

The background is a complex, layered image. It features a magnifying glass with a blue handle and frame, focusing on a document. The document has various text elements, including "CONSTITUTIONAL BUC", "XMB", "RGBS", and "XMB". There are also binary code sequences (0s and 1s) scattered throughout, particularly on the left and bottom edges. A medical device, possibly a dermoscope, is visible in the lower-left corner. The overall color palette is dominated by blues, greys, and whites, with some yellow and orange highlights from the binary code and the magnifying glass handle.

Dermatologist-level classification of skin cancer with deep neural networks

Enhancing the Expert

Andre Esteva
PI: Sebastian Thrun
Stanford University

How can technology assist a human?







A photograph of a female dermatologist with blonde hair, wearing a white lab coat over a green shirt, examining the arm of an elderly female patient. The doctor is using a magnifying glass to inspect the skin. The patient is wearing a light blue sweater and a gold watch. The background is a bright, clinical setting.

How can AI assist a dermatologist?

Skin Cancer

Skin Cancer

- 5.4M cases of non-melanoma skin cancer each year in US

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Skin Cancer

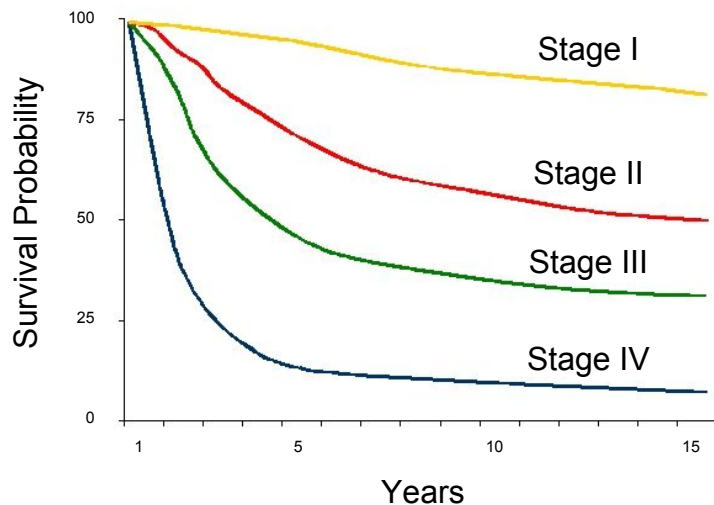
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- Actinic Keratosis (pre-cancer) affects 58 million Americans
- 76,000 melanomas each year - 10,000 deaths
- \$8.1B in US annual costs for skin cancer

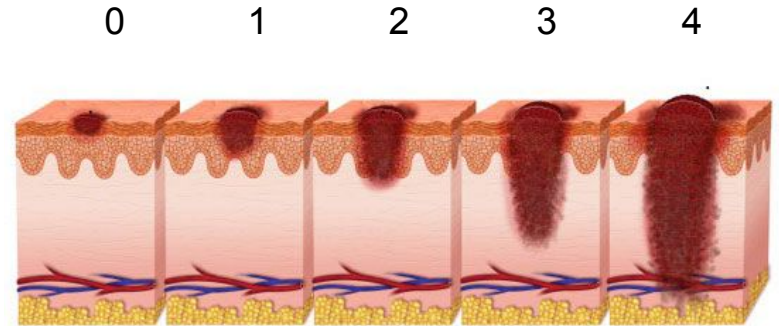
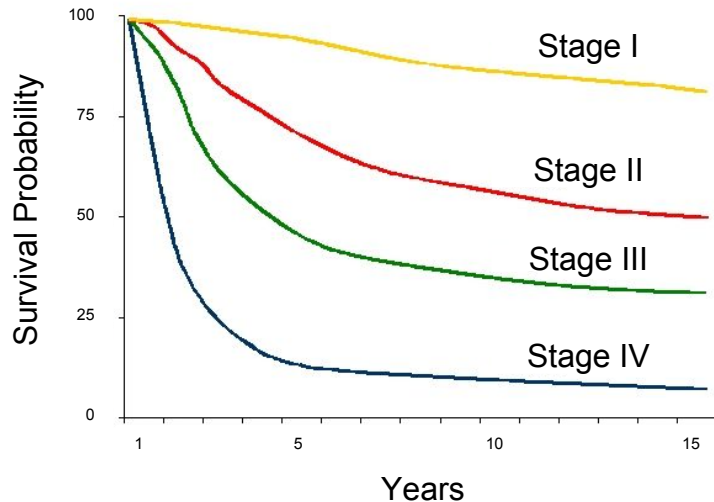
Skin Cancer

