In the Proceedings of the International Conference on Image Processing (ICIP'96), Lausanne, 16–19 September 1996

ANALYSIS OF SKIN LESIONS WITH PIGMENTED NETWORKS

Stefan Fischer, Philippe Schmid

Signal Processing Laboratory,
Swiss Federal Institute of Technology,
CH-1015 Lausanne, Switzerland
fischer@ltssg3.epfl.ch

Joël Guillod

Hôpital Cantonal Universitaire de Genève
Clinique de Dermatologie
(Director: Prof. J.-H. Saurat)
CH-1211 Geneva, Switzerland

ABSTRACT

This paper deals with image processing for automatic analysis of pigmented skin lesions. A special emphasis is put on pigmented networks in epiluminescence microscopy (ELM) images. The purpose of processing images with pigmented skin lesions is the visualisation for education and training as well as for diagnosis support.

We use a colour based segmentation applied to the Karhunen-Loève transform of the *RGB* colour vectors to separate pigmented lesions from the skin and proceed with histogram equalisation and greyscale morphology to enhance and filter the pigmented networks. We demonstrate that we can enhance pigmented networks in skin lesions visually, and make them accessible to further analysis and classification.

1. INTRODUCTION

Skin melanoma is a malignant pigmented skin lesion which needs particular medical attention. Its incidence as well as its associated mortality rate is rapidly increasing in developed countries [1]. The consequences of a late diagnosis of malignant melanoma (MM) are very significant in terms of personal health, medical procedures and costs. Many studies have clearly shown that the prognosis of MM is directly depending on an early diagnosis followed by an appropriate surgical excision [1, 2, 3]. In fact, if an MM is diagnosed at an early stage and is properly excised, the patient will recover completely. On the contrary, an invasive MM reduces drastically the chance for the patient to survive because other effective therapeutic procedures are presently lacking.

As it is not always easy for clinicians to distinguish between benign lesions and early MM, techniques like epiluminescence microscopy (ELM) have been developed to improve the diagnosis of pigmented skin lesions. ELM is now a well recognised and established method to improve the clinical diagnosis of MM when used by dermatologists [4]. ELM is a non-invasive, in vivo technique which reveals features that are not perceptible by the dermatologist during his clinical observation. It renders the skin partially translucent and reveals the lower layers of the epidermis. This makes structural components like pigmented networks visible. With some exceptions, the presence of a pigmented network allows for the diagnosis of melanocytic lesions and excludes non-melanocytic lesions [5].

Systems for computer image analysis for melanoma diagnosis that use segmentation-based shape features have been developed [6]. However features that are based on the shape of lesions like size, symmetry, circularity and regularity of the border depend strongly on the edge-detection or segmentation algorithms that are employed. The borders of lesions are not always well defined. Artificial neural networks (ANN) and neural classifiers have been proposed for mimicking the diagnosis process of dermatologists which can hardly be described in terms of sets of linear measures [7].

The increasing occurrence of malignant melanoma cases and the relatively low rate of correct classifications from clinical diagnosis calls for the development of quantitative diagnosis support methods. Automatic diagnosis is justified if a disease being sought is common, if effective treatment is available and if it is possible to show that early diagnosis improves the chances of cure significantly. These criteria are met for malignant melanoma. It must also be shown that diagnosis methods are sufficiently sensitive to detect certain classes of lesions and yet specific enough to avoid false classifications.

2. IMAGE PROCESSING

A number of different processing steps must be performed to make pigmented networks accessible for statistical analysis and decision.

Our experiments demonstrate that using a colour

based segmentation does not allow for the extraction of pigmented networks because of the weak contrast within the network. However it is a robust method for separating lesions from the surrounding skin and for extracting homogeneous and differently coloured regions within the lesion.

We suggest to process images using the LAB colour space, or to use a Karhunen-Loève (KL) transformation of the RGB colour space followed by colour segmentation of the lesion to extract regions of interest. We then propose local histogram equalisation and mathematical grey scale morphology for enhancing and filtering regions containing a pigmented network.

2.1. Colour Space Transformation

We have investigated LAB, IHS and KL transform on colour vectors in the RGB colour space.

The LAB colour space has been proposed for automatic colour segmentation of images with skin tumours [8]. The LAB colour space uses a spherical coordinate system to describe the RGB colour space. The RGB space has been defined as a three-dimensional orthogonal space with three equally significant components. The distance of a colour to the origin in the RGB space describes the luminance component, the orientation of the colour vector is described by two angles A and B.

The use of the LAB colour space is motivated by the fact that it separates colour from brightness information. By discarding the luminance component it is possible to make the analysis independent from variations of the network that result in luminance differences in the image.

The separation of brightness information from colour can also be achieved using the IHS colour space, where I is the intensity, H the hue and S the saturation. Hue and saturation components are closely related to the way in which the human visual system (HVS) perceives colour. The IHS colour space is thus ideal for the use of image processing algorithms based on some of the colour sensing properties of the HVS [9].

