Melanoma Classification from Hidden Markov Tree Features

Marco F. Duarte, Thomas E. Matthews, Warren S. Warren, Robert Calderbank

Melanoma Skin Sample Imaging

- Diagnosis currently relies on biopsy and histopathology, with many false positives
- Melanin content carries information about metabolism and location of melanocytes
- New two-color pump-probe imaging distinguishes eumelanin and pheomelanin

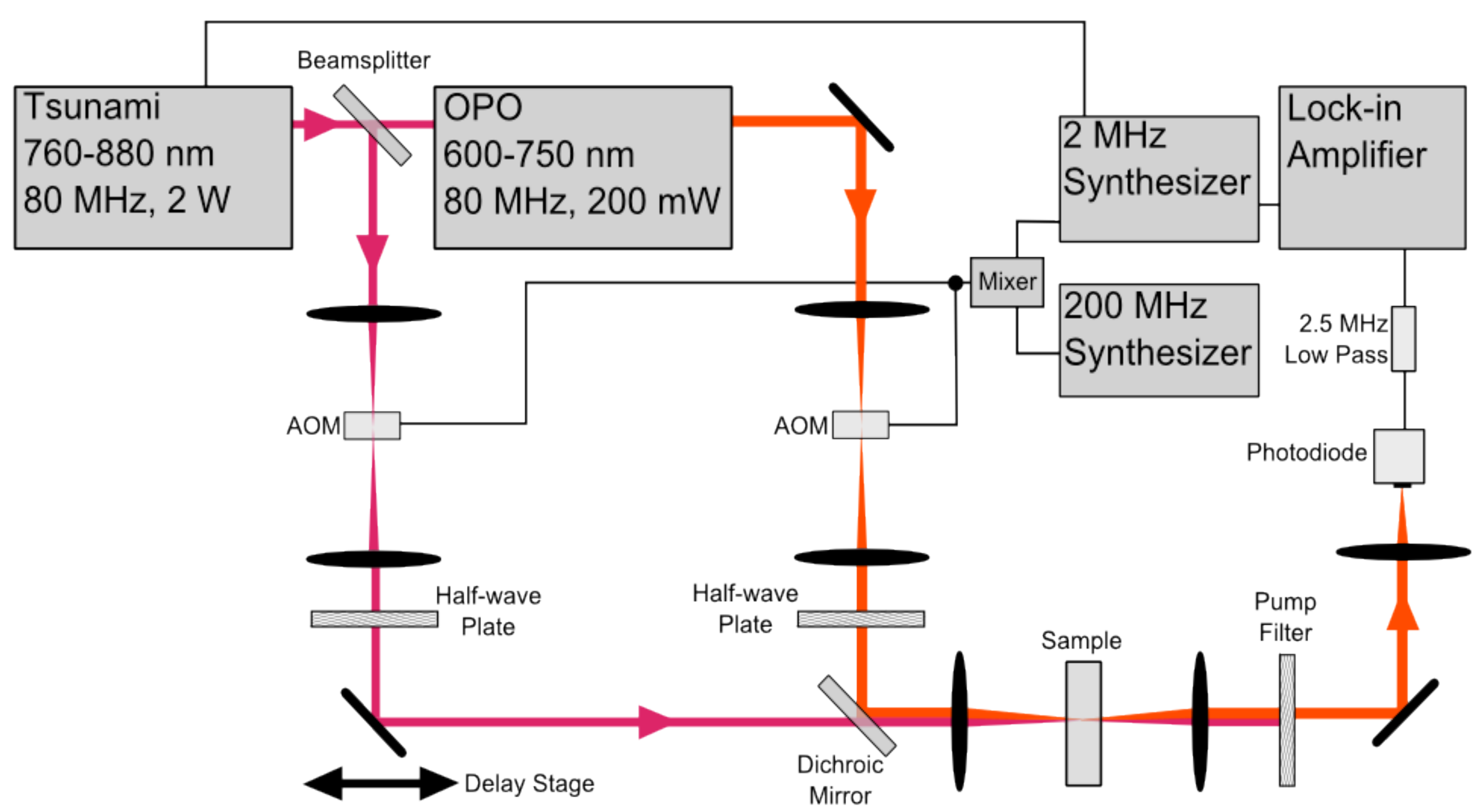
Melanoma Diagnosis

- Among ***most clinically challenging*** cancer types to diagnose
- From 1990 to 2006, US cancer deaths decreased by 17%; melanoma death rates increased by 7%
- Early detection is ***critical*** for survival - metastatic melanoma: 16%; local cancers: 98% (after five years)
- Diagnosis by biopsy and histopathology results in ***discordant conclusions*** (14% rate among pathologists)
- Erring on the side of caution ***increases the rate of false positives***