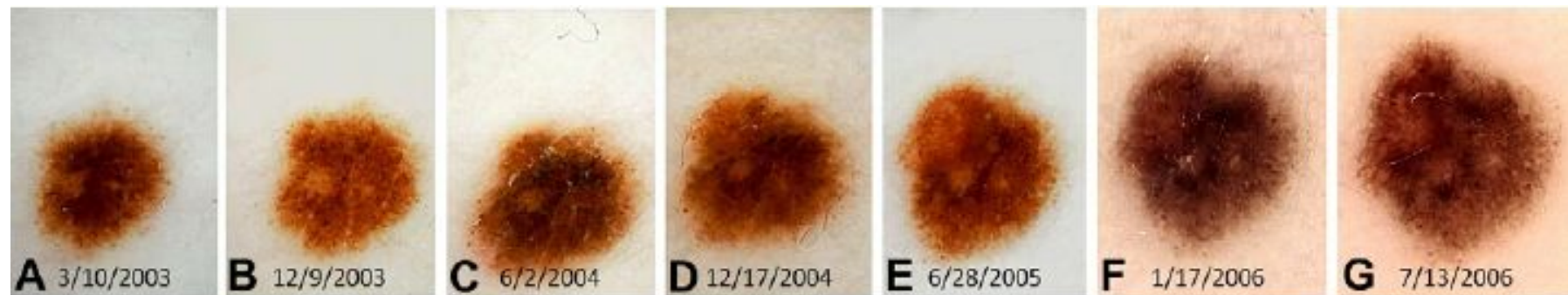
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Early detection is critical

