AK 152 15 9 6 5 1 12 0
BCC 28 86 25 9 14 8 26 4
BKL 21 31 62 7 36 30 10 3
DF 1 4 0 195 0 0 0 0
MEL 10 12 42 3 90 30 9 4
NV 5 7 21 3 41 116 6 1
SCC 11 20 9 7 8 2 143 0
VASC 0 1 1 0 0 1 0 197
0 25 50 75 100 125 150 175
Confusion Matrix
Model 2
Actual
Predicted
AK BCC BKL DF MEL NV SCC VASC
AK 126 23 7 4 11 3 25 1
BCC 33 87 19 3 8 11 28 11
BKL 14 18 72 8 41 31 12 4
DF 1 2 0 197 0 0 0 0
MEL 11 14 28 4 102 27 13 1
NV 2 7 14 5 34 132 0 6
SCC 26 27 10 1 14 5 116 1
VASC 0 0 0 0 1 2 0 197
0 25 50 75 100 125 150 175
Confusion Matrix
Model 3
Actual
Predicted
AK BCC BKL DF MEL NV SCC VASC
AK 123 24 5 6 7 2 33 0
BCC 34 90 14 11 7 5 30 9
BKL 18 13 83 5 38 25 16 2
DF 0 3 1 196 0 0 0 0
MEL 13 12 23 6 108 31 7 0
NV 2 7 15 2 35 133 2 4
SCC 22 24 8 4 18 5 118 1
VASC 0 1 2 0 0 2 0 195
0 25 50 75 100 125 150 175
Feature Importance Comparison (Top 15)
Model 1
Model 2
Model 3
Importance Score
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08
contrast_features_feature_3
hsv_color_features_feature_1
hsv_color_features_feature_2
contrast_features_feature_2
circularity_features_feature_1
hsv_color_features_feature_8
contrast_features_feature_4
hsv_color_features_feature_5
hsv_color_features_feature_3
hsv_color_features_feature_9
hsv_color_features_feature_6
circularity_features_feature_4
hsv_color_features_feature_3
hsv_color_features_feature_7
contrast_features_feature_1
Model Complexity vs Performance
Model 1
Model 2
Model 3
Test Accuracy
0.644 0.646 0.648 0.650 0.652 0.654
Number of Features
50 100 150 200 250

Best Performance Model - XGBoost Model 3

Features : 244
Accuracy : 0.6538
F1 : 0.6470
ROC-AUC : 0.9255

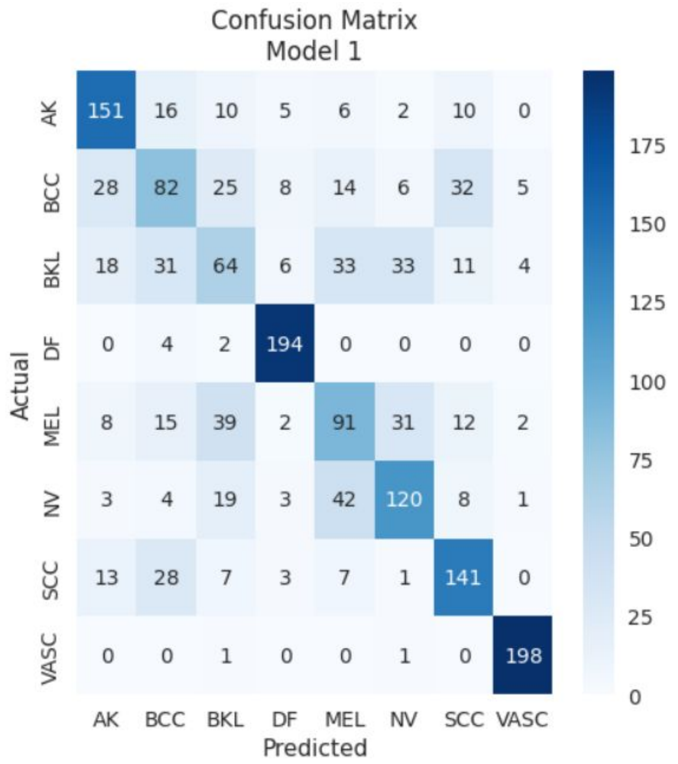
	Class	Recall	Precision	Accuracy	F1
Actinic Keratosis	AK	0.7000	0.6422	0.9138	0.6699
Basal Cell Carcinoma	BCC	0.4950	0.5789	0.8919	0.5337
Benign Keratosis	BKL	0.4600	0.5644	0.8881	0.5069
Dermatofibroma	DF	1.0000	0.8696	0.9813	0.9302
Melanoma	MEL	0.5450	0.5533	0.8881	0.5491
Melanocytic Nevus	NV	0.6950	0.6814	0.9213	0.6881
Squamous Cell Carcinoma	SCC	0.6600	0.6600	0.9150	0.6600
Vascular Lesion	VASC	0.9900	0.9124	0.9869	0.9496



