Dermatologist-level classification of skin cancer with deep neural networks

Enhancing the Expert

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PI: Sebastian Thrun
Stanford University
How can technology assist a human?
How can AI assist a dermatologist?
Skin Cancer
Skin Cancer

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

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Early detection is critical
6.3 billion smartphones
Skin Cancer Classification
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~130,000 images of skin
2000 diseases
Skin Cancer Classification

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Skin Cancer Classification

Epidermal Lesions  Melanocytic Lesions  Melanocytic Lesions (Dermoscopy)

Benign

Malignant
Skin Cancer Classification

Deep Convolutional Neural Network (Inception-v3)
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

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

\[ P[u] = \sum_{v \in C(u)} P[v] \]
Dermatologist-level performance
Skin Cancer Classification

Validation set
Skin Cancer Classification

Validation set

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Three-way accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermatologist 1</td>
<td>65.6%</td>
</tr>
<tr>
<td>Dermatologist 2</td>
<td>66.0%</td>
</tr>
<tr>
<td>CNN</td>
<td>69.5%</td>
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<td>CNN - PA</td>
<td>72.0%</td>
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Disease classes:
three-way classification

0. Benign single lesions
1. Malignant single lesions
2. Non-neoplastic lesions
Skin Cancer Classification

Validation set

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<td>Dermatologist 1</td>
<td>53.3%</td>
</tr>
<tr>
<td>Dermatologist 2</td>
<td>55.0%</td>
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Disease classes: 
three-way classification

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

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)
Skin Cancer Classification

Test set: Dermatologist Comparison (376 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)

Carcinoma: 707 images

Melanoma: 225 images

Melanoma: 1010 dermoscopy images
How does the algorithm work?
T-SNE Visualization

Van der Maaten & Hinton, 2008
T-SNE Visualization

- Basal Cell Carcinomas
- Squamous Cell Carcinomas
- Melanomas
- Seborrheic Keratoses
- Nevi

- Epidermal Benign
- Epidermal Malignant
- Melanocytic Benign
- Melanocytic Malignant
T-SNE Visualization

- Basal Cell Carcinomas
- Squamous Cell Carcinomas
- Melanomas
- Epidermal Benign
- Epidermal Malignant
- Melanocytic Benign
- Melanocytic Malignant
- Nevi
- Seborrheic Keratoses
What is the network fixating on?
What is the network fixating on?

Malignant Melanocytic Lesion

Simonyan, Zisserman, 2014
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?
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Andre Esteva*, Brett Kuprel*, Rob Novoa, Justin Ko, Susan Swetter, Helen Blau, Sebastian Thrun
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How can AI assist a dermatologist?
Community
Questions?

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