6.3 billion smartphones

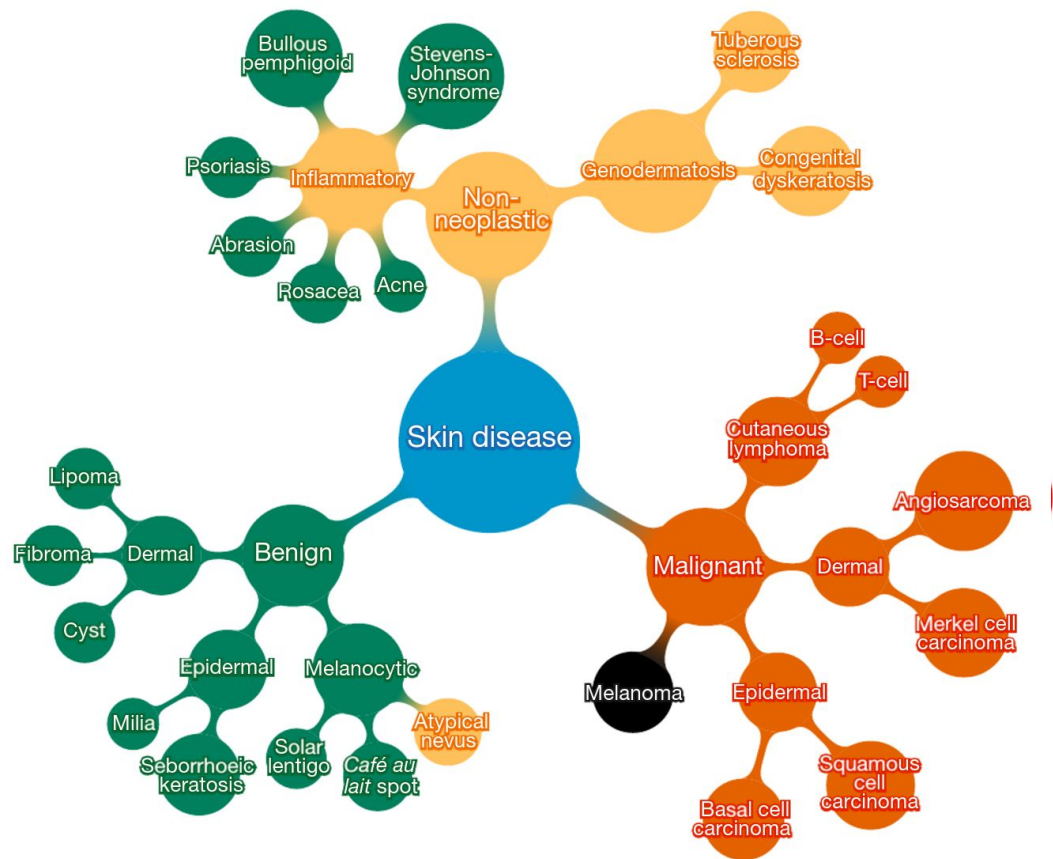
Skin Cancer Classification

Skin Cancer Classification

~130,000 images of skin

2000 diseases

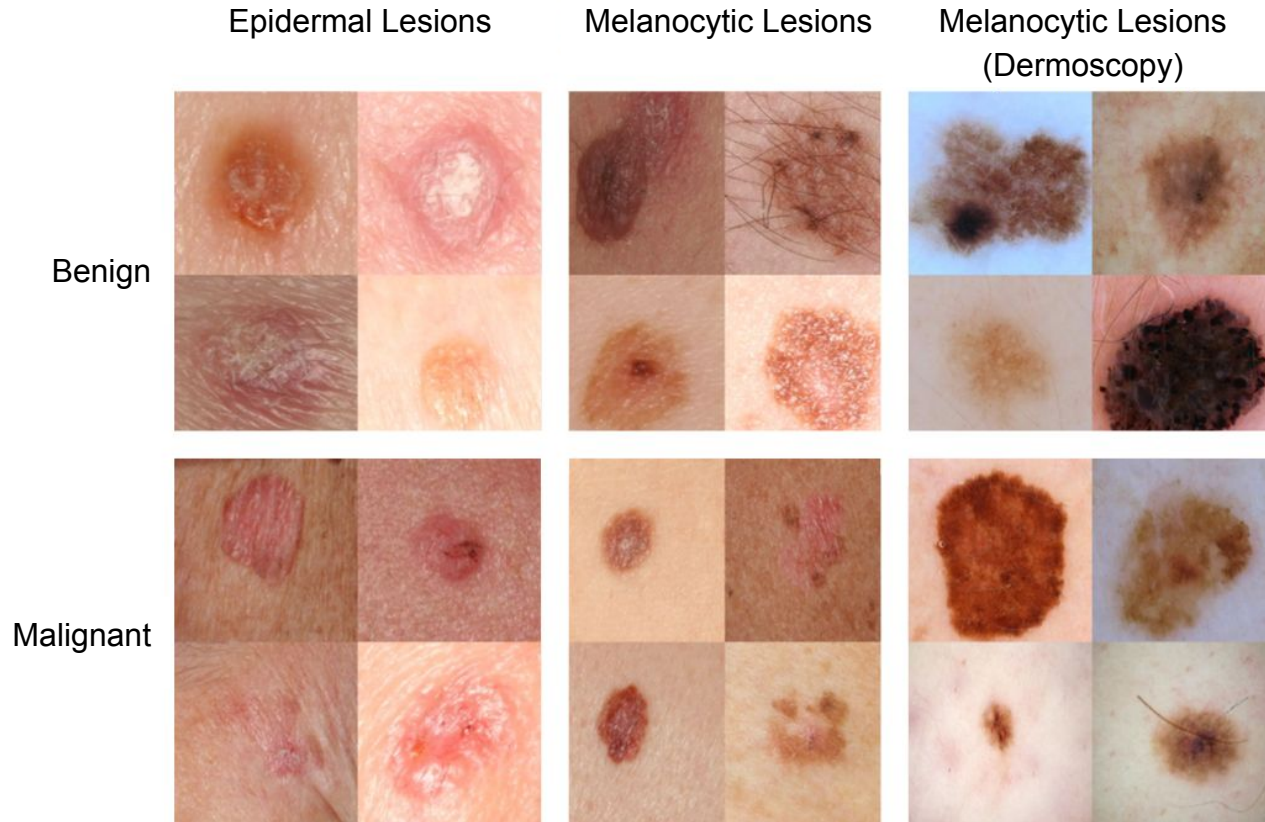
Skin Cancer Classification



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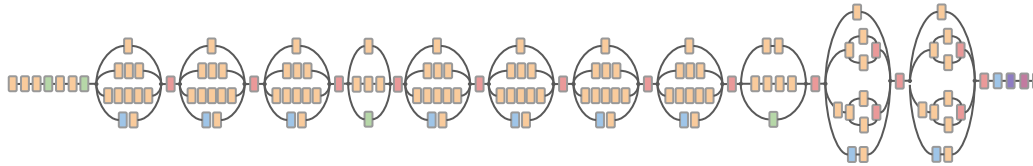
2000 diseases

Skin Cancer Classification



Skin Cancer Classification

Deep Convolutional Neural
Network (Inception-v3)

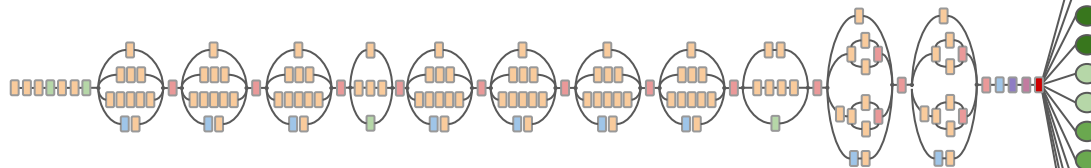


Skin Cancer Classification

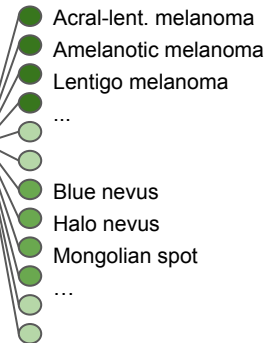
Skin Lesion Image



Deep Convolutional Neural
Network (Inception-v3)



Training Classes
(757)



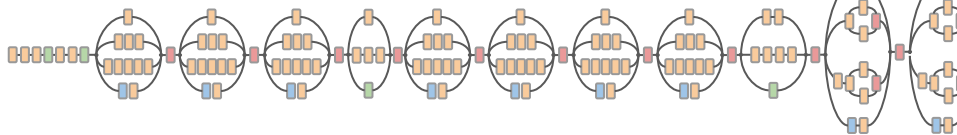
Partitioning Algorithm

Skin Cancer Classification

Skin Lesion Image



Deep Convolutional Neural
Network (Inception-v3)



Training Classes
(757)

- Acral-lent. melanoma
- Amelanotic melanoma
- Lentigo melanoma
- ...
- Blue nevus
- Halo nevus
- Mongolian spot
- ...