Best Efficiency Model - XGBoost Model 1

Features : 16
Accuracy : 0.6506
F1 : 0.6423
ROC-AUC : 0.9071

	Class	Recall	Precision	Accuracy	F1
Actinic Keratosis	AK	0.8050	0.7285	0.9381	0.7648
Basal Cell Carcinoma	BCC	0.4300	0.5150	0.8781	0.4687
Benign Keratosis	BKL	0.3550	0.4226	0.8588	0.3859
Dermatofibroma	DF	1.0000	0.9009	0.9863	0.9479
Melanoma	MEL	0.4450	0.4495	0.8625	0.4472
Melanocytic Nevus	NV	0.5850	0.6223	0.9038	0.6031
Squamous Cell Carcinoma	SCC	0.8350	0.7422	0.9431	0.7859
Vascular Lesion	VASC	1.0000	0.9479	0.9931	0.9732

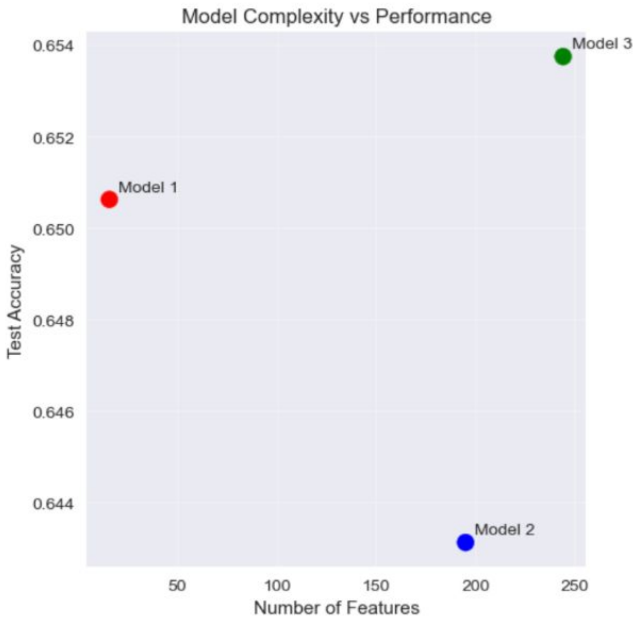


Conclusion

XGBoost models performed comparably across increasing dimensionality, and outperformed SVM models.

SVM models performed better with more complex feature sets.

Due to the high cost in compute time to fine-tune and get inferences from VGG16, and the small trade-off in performance, we would recommend using an XGBoost model with simple features, as Model 1.



