AUTOMATED MONITORING OF SKIN LESIONS USING A 3D BODY MODEL

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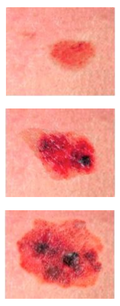
Abstract

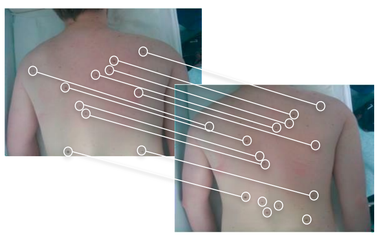
We propose an automated pre-screening system for detecting new melanocytic lesions or changes in existing ones, as small as 2-3mm, over almost the entire body surface.
Our solution relies on a multi-camera 3D stereo system.
We capture textured scans of a subject at different times, and bring these scans into correspondence by aligning them with a learned, parametric 3D body model. Captured skin textures are in accurate alignment across scans, facilitating the monitoring of lesions over time.

Monitoring melanocytic lesions

- Malignant melanoma is an aggressive form of skin cancer; its incidence is rapidly increasing [3]
- In its early phases, a melanoma is often indistinguishable from a common mole
- A change in an existing lesion or the appearance of a new one is a sensitive sign of melanoma; stability speaks against the presence of a disease

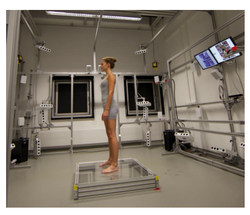


- Digital imaging systems allow a dermatologist to compare pictures of a patient taken at different times



- Manual comparison is challenging and time-consuming
- Previous approaches, working in 2D, do not handle non-rigid changes in body shape and pose

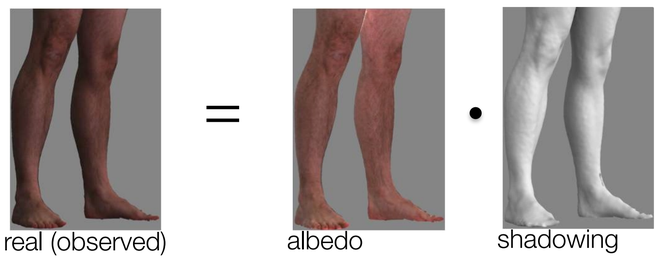
Scan acquisition



- Scans are acquired with a high-accuracy 3D multi-stereo system:
  - 22 pairs of stereo cameras
  - 22 RGB cameras for texture capture
- Acquisition is fast: a few milliseconds per scan

Albedo extraction

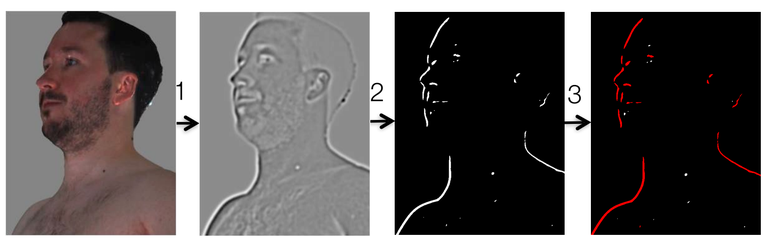
- Automated lesion segmentation may suffer from the presence of shadows
- We estimate scene lighting and remove shadows from the camera images, assuming a Lambertian skin reflectance model