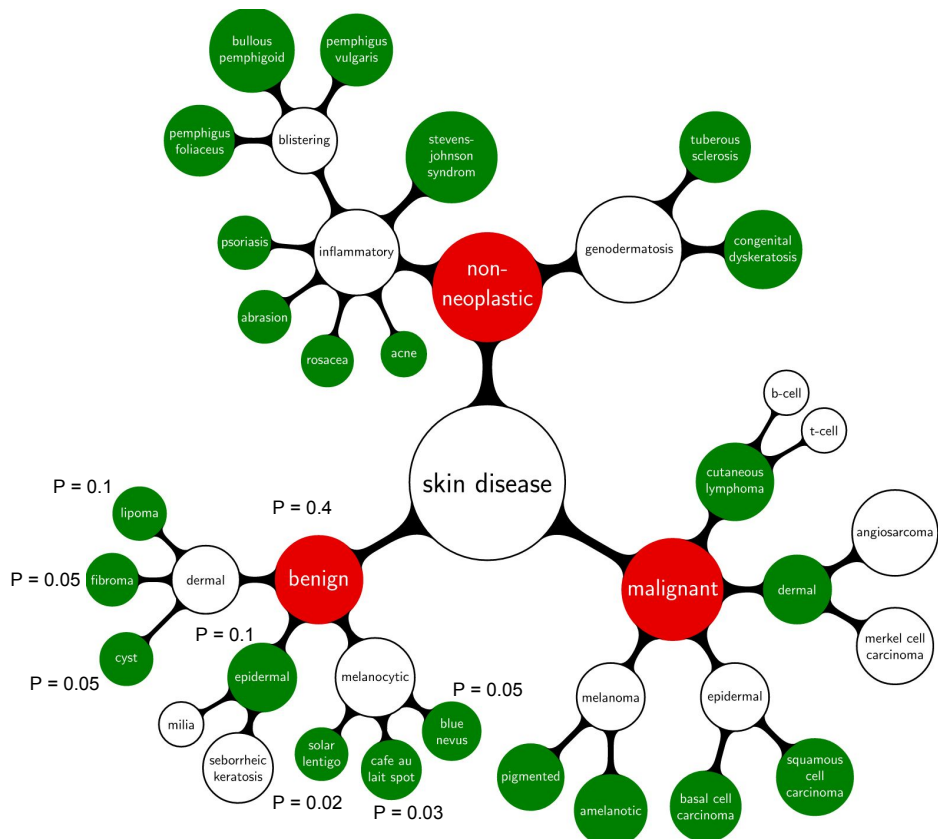
Inference Classes
(varies by task)

92% Malignant

8% Benign

Partitioning Algorithm

Skin Cancer Classification



$$P[u] = \sum_{v \in C(u)} P[v]$$

- Training Classes
- Inference Classes

Dermatologist-level performance

Skin Cancer Classification

Validation set

Skin Cancer Classification

Validation set

Classifier	Three-way accuracy
Dermatologist 1	65.6%
Dermatologist 2	66.0%
CNN	69.5%
CNN - PA	72.0%

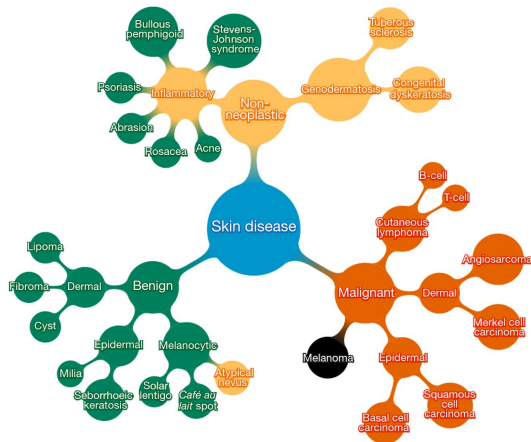
Disease classes: three-way classification

0. Benign single lesions
1. Malignant single lesions
2. Non-neoplastic lesions



Skin Cancer Classification

Validation set



Classifier	Three-way accuracy
Dermatologist 1	65.6%
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Disease classes: three-way classification

0. Benign single lesions
1. Malignant single lesions
2. Non-neoplastic lesions

Classifier	Nine-way accuracy
Dermatologist 1	53.3%
Dermatologist 2	55.0%
CNN	48.9%
CNN - PA	55.3%

Disease classes: nine-way classification

0. Cutaneous lymphoma and lymphoid infiltrates
1. Benign dermal tumors, cysts, sinuses
2. Malignant dermal tumor
3. Benign epidermal tumors, hamartomas, milia, and growths
4. Malignant and premalignant epidermal tumors
5. Genodermatoses and supernumerary growths
6. Inflammatory conditions
7. Benign melanocytic lesions
8. Malignant Melanoma