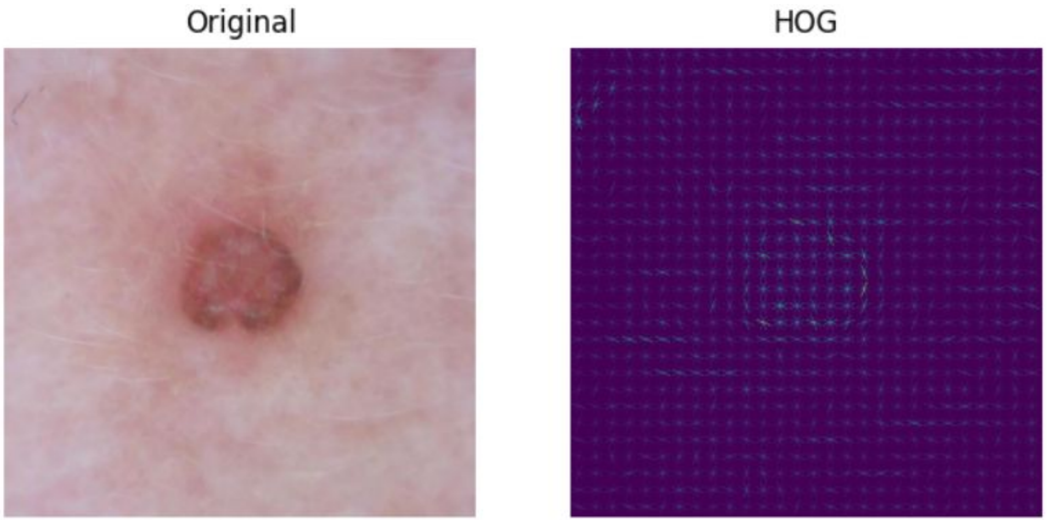
Thank You

Appendix

HOG

Hog was calculated using the following parameters:

- Orientations = 4
- Pixels per cell = 16 x 16
- Cell per block = 2 x 2
- Block Normalization Method = 'L2-Hys'

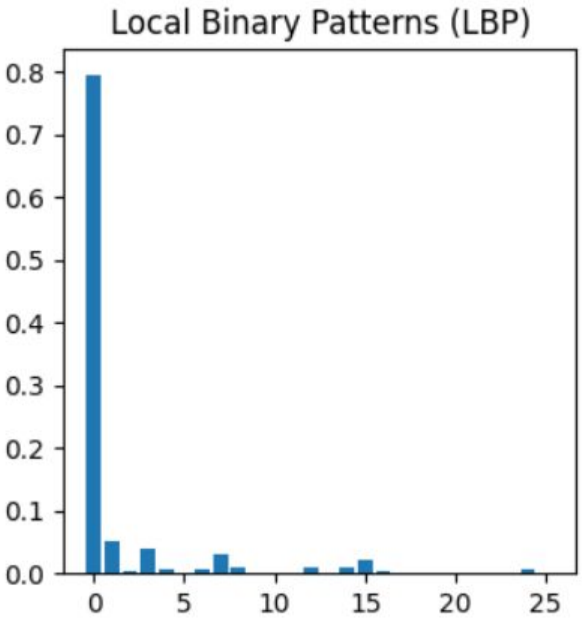


LBP

LBP was calculated using the following parameters:

- Radius = 3
- Points = 24

The graph below shows the histogram of binary patterns for the same image above.



GLCM

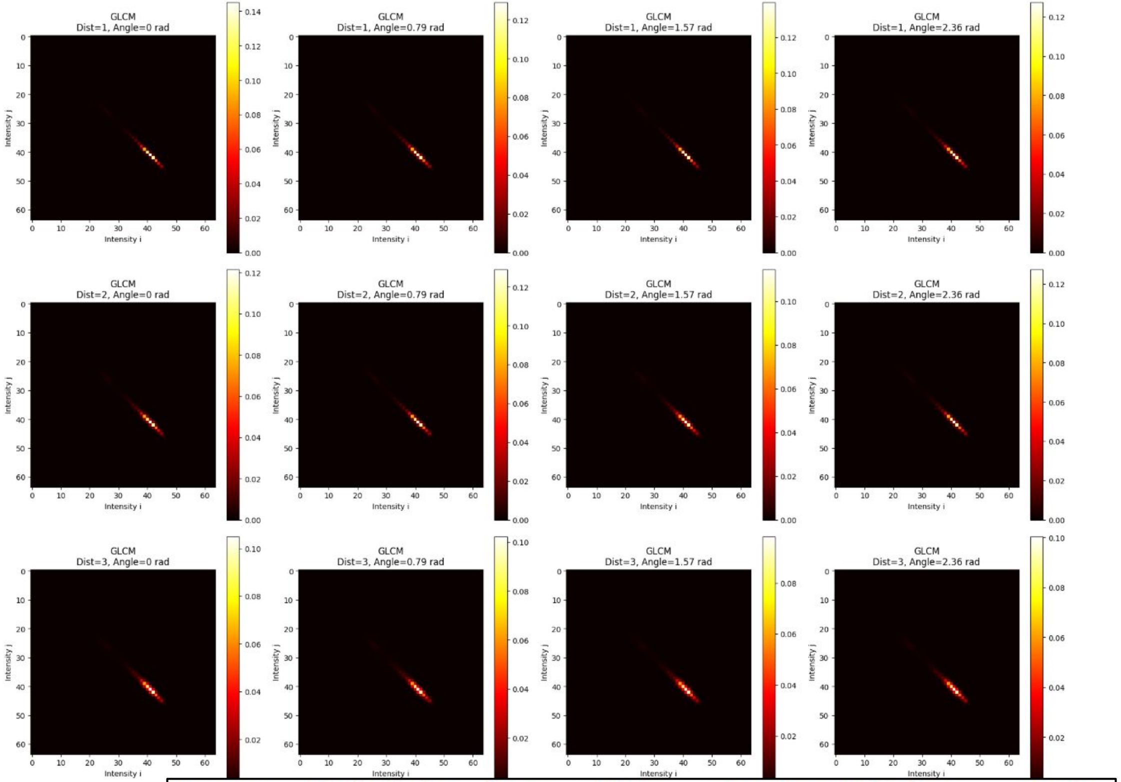
(Gray-Level Co-occurrence Matrix)

