Stereoscopic Skin Mapping for Dermatology

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Abstract. Dermatological assessment of localization and extent of skin involvement is often a pre-requisite for therapy planning and therapeutic effects evaluation. Topodermatographic Image Analysis systems use only 2D information for mole mapping which does not allow precise 3D measurements. Photogrammetry can reconstruct surfaces in the 3D space from multiple 2D image data. For this purpose, a stereoscopic prototype system was created that uses two or more digital consumer cameras. Structured projected light is used for the stereo reconstruction of the skin surface, and patient-pose invariant light for the actual skin texture. The patient is rotated on a motorized turntable for a full coverage of the trunk. Dense stereo matching results in a point cloud overlaid with texture from the skin. After merging the results of different views a full textured reconstruction of the patient's trunk is available as digital surface model (DSM) projected on a near-elliptical shape. Visualization is done by triangulation that generates a VRML2.0 file (3D and high-resolution texture). The system has been realized as a low-cost solution covering the principle requirements of 3D documentation in dermatology. The hard- and software is described, examples and performance are demonstrated. It is an operational tool for image data management, visualization, measurement on the unwrapped surface, and 3D data export. First reconstructions are shown together with software that allows time-series comparison in 3D. Data collection and dermatologic exploitation has started begin of 2003. *Skin Mapping* is a joint development of JOANNEUM RESEARCH, the University of Graz Department of Dermatology and DIBIT Messtechnik GmbH of Mils, Austria.

1 Introduction and Scope

Mole mapping is a key to therapy planning and the assessment of therapeutic effects, particularly in clinical studies concerning investigational new drugs. Objective and repeatable methods for the measurement and mapping of lesions in a global geometric context as well as high resolution optical documentation are needed for quantitative change detection. Localization and extent of skin involvement so far has largely been done by subjective, semi-quantitative scoring systems [2]. Digital images are a widely used means of documentation, but they provide only two-dimensional information and are therefore inappropriate when large areas of the body surface and the geometrical relations have to be considered.

Photogrammetric methods that combine a high resolution textural documentation with three dimensional information have evolved in many medical application areas such as anatomical measurements, anthropometry, body motion analysis and surgery. For the determination of body shapes several systems are already on the market [4]. However, these solutions are in most cases either based on high cost hardware equipment, or are in prototype stage. To the knowledge of the authors a link between skin texture and 3D body structure has not been established yet. In dermatology many attempts have been made to locate moles on the skin. Digital dermoscopy (incident light microscopy, surface microscopy) has been used to create diagnostic classification procedures. In particular, colour and texture features have been evaluated by linear discriminant analysis [3], classification and regression trees, k-nearest-neighbour analysis and neural networks. Topodermatographic measurements use high resolution 2D digital photographs from different viewing angles under controlled illumination conditions. Digital cameras are available that allow surface resolutions in the range of 0.2mm per pixel on an image covering the full trunk. Consumer cameras have not reached this up to now due to cost driven compromises, but the rapidly growing market enables quick enhancements. For the system described in this paper it means that diagnosis directly from the images provided here may be possible within the next 3 years.

To give access to 3D mole mapping in the global three-dimensional context of the human body within an operational system the *Skin Mapping* system has been developed. It consists of a stereoscopic camera setup acquiring image and 3D data from either the trunk or one leg of a patient at a time. Section 2 describes the system hard - and software. After an installation end of 2002 some preliminary results are available, those and the current performance are outlined in Section 3. Section 4 gives a brief conclusion as well as an outlook for the next development steps and open questions.

2 System Layout

The patient is placed and rotated on a motorized turntable for a full coverage of the Torso or other roughly convex parts of the body, a graphical data acquisition user interface is available (Figure 1). The images are stored in a data base. Three low-cost consumer digital cameras are used for stereoscopic image acquisition. Structured light is provided by a flash in a consumer slide projector, two cameras take stereo images with this random noise pattern projected onto the visible skin surface patch. The third camera, placed in between, takes high resolution texture images. It triggers 4 flashes arranged each 90° below the patient that are also rotated in order to get consistent illumination. The system covers an area of about 3×2 m. The cameras are calibrated in terms of *interior orientation* (lens parameters), *relative orientation* with respect to each other and *exterior orientation* to the turntable rotation axis. Calibration is determined by calibration target images in different rotational states, and photogrammetric adjustment. White balance for objective colours is an available tool as well, but not