The KL transform of the colour components allows for the enhancement of structures that are poor in contrast [9]. We use projections of the colour vectors onto the eigenvectors of the covariance matrix that models the variations of the colour components. The covariance matrix is computed with all colour vectors of the image.

2.2. Segmentation

The segmentation algorithm we used is based on an analysis of the histograms of each colour component [10]. A scale-space filter is applied to every histogram to calculate fingerprints that allow for the determination of colour classes. The fingerprints are described by the zero-crossings of the second derivatives of the histograms. Fingerprints are used in the histogram to define intervals that contain a dominant maximum. A coarse classification assigns pixels in intervals to a class defined by a maximum in the histogram, unclassified pixels are then assigned to the closest class using the fuzzy c-means technique.

We have developed a modified version of this algorithm that uses a two-dimensional histogram based on two chrominance components while discarding the luminance component. The idea is to avoid the contribution of different colours to one maximum in a histogram.

2.3. Local Histogram Equalisation

Although a region can be determined that contains pigmented networks, the network itself and the background does not have a homogeneous luminance and contrast in that region. We use a local histogram equalisation in a circular region to enhance the pigmented network homogeneously.

2.4. Grey Level Morphology

Because of the simple structural appearance of the pigmented networks a structural approach that uses mathematical morphology has been employed [9]. We use a morphological grey scale closing followed by an opening to smooth out impulsive noise without destroying the structure of the pigmented network.

3. EXPERIMENTS

It has been shown that digital images of a certain minimal spatial and pixel depth resolution are as informative for the diagnosis of skin lesions as photographic slides [11].

Our observation is that images from interlaced video signals require additional preprocessing. A Gaussian low-pass filter has been applied to eliminate horizontal lines that are visible in the image particularly when the camera has moved during image acquisition. Without smoothing the segmentation scheme we used (see paragraph 2.2) tends to enhance such horizontal structures and to produce artifacts. The filtering also prevents over-segmentation in noisy regions.

Fig. 1 shows an unclassified pigmented lesions captured with the ELM technique. Three regions can be observed: surrounding skin, light brown ring with pigmented network, dark centre of the lesion with globules and pigmented network that is poor in contrast.

The boundaries of the segmented regions are shown in Fig. 2. The segmentation result corresponds to the visual classification into three regions. We have compared segmentation results using IHS, La^*b^*, Lu^*v^*, UVW and LAB colour spaces as well as a KL transform of the vectors in the RGB colour space [12, 8]. Only lesions with well defined borders can be extracted by using a segmentation in the IHS or UVW colour spaces. By using a segmentation based on the chrominance components of the LAB, La^*b^*, or Lu^*v^* colour spaces we can completely separate the lesion from the surrounding skin even if the borders of the lesion are evanescent. The best results can be achieved by using the two principal components of a KL transform of the RGB colour vectors as shown in Fig. 2.

Fig. 3 displays a grey scale image of the region with pigmented networks. The grey levels of this image correspond to the most significant component of a KL transform applied to the RGB colour vectors in the region with the network. Fig. 4 shows the enhanced pigmented network. A local histogram equalisation in the segmented region has been applied followed by a smoothing with grey level morphology.

4. DISCUSSION

We can show that pigmented networks can be visibly enhanced with image processing methods. This makes them accessible for statistical analysis and classification.

We propose to use structural analysis because the networks are not regular enough to be described in terms of frequency components. Structural analysis with mathematical grey level morphology can result in binary images. The resulting binary network can then be analysed statistically to describe geometrical properties of the network. These measures can be used together with other features for the classification of pigmented skin lesions.

Especially in the context of differential diagnosis the analysis of images with pigmented skin lesions can be considered as a data base problem. Properties of pigmented networks can be used as features for searching and retrieval in dermatological image data bases.

Most of the available sensors and image acquisition systems use analog video standards. These standards are based on perceptual properties of the HVS, and are not necessarily optimal for the automatic diagnosis of pigmented skin lesions. The number of spectral channels we use is presently only defined by the available image sensors and colour reproduction systems and not by the requirements of an optimal diagnosis. The choice of spectral channels could be optimised for the analysis of pigmented skin lesions or other skin pathologies. The combination with other modalities like high-frequency ultrasound, tomographic imaging techniques, in-vivo confocal microscopy or in-vivo range-imaging of the skin surface could provide additional features for a more reliable diagnosis [13].

5. REFERENCES

[1] "NIH consensus development conference statement on diagnosis and treatment of early melanoma January 27-29, 1992". *The American Journal of Dermatopathology*, Vol. 15, No. 1, pp. 34–43, 1993.

[2] M. C. Mihm A. J. Sober, T. B. Fitzpatrick. "Primary melanoma of the skin: recognition and management". *Journal of the American Academy of Dermatology*, Vol. 2, No. 3, pp. 179–197, March 1980.

[3] A. Breslow. "Thickness, cross-sectional area and depth of invasion in the prognosis of cutaneous melanoma". *Annals of Surgery*, Vol. 172, No. 5, pp. 902–908, 1970.