Skin Cancer Classification

Test set

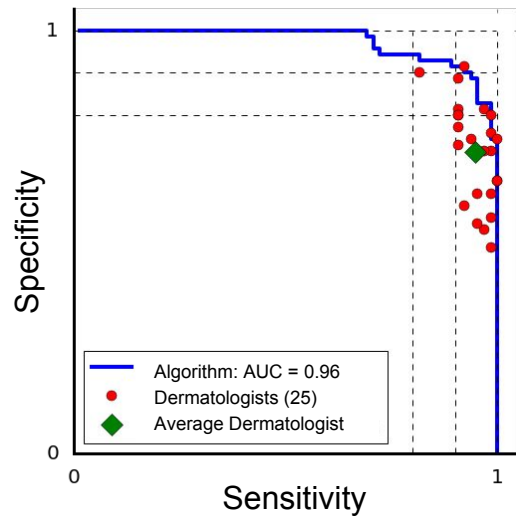
Skin Cancer Classification

Test set: Dermatologist Comparison (376 images)

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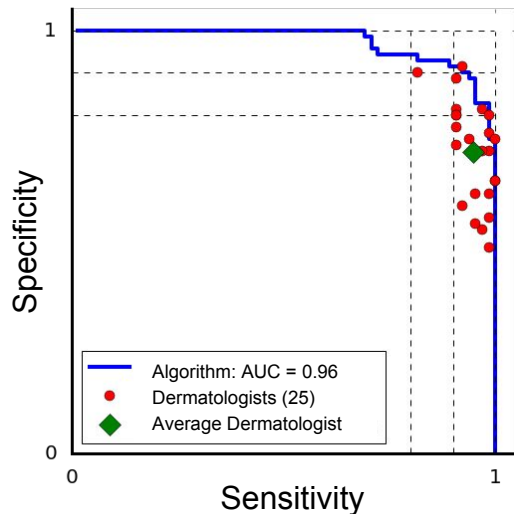
Carcinoma: 135 images



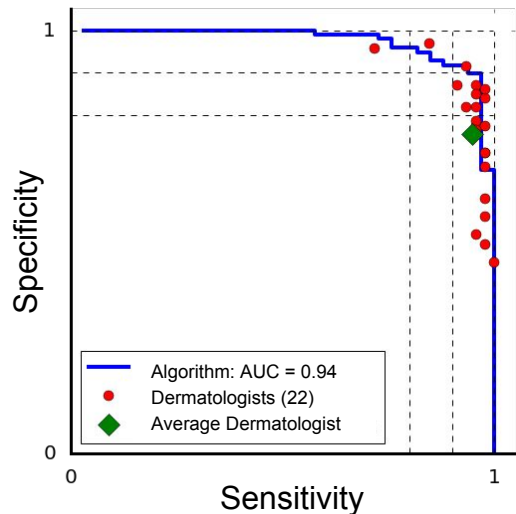
Skin Cancer Classification

Test set: Dermatologist Comparison (376 images)