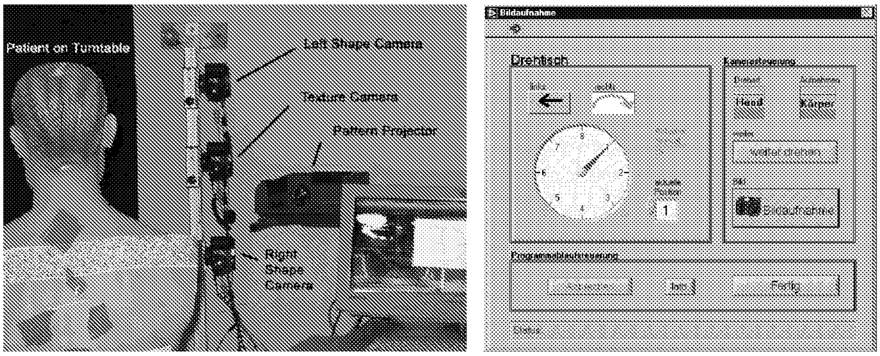

Fig. 1. *l:* Skin Mapping system layout. *r:* User interface for image acquisition.

yet integrated in the system. Dense stereo matching [6] is performed, the camera and rotation axis calibration are used for the 3D projection of each stereo disparity [5]. The texture camera orientation allows a texture projection onto the reconstruction result. After smoothly merging the reconstructions of 8 views on a DSM projected on a surface model (a near-elliptical shape) a full textured reconstruction of the patient's trunk is available, which means a geometrically correct high-resolution virtual model of the surface. Measurement of location and geometric features of lesions in 3D is then possible using the DSM and an ortho image (colour texture projection onto the DSM). The visualization user interface allows a quick comparison between different temporal stages.

3 System Performance and Results

Camera synchronization for the consumer cameras [1] on a Windows XP® system is possible down to a resolution of 100 msec. Data acquisition time is mainly restricted by the flash charging, all 8 positions are taken within less than 5 minutes. The pose-invariant illumination allows an a-posteriori change detection of skin regions that might not have been considered as interesting at earlier diagnostic sessions, but later turned into focus of clinical interest. Figure 2 shows an image data set of one position. Since the resolution of the 3D data is not a crucial parameter for the current application the shape images are resampled to 640×480 pixels, the texture images are kept at 2272×1704. Automatic stereo matching and reconstruction (DSM & ortho image with a resolution of 0.5mm and Vrml files) takes less than 20 minutes. The inconsistencies on overlapping areas between individual patches are typically better than 3mm on a full trunk. Figure 3 shows the user interface using the unwrapped ortho image and DSM. Some individual Vrml patches as well as a combination of the patches (not yet smoothly merged) are shown on Figure 4. The system has been installed by the end of 2002 at the Institute of Dermatology at the University of Graz, therefore statements about medical impact or experience are not yet available at this point.

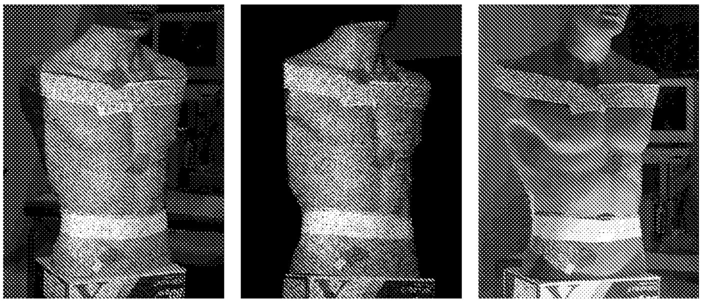

Fig. 2. *l:* Input images of one sector (of eight). *left and middle:* Random pattern projected for left and right shape camera, *right:* Texture image. The target is a male dress doll, with some auxiliary target patterns glued on the surface (see also Figure 2).

