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Computer aided lesion border detection applied to macroscopic images

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ABSTRACT: Computer based techniques are playing increasingly important role in the diagnosis and early detection of malignant melanomas. However, this requires classification of pigmented lesions into benign and malign using imaging techniques and this is a challenging task. For the classification process first meaningful features must be extracted from the digital image. For feature extraction and the further classification process it is important to find the accurate boundary location of the lesion. There are many well known image processing algorithms, but there are also many problems to solve to get the best fitting mole border. In this article the main image processing problems for lesion border detection are discussed. Subsequently, two different approaches, namely edge and region based approaches to detect the lesion boundary, are described. We present example solutions, including an interactive region based method, which is mainly based on distance measurement in the CIE L*a*b colour-space and global thresholding of the resulting distance map.

INTRODUCTION

Skin cancer, especially the malignant melanoma is one of the deadliest cancers. Over the last years the incidence of the malignant melanoma has continuously increased. Because the cure of the cancer depends highly on its early diagnosis followed by an appropriate surgical excision, it is important to enhance the diagnostic capability of primary care clinicians to increase the accuracy of screening for skin cancer.
In dermatological departments of hospitals a great amount of macroscopic photographs of normal and abnormal moles are already available. These stored knowledge could be used to set up an intelligent system, which provides the functionality's to detect and classify pigmented lesions into non suspicious, suspicious and malignant.
After bringing the photographs into digital form, meaningful features for the classification process must be extracted. One important step is the separation of the mole from the surrounding healthy skin. A result of the separation process is the mole border. In several publications e.g. [1] it has been shown that the mole border is one important feature for the classification.
The success of the border segmentation and the following classification process is influenced by several attributes of the digital image. Therefore we will describe the major problems which are affecting the result of the segmentation process.
Next a short review of major border detection and lesion segmentation approaches are given. Several border detection methods are briefly discussed regarding their suitability for the border detection process including edge and region based operators. Finally we present a border detection algorithm which is based on an approach from Xu et. al. [2].

MAJOR PROBLEMS

The segmentation of the mole border in digital macroscopic images is affected by many problems which are mainly covered by the digital image. Some can be solved by altering the acquisition process and others are inherent within the image.

Major problems are:

1. *Floating border line:*
   The contrast between the pigmented lesion and the surrounding skin is very low. So the boundary between lesion and surrounding skin is difficult to establish.
2. *Hair:*
   The border of the mole is superimposed by hair which has a high contrast compared to 'normal' skin.
3. *Small size of the mole in the taken photo:*
   Is the mole in proportion to the surrounding skin too small it will reduce the usefulness of the border as an important feature for the classification.
4. *Reflections and shadows:*
   Reflections and shadows caused by wrong illumination are problems which occur very often. Reflections are highlights in the image while shadows are perceived as dark areas. The contrast of both to the surrounding skin can be cause problems for segmentation algorithms.
5. *Colour variation:*
   A change of e.g. the film, camera or the scanner is often responsible for colour variations. Before colour can be used as a feature a colour adjustment should be accomplished.
6. *Blurring within the image:*
   For example a false adjustment of e.g. the camera or the scanner can cause blurring in the digital image.

7. *Image contains other artefacts:*
   Due to registration and management in many dermatological images other objects like rulers, colour charts or the image number which reefers to the patient file can be found. For this reason the localisation of the mole is more difficult.

All the mentioned problems must be solved for the feature extraction process. Problem 3 and 6 can only be solved by altering the acquisition process. The others can be tackled by image processing methods. For the border detection all listed points are relevant. In publications many approaches are described to get rid of these difficulties. In the next section a short review of several segmentation schemes is given.

CURRENT RESEARCH

Umbaugh [3] proposed a combination of median filtering and a Nonskin masking algorithm to mask out noise, reflections and other unwanted artefacts, like hairs and rulers. At first the median filter is applied to suppress noise. In the second step the Nonskin algorithm is used. The Nonskin algorithm is a heuristically approach which suppresses all kind of non skin objects within the digital image. It removes also hair, but does not interpolate values for the suppressed pixels.
After the pre-processing phase six different colour segmentation methods are proposed: Adaptive Thresholding, Fuzzy c-Means, SCT/Center Split, PCT/Median Cut, Split and Merge and Multiresolution (for details see [3]). Next a data reduction by a grey-scale morphological opening and labelling of the remaining objects in the image is applied. The mole localisation is realised by calculating object properties. Area and circularity is used to determine the mole. After an object has been chosen, the border of the mole is encoded using the Freeman chain code [4].
Schmid [5] also noticed the problem that hair and reflections are induce for many segmentation algorithms. He also proposed an algorithm which masks out hair. The algorithm does not remove rulers or other objects, because it was developed for dermatoscopic images. Dermatoscopic images only show the lesion and the surrounding skin with an magnification of 1:10. Hair is very light absorbent and therefore the method uses a morphological closing with a spherical structuring element to each component of the image in the L* u* v* colour-space. Now the difference between the luminance of the original and the transformed image is detected. The difference represents mainly hair and for these pixels new values are interpolated in consideration of the neighbour pixels of the original image. Schmid investigated several edge preserving filtering techniques, including the well known median filter, which is suitable to filter lesion images.
Several segmentation techniques have been investigated including those mentioned by Umbaugh[3].
As described below Schmidt[5] investigated also the following edge oriented technique.
The approach was originally proposed by Denton et. al.[6]. First an edge preserve filtering is applied to reduce image noise. Denton proposed a 7x7 median filter. Next the lesion is located via thresholding, subsequent morphological closing and identification by size and shape. Now the diameter of the lesion is used for calculating the initial bounding box (lesion with surrounding skin). The diameter is also used for the calculation of the space constant σ for the Laplacian-of-Gaussian (LoG) edge detector. After the initial boundary is found, a successive refinement of the LoG and its application to the image leads to the resulting mole boundary.
In many publications (e.g. Schindewolf[7] and Hintz-Madsen[8]) a combination of the Karhunen - Loève transformation (also known as Hotelling transformation) of the RGB colour image and (optimal-)thresholding of the resulting grey-scale image have been proposed.
Another approach was introduced by Xu et. al.[2]. They are calculating the distance from the background colour to every pixel of the image in the CIE L*a*b colour-space. In the following step the distance map is converted through a suitable function into an intensity image. The intensity image is used to find an edge mask. All edges within the mask are used to calculate the final boundary of the lesion. For the edge detection a sobel edge detector is used.