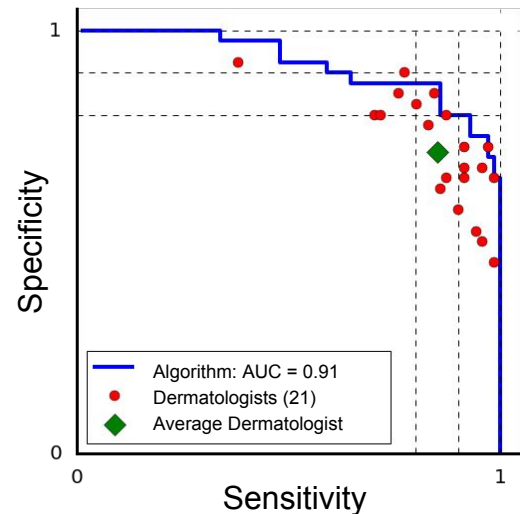
Carcinoma: 135 images



Melanoma: 130 images

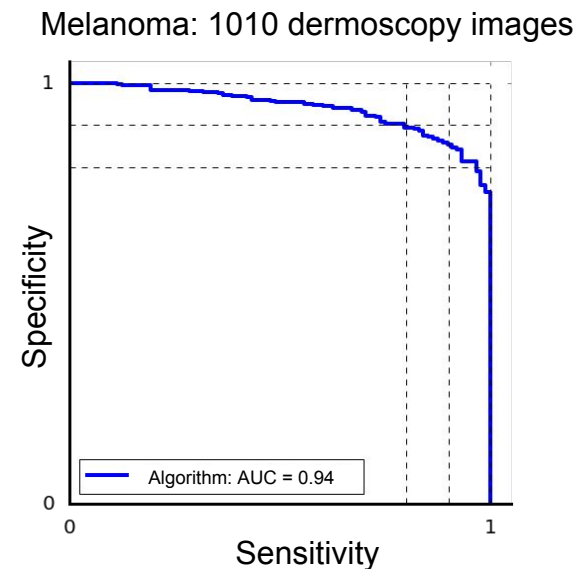
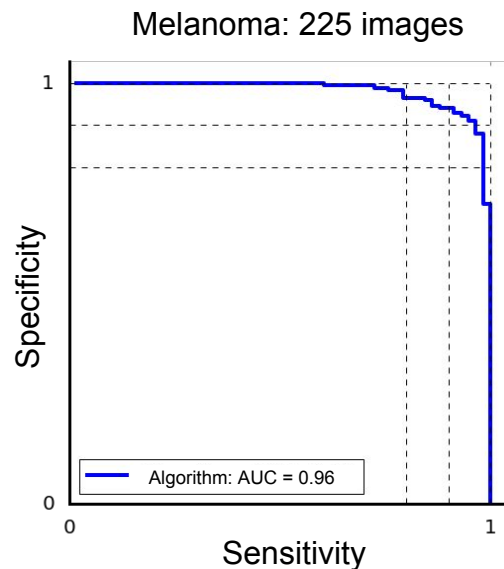
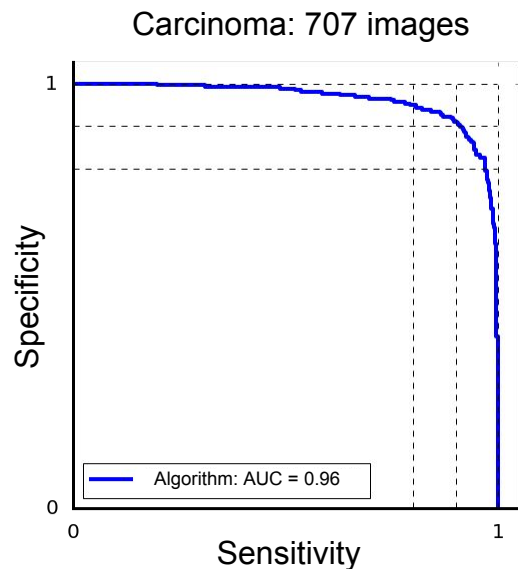


Melanoma: 111 dermoscopy images



Skin Cancer Classification

Test set: Total (1942 images)

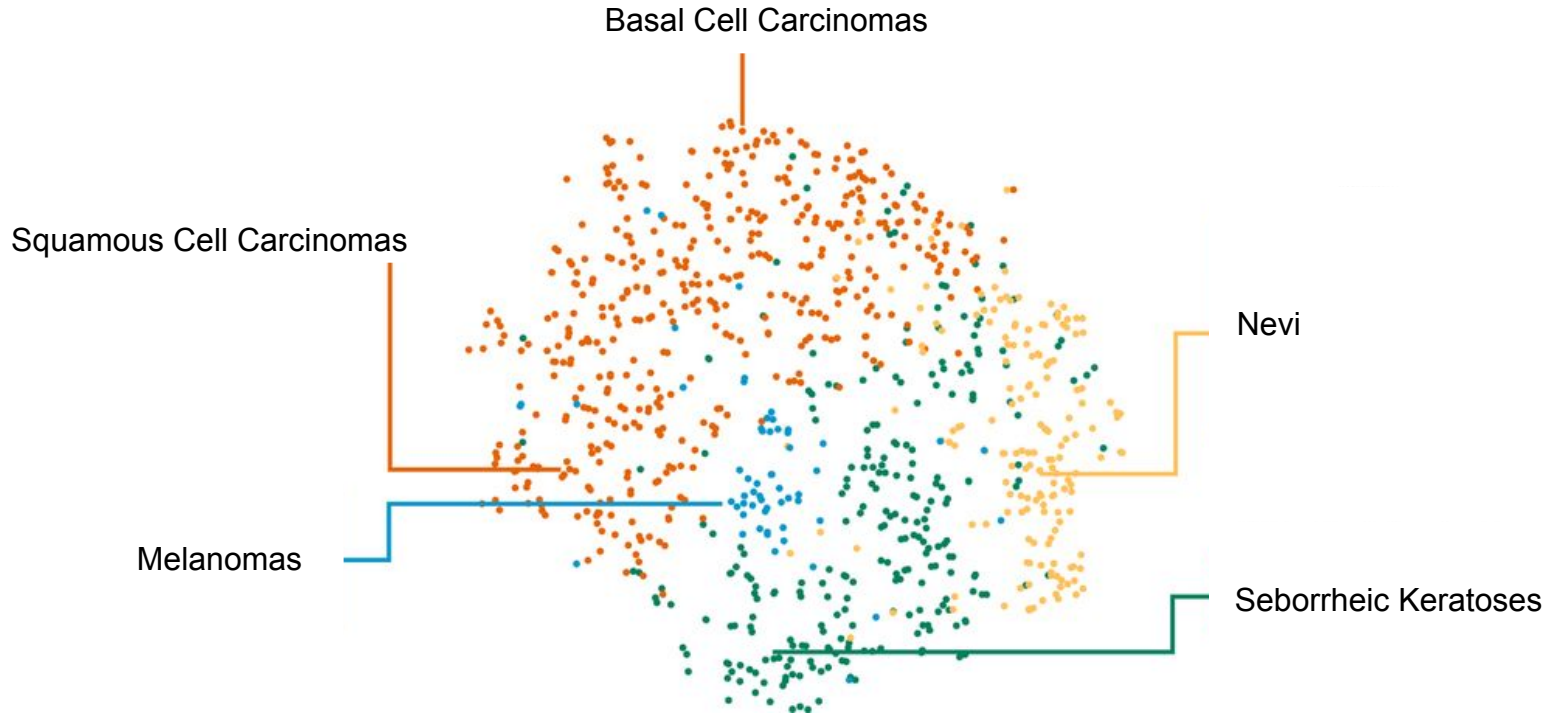


How does the algorithm work?