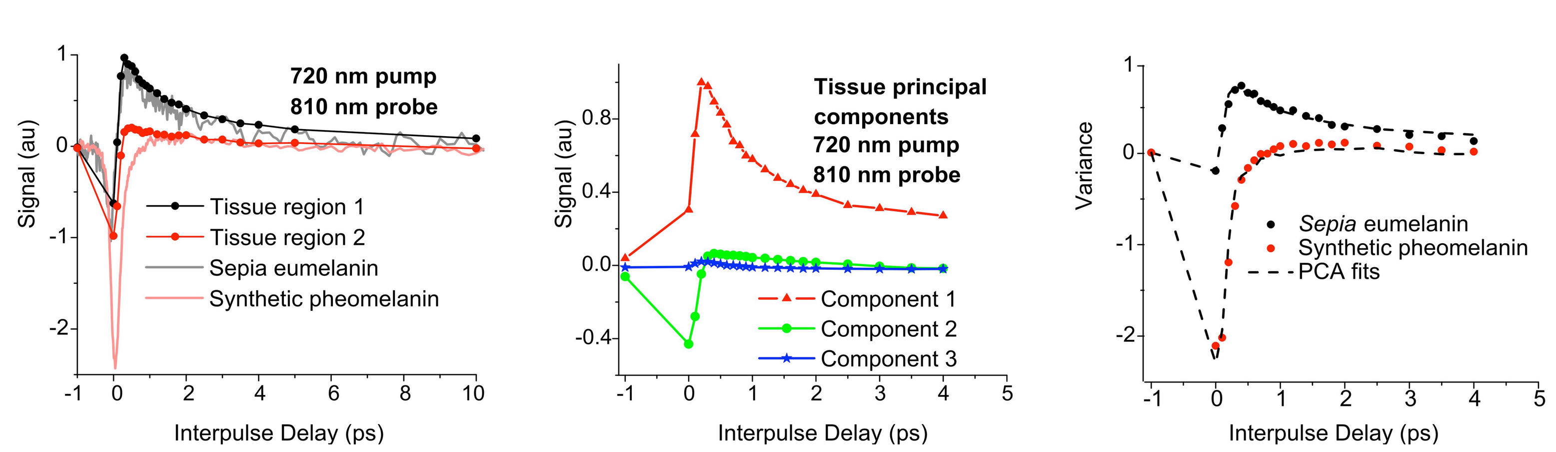
New Imaging Modalities for Melanoma Detection and Classification

- Melanomas are amenable to optical diagnosis - lesions are accessible and disease occurs close to skin surface
- Melanin carries information on metabolism and location of melanocytes
- Eumelanin and pheomelanin content may act as markers for disease

Two-Color Pump-Probe Spectroscopy Imaging System [1]