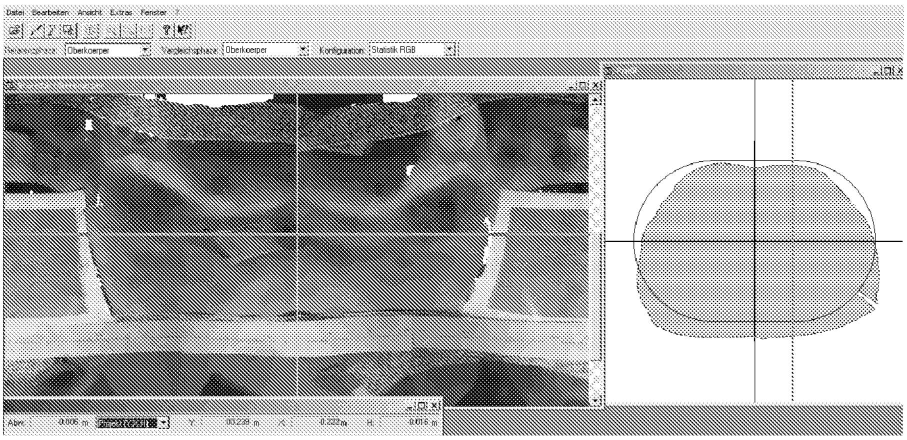

Fig. 3. *l:* Skin Mapping measurement tool. *l:* Unwrapped trunk surface (ortho image), *r:* body shape profile at current cursor position. Coordinates on the ortho image cursor position are shown below. Switching between different temporal states is possible. SW courtesy of DIBIT Messtechnik, Mils, Austria, http://www.dibit-scanner.at/

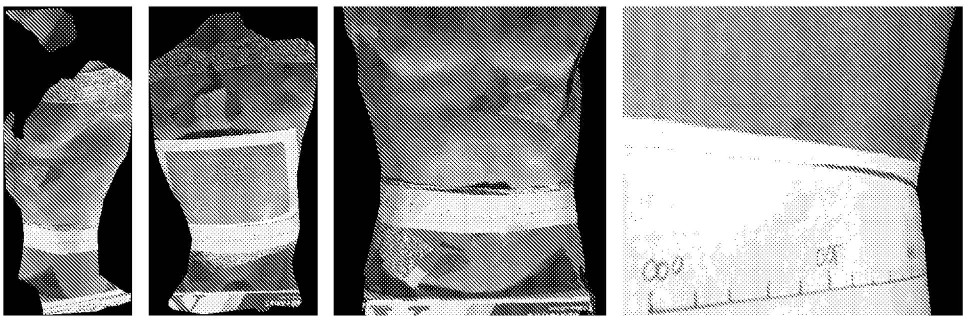

Fig. 4. *l:* Individual Vrml patches (left) and combination of all 8. *r:* Highest resolution (zooming in the Vrml, underlying the 2272 $\times$ 1704 texture image), tick marks in cm.

4 Conclusion and Outlook

The *Skin Mapping* system based on stereoscopic images enables objective mapping and unwrapping of the skin surface for a description of lesions in the global geometric context of the body surface. Measurements are possible in all three dimensions. Current developments consider automation aspects, new representations of the body, interactive visualization, and measurement and manipulation tools for the doctor. The current system does not align overlapping patches, which creates overlapping artefacts when the patient is moving during image acquisition or reconstructions from different temporal states are overlaid. Solutions are available from tunnel reconstruction and need to be adopted to the 3-camera data set. Another important issue is body model determination individually for each patient since the current ellipse - like representation does not allow area-keeping mapping. From a clinical point of view, application will be mainly focused on the detection and automated screening of pigmented skin lesions. In the future, a comparison between time sequence images may help to detect gross morphologic changes, particularly the development of new individual pigmented lesions. The present resolution, however, does not seem to be sufficient for an automated classification of individual pigmented lesions. Therefore, the system will serve as a guiding system, recognizing regions of interest, with close-up views obtained with digital dermoscopy as a second step.

In summary the approach presented here is a candidate for a low-cost solution to 3D mole mapping, particularly when the resolution of and data interfacing to consumer cameras are further increased. Current deficiencies like the accurate overlapping of the individual patches already have solutions from other application fields, adaptations will be addressed in the near future. Midterm aim is a linkage with commercial vision systems for dermatology, covering the full range of global mapping down to the high resolution representations used for diagnostic purposes.

References

1. http://www.synccapture.de/
2. Bahmer FA, Schäfer J, Schubert HJ: Assessment of the extent and the severity of atopic dermatitis - the ADASI-score. Arch.Dermatol. 127: 1239-1240, 1991.
3. Smolle J: Computer Recognition of Skin Structures Using Discriminant and Cluster Analysis. Skin Research and Technology 6: 58-63, 2000
4. Simmons KP, Istook C: Body measurement techniques: A comparison of 3-D body scanning and physical anthropometric methods. 2001 Seoul KSCT/ITAA Joint World Conference, Seoul, South Korea, June 13, 2001.
5. Bauer A, Paar G: Stereo Reconstruction from Dense Disparity Maps Using the Locus Method. Procs. 2nd Conference on Optical 3-D Measurement Techniques, pp 460-466, Zürich, Switzerland, October 1993
6. Paar G, Pölzleitner W: Robust Disparity Estimation in Terrain Modeling for Spacecraft Navigation. Procs. 11th ICPR. International Association for Pattern Recognition, 1992.