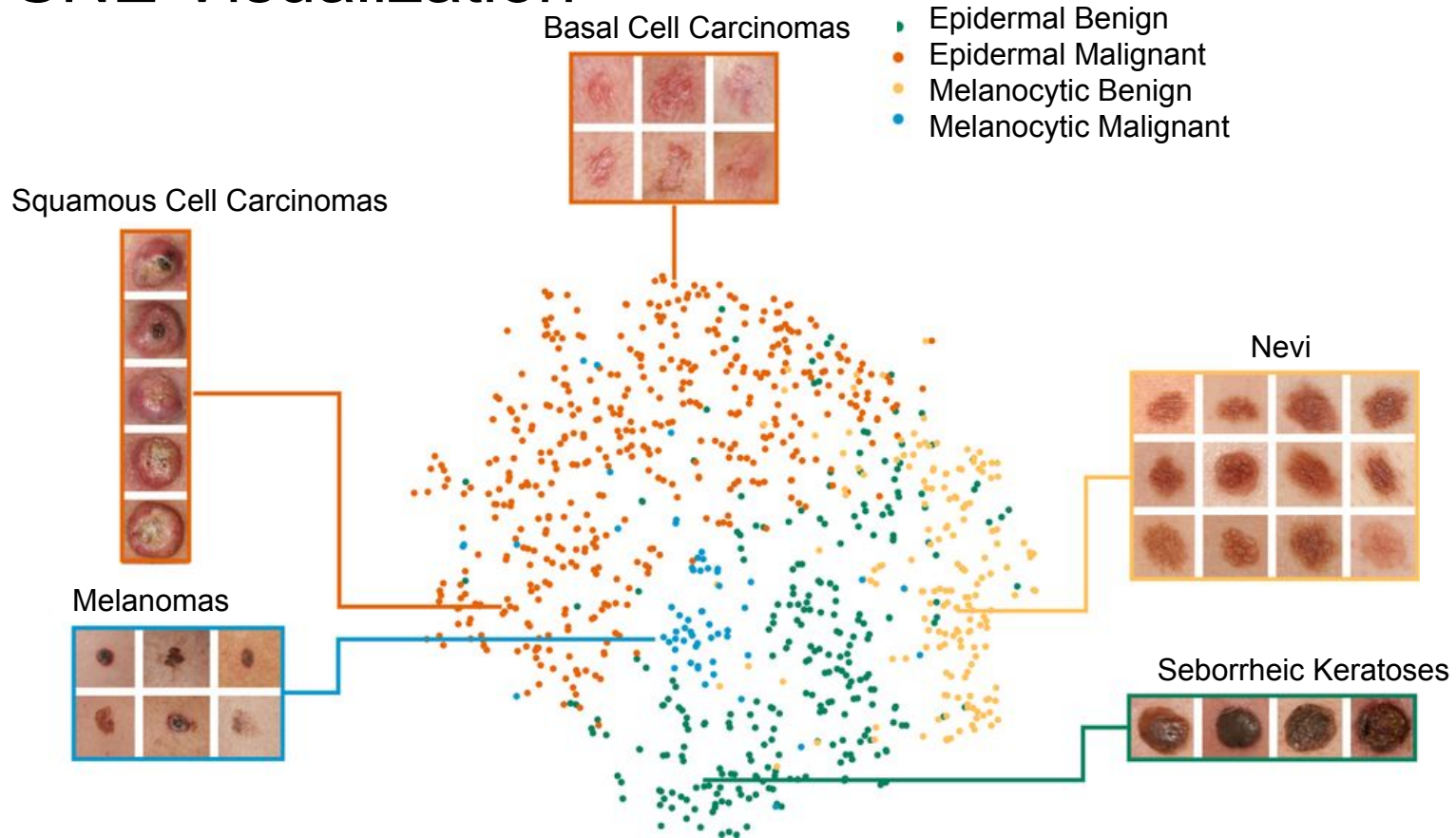
T-SNE Visualization

T-SNE Visualization

- Epidermal Benign
- Epidermal Malignant
- Melanocytic Benign
- Melanocytic Malignant



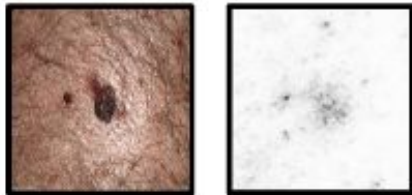
T-SNE Visualization



What is the network fixating on?

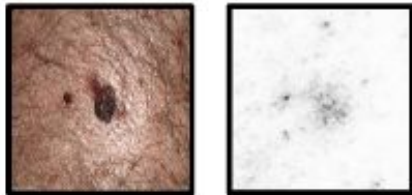
What is the network fixating on?

Malignant Melanocytic Lesion



What is the network fixating on?