Pump-Probe Imaging Distinguishes Eumelanin and Pheomelanin

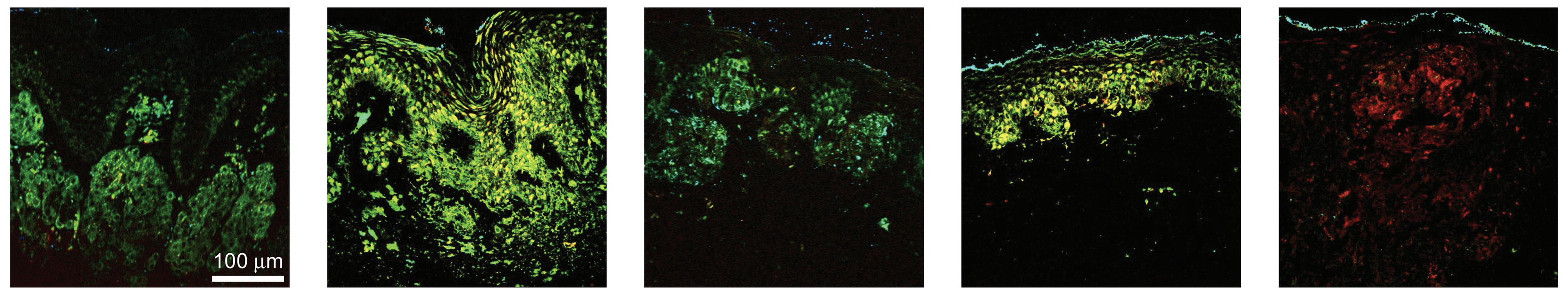


The Structure of Skin Sample Images

- Different stages of melanoma exhibit different types of spatial image structure
- Hidden Markov trees (HMT) provide statistical model for image wavelet coefficients
- HMT parameters provide features capturing image structure, suitable for classification

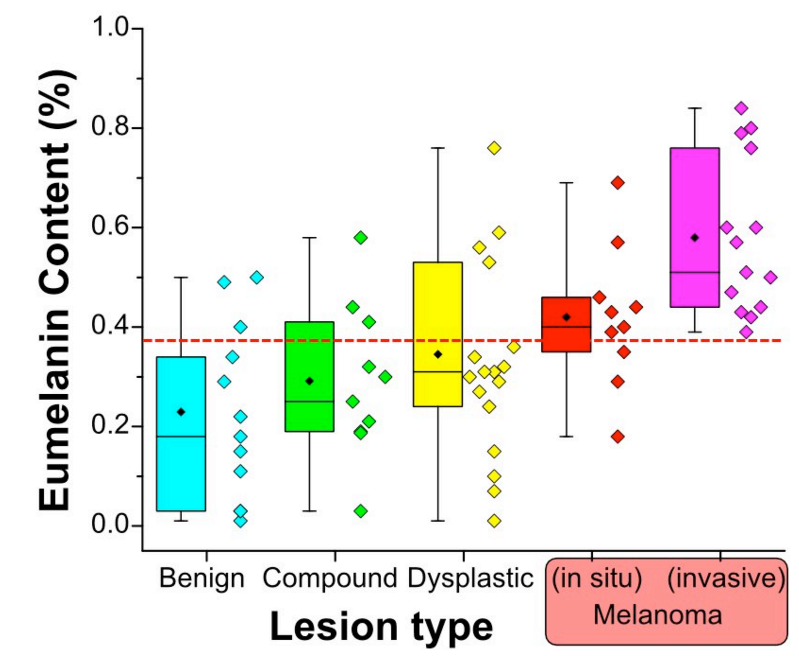
Melanoma Classification by Melanin Concentration

