Automated Detection of New or Evolving Melanocytic Lesions Using a 3D Body Model

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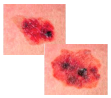
Monitoring melanocytic lesions

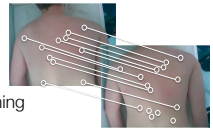
- Malignant melanoma is an aggressive form of skin cancer; its incidence is rapidly increasing worldwide [2]



- Detecting *changes* in an existing lesion or the *appearance* of a new one is crucial for early diagnosis

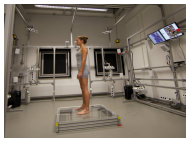
Automated systems

- Manual comparison between images taken at different times is challenging and time-consuming



- Approaches in 2D cannot handle non-rigid changes in body shape and pose

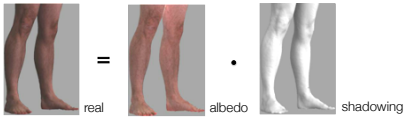
Scan acquisition



- Scans acquired with a high-accuracy 3D stereo system:
  - 22 pairs of stereo cameras
  - 22 RGB cameras for texture capture
- *Fast* acquisition: a few milliseconds per scan

Albedo extraction

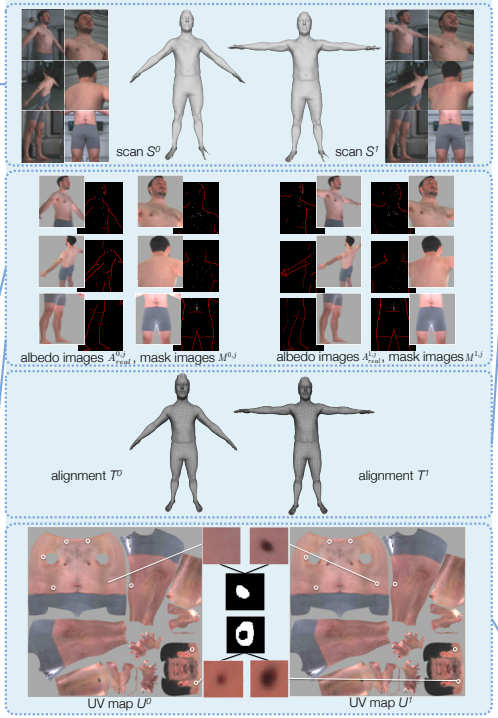
- Light and albedo estimation, assuming Lambertian skin reflectance and Spherical Harmonics lighting



Preliminary lesion segmentation

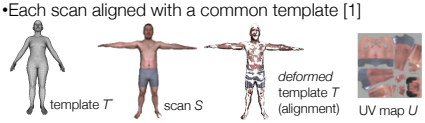
1. Laplacian-of-Gaussian (LoG) filtering at 5 scales
2. Classification through Linear Discriminant Analysis (LDA)
3. Removal of occlusion boundaries / elongated artifacts

System overview



Model-based registration

- Each scan aligned with a common template [1]



- Objective minimized during registration:

$$E(T,\theta;S) = \lambda_S E_S(T;S) + \lambda_C E_C(T,\theta;S) + \lambda_U E_U(T;S)$$

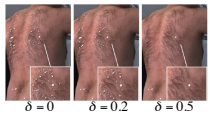
- E_S penalizes 3D distance between S and T surfaces
- E_C penalizes deviations from the statistical body model, parameterized by pose θ
- E_U penalizes appearance dissimilarity between S and T

$$E_U(T;S) = \sum_{\text{cameras } j} \sum_{\text{pixels } y} w_{M^j}(RoG_{\sigma_1,\sigma_2}(A^j_{real})[y] - RoG_{\sigma_1,\sigma_2}(A^j_{rend})[y])^2$$

Change detection in UV space

- Segmentation refinement based on the 3D model:

weighted majority voting based on all the cameras



mask image

$$\frac{\sum_{\text{cameras } j} M^j[\pi^j(x)] \max(\omega_{x,j}, 0)}{\sum_{\text{cameras } j} \max(\omega_{x,j}, 0)} > \delta$$

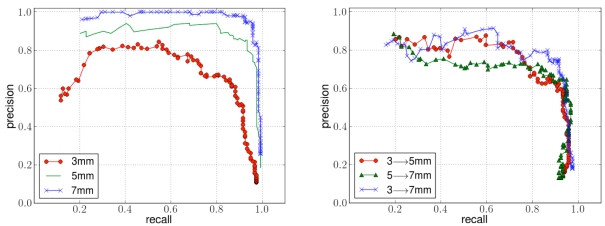
surface normal/viewing vector dot product

- Detection of new lesions or increased lesion size by direct comparison between UV maps

Experimental evaluation

- 12 subjects (6 male, 6 female)
- Variations in skin phenotype and pose

- Synthetic lesions of different diameter (3mm, 5mm, 7mm) drawn on the skin with a marker



- Precision/recall curves for different values of δ, for detecting new lesions (left) and increased lesion sizes (right)

References

[1] F. Bogo, J. Romero, M. Loper, M.J. Black, FAUST: Dataset and evaluation for 3D mesh registration. *CVPR* 2014.

[2] E. Dunki-Jacobs, G. Callender, K. McMasters, Current management of melanoma. *Current Problems in Surgery,* 50: 351—382, 2013.