Malignant Melanocytic Lesion



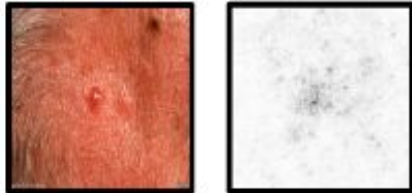
Benign Melanocytic Lesion



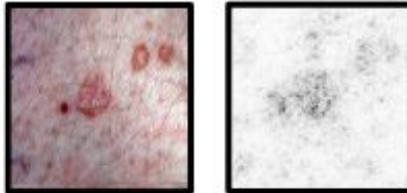
Inflammatory Condition



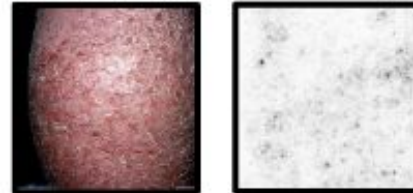
Malignant Epidermal Lesion



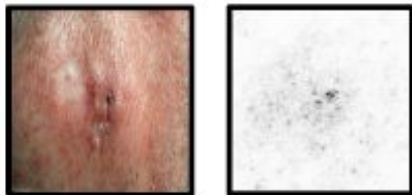
Benign Epidermal Lesion



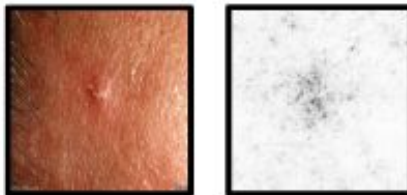
Genodermatosis



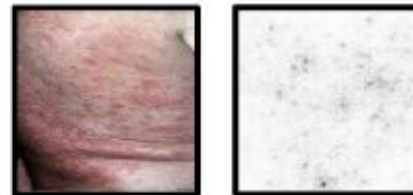
Malignant Dermal Lesion



Benign Dermal Lesion

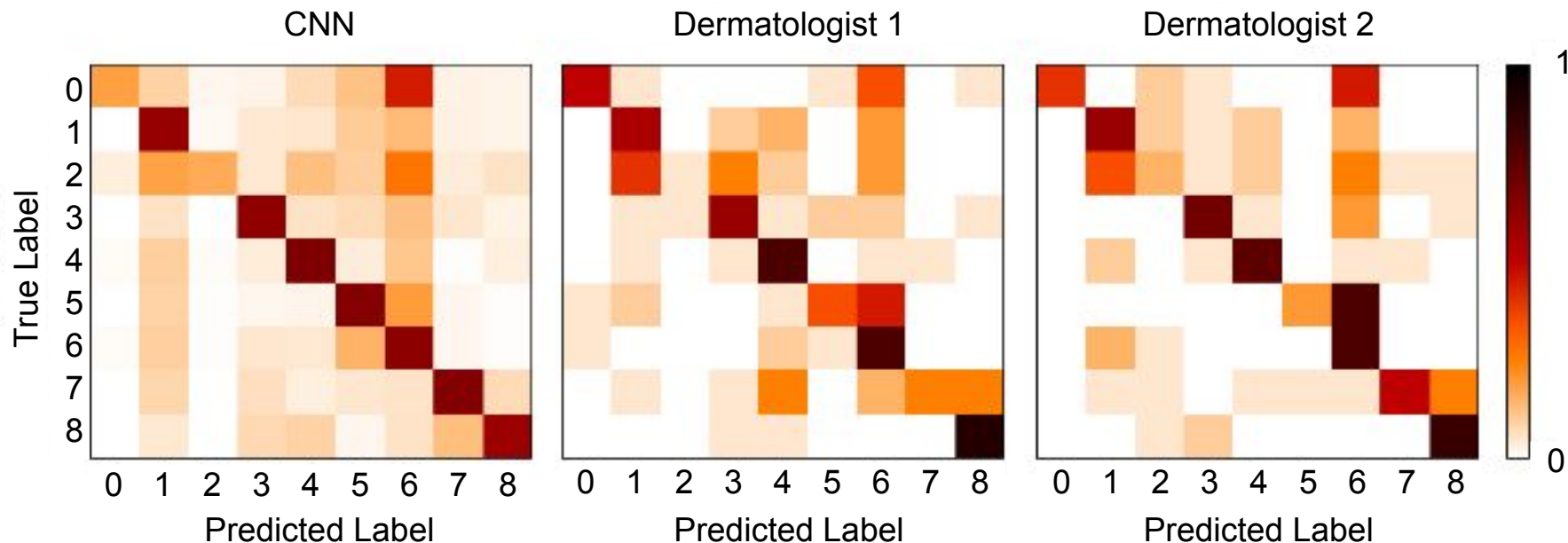


Cutaneous Lymphoma



What does the network misclassify?

What does the network misclassify?



Dermatologist-level Classification of Skin Cancer with Deep Neural Networks

Andre Esteva*, Brett Kuprel*, Rob Novoa, Justin Ko, Susan Swetter, Helen Blau, Sebastian Thrun
Nature, 2017
(Equal contribution authors*)



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Community

Questions?

esteva@cs.stanford.edu
@andreesteva
cs.stanford.edu/people/esteva