[4] M. Binder, M. Schwarz, A. Winkler, A. Steiner, A. Kaider, P. Wolff, and H. Pehamberger. "Epiluminescence microscopy; a useful tool for the diagnosis of pigmented skin lesions for formally trained dermatologists". *Arch. Dermatol.*, Vol. 131, pp. 286–291, March 1995.

[5] W. Stolz, O. Braun-Falco, P. Bilek, M. Landthaler, and A. B. Cognetta. *Color Atlas of Dermatoscopy.* Blackwell Science, 1994.

[6] A. Green, N. Martin, J. Pfitzner, M. O'Rourke, and N. Knight. "Computer image analysis in the diagnosis of melanoma". *Journal of the American Academy of Dermatology*, Vol. 31, pp. 958–964, December 1994.

[7] F. Ercal, H.C. Lee, W. V. Stoecker, and R. H. Moss. "Skin cancer diagnosis using hierarchical neural networks and fuzzy systems". In C. H. Dagli, B. R. Fernàndez, J. Ghosh, and R. T. Soundar Kumara, editors, *Intelligent Engineering Systems Through Artificial Neural Networks; Proceedings of the Artificial Neural Networks in Engineering conference (ANNIE '94)*, pp. 613–618. ASME Press, November 1994.

[8] S. E. Umbaugh, R. H. Moss, and W. V. Stoecker. "Automatic color segmentation of images with application to detection of variegated coloring in skin

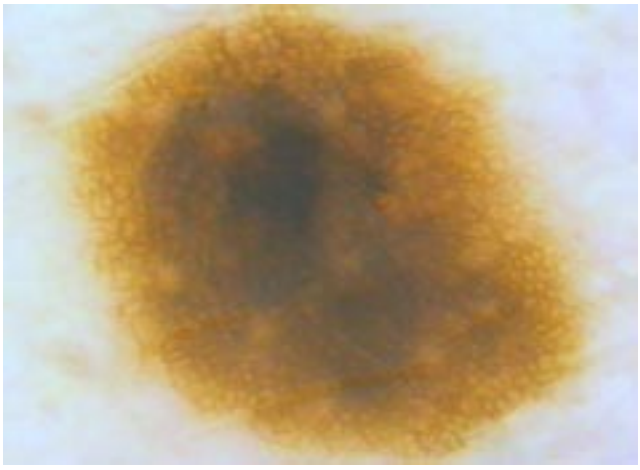

Figure 1: Original image of an unclassified skin lesion with a pigmented network.

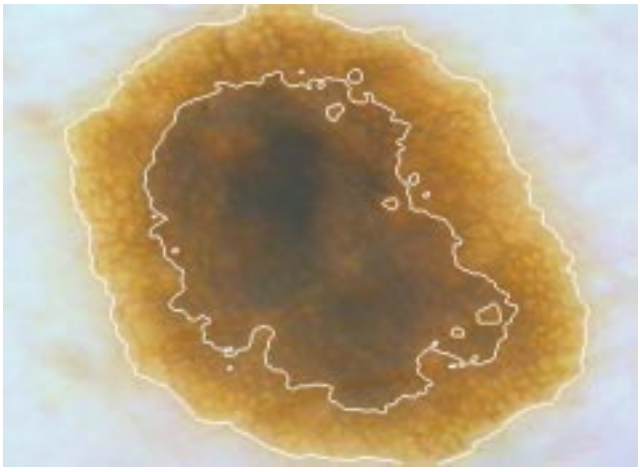

Figure 2: The borders of the segmented regions are shown as white lines.

Figure 3: Region with pigmented network, extracted by using the result of the segmentation.

Figure 4: Pigmented network after local histogram equalisation and morphological filtering.

tumors". *IEEE Engineering in Medicine and Biology*, Vol. 8, No. 4, pp. 43–52, December 1989.

[9] R. C. Gonzalez and P. A. Wintz. *Digital Image Processing*. Addison-Wesley, Reading, MA, 1977.

[10] Y. W. Lim and S. U. Lee. "On the color image segmentation algorithm based on the thresholding and the fuzzy c-means techniques". *Pattern Recognition*, Vol. 23, No. 9, pp. 935–952, 1990.

[11] D. A. Perednia, J. A. Gaines, and T. W. Butruille. "Comparison of the clinical informativeness of photographs and digital imaging media with multiple-choice receiver operating characteristic analysis". *Arch. Dermatol.*, Vol. 131, pp. 292–297, March 1995.

[12] G. Wyszecki and W. S. Stiles. *Color Science: Concepts and Methods, Quantitative Data and Formulae*. Wiley, second edition, 1982.

[13] L. Goldman. "New dermatological biomedical microscopes for early clinical diagnosis". In A. O. Wist and K. S. Heiferman, editors, *Clinical Applications of Modern Imaging Technologies; Proceedings of the SPIE*, Vol. 1894, pp. 4–7, 1993.