real (observed) albedo shadowing

Preliminary segmentation

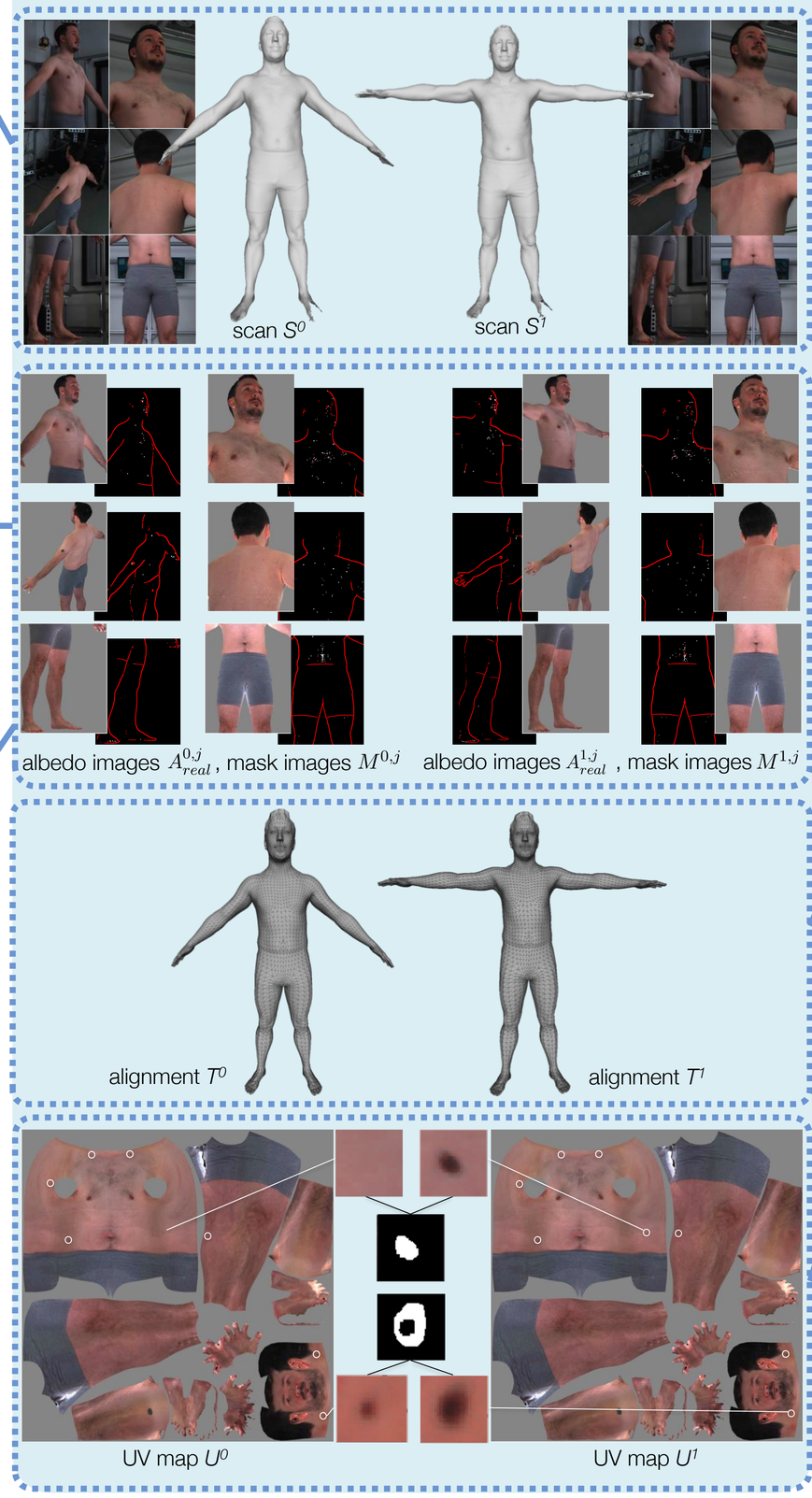
- Preliminary lesion segmentation in camera image space, using a simple blob-detector



1. Feature extraction: Laplacian-of-Gaussian (LoG) filtering at 5 different scales
2. Classification through Linear Discriminant Analysis (LDA)
3. Removal of occlusion boundaries and other elongated artifacts

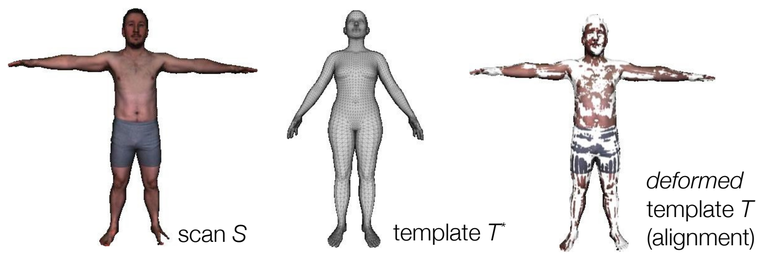
The presence of sparse hair, small artifacts or generic image noise may cause many false positives. In a subsequent step, the segmentation is refined by introducing a 3D body model.

