Non-contact dermatoscopic device with full polarization control and liquid lens based autofocus function

Dierk Fricke*, Thomas Hildebrandt*, Merve Wollweber*, Bernhard Roth*

Hannoversches Zentrum für Optische Technologien

dierk.fricke@hot.uni-hannover.de

Epiluminescence microscopy on the skin, also called dermatoscopy, is a well-known diagnostic tool since approximately 50 years [1]. Epiluminescence mircroscopes (dermatoscopes) are mostly contact based devices which have several disadvantages due to the skin contact. In order to develop a non-contact dermatoscope, challenges like fast and automatic focusing and adaption to different ambient lighting situations must be considered. Here, we present a prototype of a non-contact dermatoscope with liquid lens based autofocus and full polarization control.

1 Introduction

The malignant melanoma is the deadliest form of skin cancer. Numbers of incidence are rising especially in the white population in, for example, Europe and North America [2]. The risk assessment, i.e. whether a naevus is benign or malignant, is based on optical criteria like the ABCDE rule [3]. The standard device for the examination of skin lesions is a dermatoscope, which generally is a contact-based system. Due to this fact, such devices have several disadvantages compared to non-contact systems as can be seen in Tab. 1. There, standard contact-based devices are compared with our prototype of a non-contact dermatoscope.

Contact-based dermatoscope	Non-contact dermatoscope
+ Established	- Not yet established
+ Images digitally available	+ Images digitally available
- May distort the geometry	+ No distortion of geometry
- Suppresses perfusion	+ Perfusion not disturbed
- Possibly painful	+ No pain
- Often unnatural colors	+ Natural colors
- Small field of view	+ Large field of view

Tab. 1 *Comparison of standard contact-based dermatoscopes with the prototype of a non-contact dermatoscope*

There are already some non-contact dermatoscopes available on the marked but their working distance is either very short (<10 cm) with a high zoom factor or they work at high distances and only provide overview images [4,5]. Furthermore, the light situation is generally not fully determined by the light source of the device and, therefore, colors in different images taken with different ambient light situations cannot be compared. Besides, some devices are using a rigid spacer to solve the problem of the variable focus.

2 Prototype of a non-contact dermatoscope

The prototype of the non-contact dermatoscope presented here consists of a camera-unit and an LED-illumination part. A liquid lens (LL) is mounted in front of the camera lens and realizes the autofocus in combination with a distance sensor. Polarizers are mounted in front of the light source and the camera. The polarizer in front of the camera can be rotated so that cross or parallel polarization as well as all states in between can be realized. Due to the arrangement of the elements, the setup is optimized for a distance of 45 cm from the LL. At a distance of 45 cm $\pm$ 3 cm, the laser spot of the distance sensor is in the field of view.

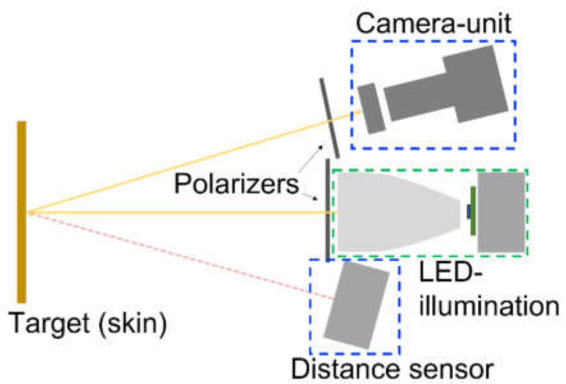

Fig. 1 *Sketch of the experimental setup of the prototype. Lighting is provided by an ultrabright LED light source and a distance sensor provides the information used by the liquid lens as part of the camera unit to allow for automatic focusing of the images.*

3 The autofocus

To solve the problem of a variable focus for non-contact dermatoscopic devices, we built an LL

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based autofocus. The functionality of a LL is shown in Fig. 2. If a voltage is applied to the piezo ring, it displaces an opto-fluid which results in increased pressure on the flexible membrane. This membrane is often made of silicone or thin glass. In our prototype, the EL-16-40-TC lens (Optotune AG, Dietikon, Schweiz) was used. It has an aperture of 16 mm. To adjust the lens, an infrared distance sensor was used. The sensor has an analog output, which rises linearly with the measured distance. This signal was coupled to the lens driver. In this way, it is possible to calibrate the system by focusing on targets at different distances and save the voltage given on the LL in relation to the output voltage of the distance sensor. In this way, a lookup table is created where the voltage needed for the LL can be linearly interpolated from the voltage at the distance sensor if at least two values are measured. The combination of liquid lens and camera lens yields a resolution of 27.87 µm at a distance of 45 cm.

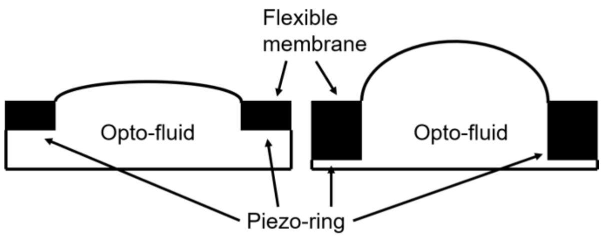

Fig. 2 *Concept of a liquid lens If a voltage is applied to the piezo-ring, it displaces the opto-fluid. This results in increased pressure on the flexible membrane of the lens.*

4 Light source and polarization control

The CBT-90 White LED (Luminus Inc., Sunnyvale, California, USA) with a color-correlated temperature (CCT) of 6350 K and a color rendering index of 76 is used as light source in our prototype. A reflector for the LED was simulated with OpticStudio (Zemax LLT, Kirkland, Washington, USA) to maximize the luminous flux in the area of interest where the image is taken. At a working distance of 45 cm, this area is 17 mm x 13 mm. The overall luminous flux of the light source is 378.5 lm. Within the area of interest, the luminous flux is 35.8 lm resulting in a polarized illuminance of 162.000 lx. For comparison, the illuminance in offices is 500 lx [6] and 1000 lx are recommended for examination rooms [6].

As described, the setup is equipped with polarizers that can be rotated to achieve any desired polarization state for both lighting and imaging. In cross polarization mode, the light which is reflected directly by the surface is supressed, whereas in parallel polarization mode, the light reflected is enhanced. Every polarization state in between is also possible.

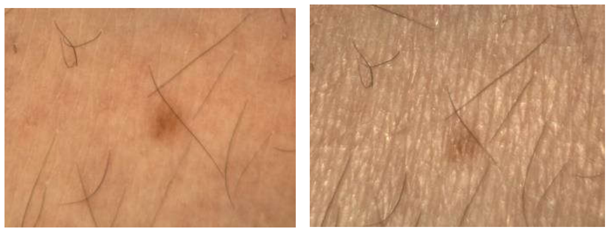

Fig. 3 *Example of a cross polarization image (left) and a parallel polarization image (right). In the left image surface reflection is suppressed.*

5 Conclusion and Outlook

In this work, we describe a prototype of a non-contact dermatoscope. The setup combines a high zoom factor with a comparably long working distance setting it apart from standard devices. To solve the problem of a variable focus, a LL is successfully employed. The automated focus improves handling and provides the opportunity for further automatization of the device. Due to the bright light source, we ensure comparable lighting situations for different examination conditions. This renders colors more comparable in different images. First results made with an earlier stage of the prototype already show the advantage of a non-contact dermatoscope device [7]. In the future, the arrangement of the elements can be further improved to realize a larger range in which the focus can be controlled. In combination with algorithms developed to appropriately analyze the images, this could lead to an improved and automated skin scanning device.

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