Green: Pheomelanin; Orange: Eumelanin

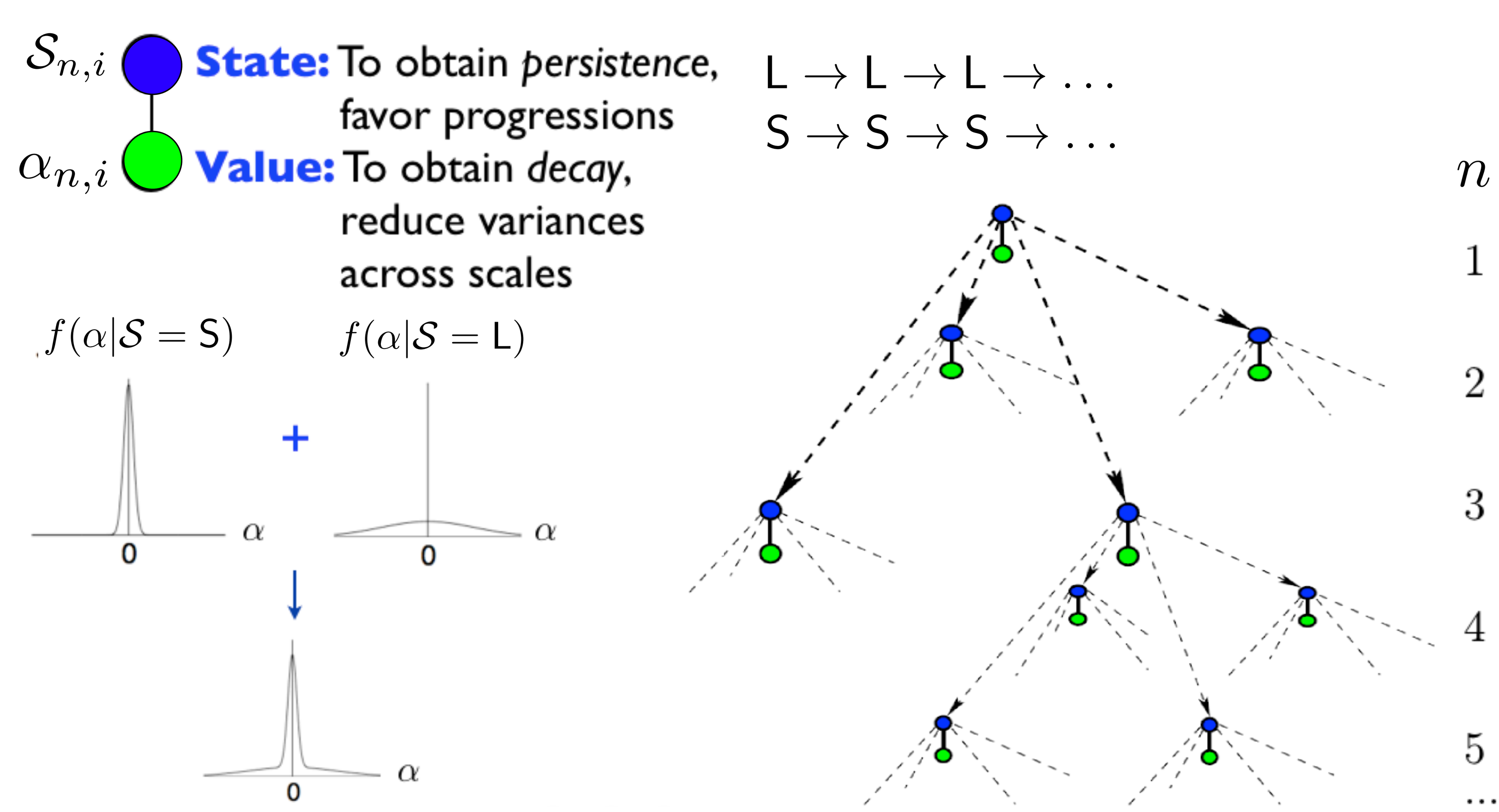


Benign Nevi | Compound Nevi | Dysplastic Nevi | Melanoma *In Situ* | Invasive Melanoma

- Concentration of melanin characteristic for different classes
- Minimum eumelanin content of 38% separates most melanomas from 75% of nevi samples [2]
- Single metric cannot distinguish between nevi or capture structural image information



Hidden Markov Tree Models [3]



One tree per orientation $(\mathsf{H}, \mathsf{V}, \mathsf{D})$

Parameters for each tree:

- Probability of small and large states for each scale:

$$p_n^{\mathsf{S}} = p(\mathcal{S}_n = \mathsf{S}) \qquad p_n^{\mathsf{L}} = p(\mathcal{S}_n = \mathsf{L})$$

- Variances of Gaussians for small and large states for each scale: $\sigma_{\mathsf{S},n}, \sigma_{\mathsf{L},n}$