System overview



Model-based registration

- We register scans captured at different times by bringing each scan into alignment with a common template mesh:

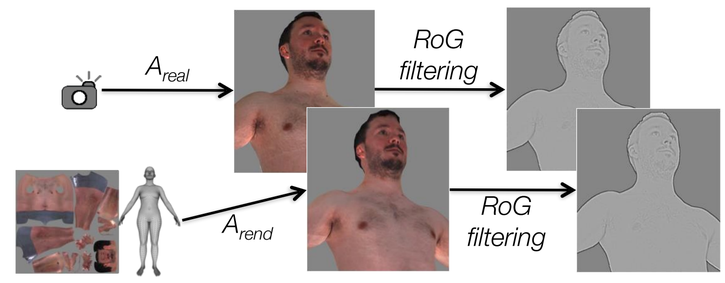


- During the alignment, we minimize an error function considering both 3D geometry and texture information [1]:

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

- E_S penalizes distances between the mesh surfaces in 3D space
- E_C penalizes deviations from our statistical body model, parameterized by pose θ
- E_U penalizes dissimilarity in appearance between S and T:

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



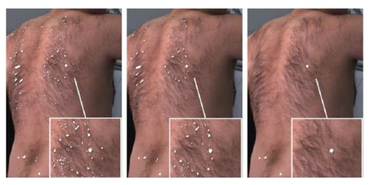
Change detection

- Working directly in the parameterized space defined by the template (i.e. in *UV space*)
- First, we refine the lesion segmentation, by averaging the classifications provided by different cameras.
  A UV map pixel corresponding to the template surface point x is classified as lesional iff:

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

($\omega_{x,j}$ is the cosine of the angle between the surface normal at x and the ray from x to the camera's center; δ is a system parameter)

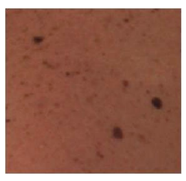
Artifacts (e.g. sparse hair) tend not to be consistent across views and are filtered out



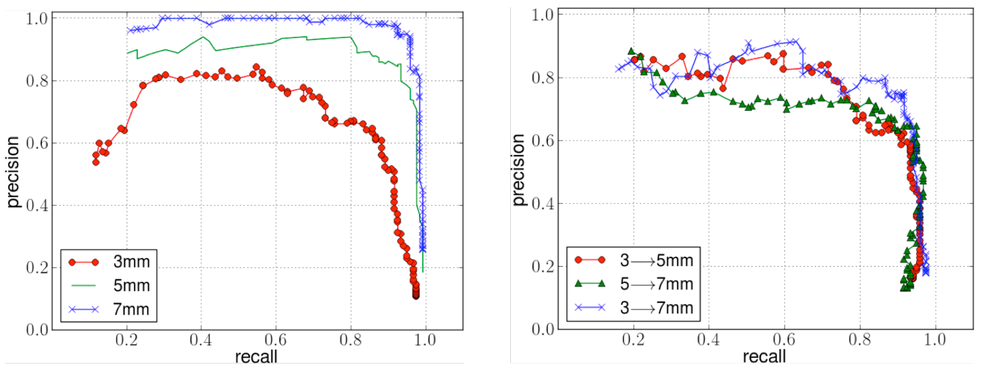
- Then, we detect new lesions or lesions that have grown by direct comparison between the segmentations in UV space

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] F. Bogo, J. Romero, E. Peserico, M.J. Black, Automated detection of new or evolving melanocytic lesions using a 3D body model. *MICCAI* 2014.
[3] E. Dunki-Jacobs, G. Callender, K. McMasters, Current management of melanoma. *Current Problems in Surgery,* 50: 351—382, 2013.