The GLCM features were extracted using the graycomatrix from the skimage package, using the following parameters:

- Distances = 1, 2, and 3.
- Angles = 0°, 45°, 90°, and 135°

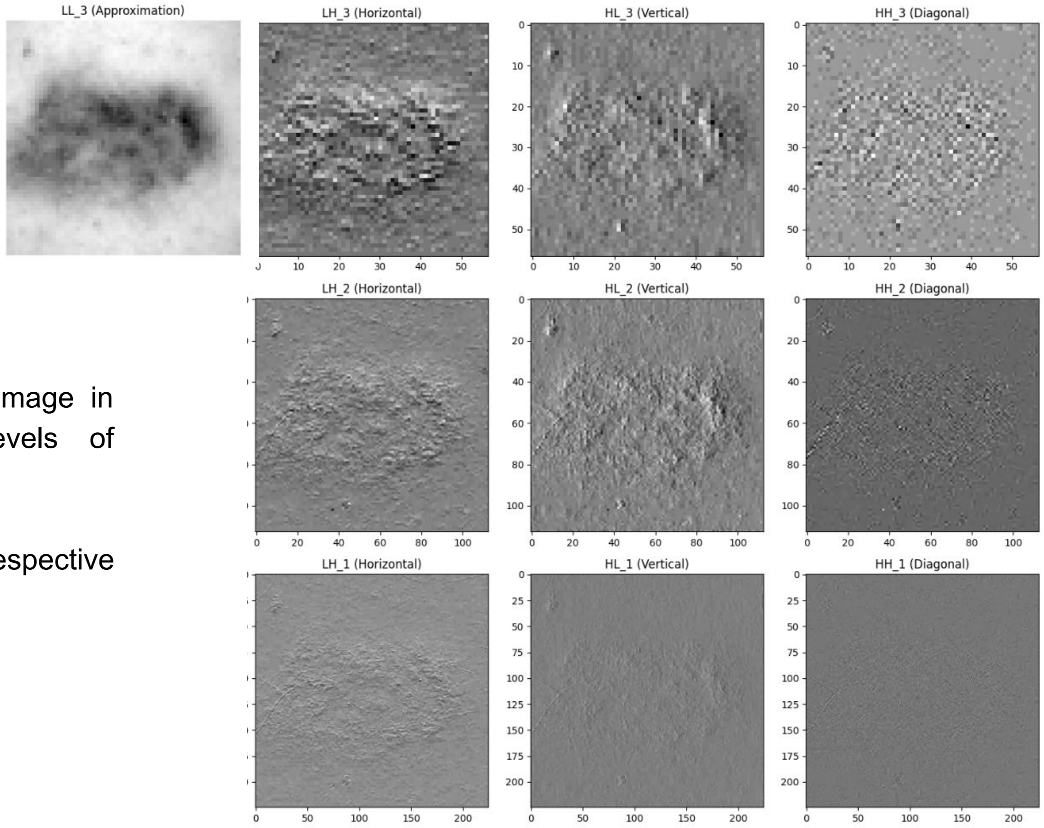
For each image we extracted the following metrics:

- Contrast
- Dissimilarity
- Homogeneity
- Energy
- Correlation
- ASM



contrast	dissimilarity	homogeneity	energy	correlation	ASM
0.232685	0.211581	0.896208	0.277081	0.993266	0.076774

Wavelet



- The Wavelet method helps to analyze the image in several frequencies, showing different levels of textures.
- For the final model we used two levels.
- Here is an example with 3 levels, and the respective LL, HL, LH, and HH filters.