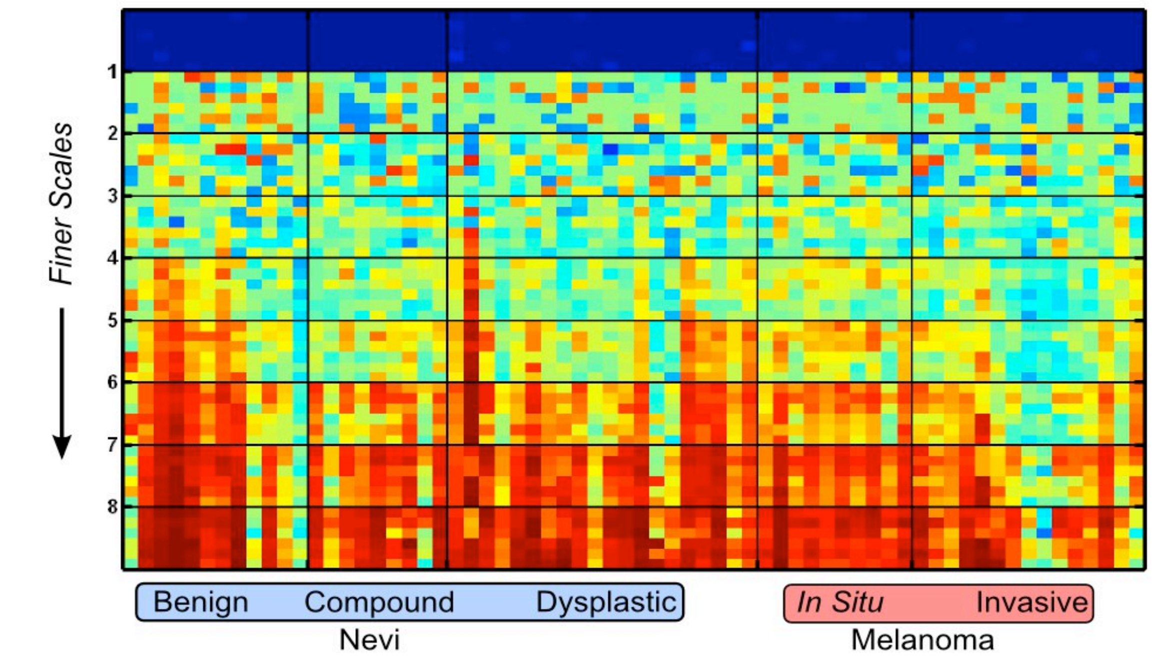
Melanoma Detection & Classification

- Selection of small state likelihood among scales as feature vector
- Features quantify presence/absence of image structure at multiple scales
- Features distinguish between concentrated and disseminated content

Hidden Markov Tree-Based Image Features

Three detection/classification feature types:

- ***F1***: One HMT for sample image depicting only total melanin concentration (no discrimination of eumelanin and pheomelanin)
- ***F2***: Two HMTs on eumelanin and pheomelanin concentration images (no discrimination of chemically homogeneous and heterogeneous regions)
- ***F3***: Two HMTs on % eumelanin and pheomelanin concentration images



F2 - Blue: Small; Red: Large

Collect probabilities of small state $p_{\mathsf{O},n}^{\mathsf{S}}$ for each orientation and scale

512×512-pixel skin sample images produce vectors of size 27(F1)/54(F2/F3)

2ν-Support Vector Machines for Neyman-Pearson-Style classification [3]

Test	Success Rate	Detection Rate	False Alarm Rate
Melanoma vs. Nevi	73%	72%	74%
Melanoma vs. Nevi and Sebhorreic Keratoses	61%	62%	60%
Invasive Melanoma vs. Nevi	57%	54%	57%
In Situ Melanoma vs. Nevi	72%	73%	72%
Melanoma vs. Benign	59%	60%	58%
Melanoma vs. Dysplastic	56%	52%	60%

References

(1) D. Fu, T. Ye, T. E. Matthews, G. Yurtsever, and W. S. Warren, “Two-color, two-photon, and excited-state absorption microscopy,” *J. Biomedical Optics*, vol. 12, no. 5, 2007.

(2) T. E. Matthews, I. R. Piletic, M. A. Selim,M. J. Simpson, and W.S. Warren, “Pump-probe imaging differentiates melanoma from melanocytic nevi,” *Science Translational Medicine*, vol. 3, no. 71, Feb. 2011.

(3) M. S. Crouse, R. D. Nowak, and R. G. Baraniuk, “Wavelet-based statistical signal processing using Hidden Markov Models,” *IEEE Trans. Signal Processing*, vol. 46, no. 4, pp. 886–902, Apr. 1998.

(4) M. A. Davenport, R. G. Baraniuk, and C. D. Scott, “Controlling false alarms with support vector machines,” in *ICASSP*, Toulouse, France, May 2006, vol. V, pp. 589–592.