SEGMENTATION SCHEME

The segmentation scheme we propose in this paper is mainly a combination of interactive selection, to clip the region of interest and subsequent distance measuring of the average background colour to every pixel of the lesion image. The measuring is similar to the above mentioned scheme of Xu et. al. [2]. Next we will describe the scheme in detail.

First the lesion must be manually pre-selected (see Fig. 1). The lesion must be surrounded by 'normal' skin, because the average background colour **b** is calculated of several pixels which are placed on the clipping rectangle.

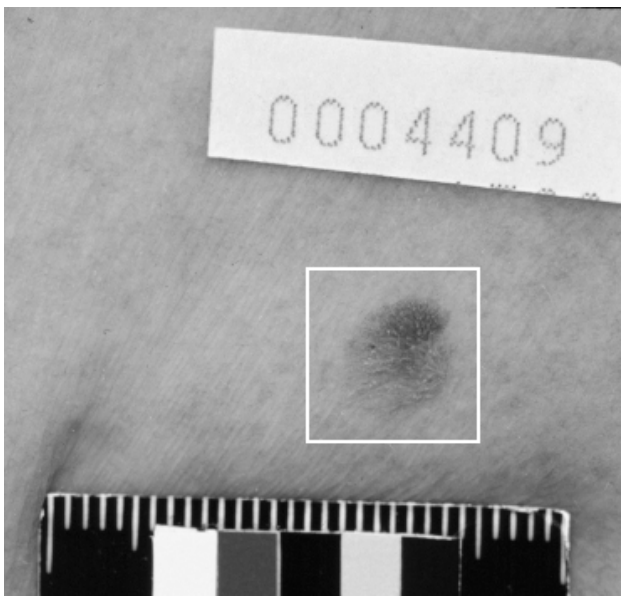

Figure 1: Marked region of interest (white rectangle).

Now the distance from the average background colour to every pixel of the clipped image is calculated. Before the measurement every pixel is converted into the CIE L*a*b colour-space. The CIE L*a*b spherical colour-space is device independent and uniform and therefore more suitable for measuring Euclidean distances than the RGB colour-space.

It is important to visualise every major step of the segmentation process to keep the technique transparent for the physician. For this reason the distances are transformed through a mapping equation into a 8 Bit grey-scale image. The mapping equation suppresses low distances and increases higher values. Lower values represents 'normal' skin while higher values are potential pixels of the lesion (see Fig. 2).

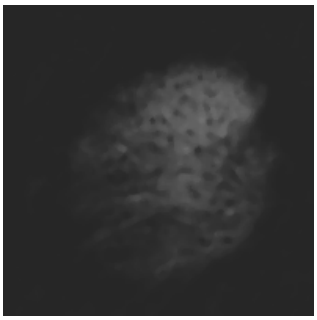

Figure 2: Intensity image

As mentioned before reflections, shadows and hair are a major problem for mostly all border detection methods. Therefore the intensity image is filtered using a median filter with the size 3x3 or 5x5.
The median filter could also be applied on the clipped image. But this is very time consuming because the calculation time for a median operator on colour images needs three times longer than a median applied on grey-scale images.
Figure 2 shows an example of a mapped distance image which is filtered by a 5x5 median (compare with marked lesion in Figure 1).

Next a histogram of the intensity image is calculated. Very low (=0) and high (=255) values are masked out because they only represents 'normal' skin or reflections which are not suppressed despite the median operator. Additionally the histogram is smoothed. Now a initial threshold $T_{initial}$ is determined. The first peak which is found in the histogram is set to $T_{initial}$. The final threshold is made up of $T_{initial}$ and a user defined constant ΔT :

$$T = T_{initial} + \Delta T$$

In preliminary tests ΔT set to 5 has shown good results for the thresholding process.

Thresholding with T is now performed on the intensity image. The result is the mask of the lesion. But there could be several small regions which are too small to be a proper skin lesion. After labelling of the different regions and calculating of their sizes, small regions can be localised and deleted.
The result consists of the final lesion mask. An example for a detected lesion mask is shown in figure 3.

Figure 3: Detected lesion mask

Chain encoding is the last step in our proposed segmentation scheme. The well known Freeman chain encoding[4] is used to represent the mole boundary in a more sophisticated way. In figure 4 the detected boundary of the lesion (compare with Fig. 1) is shown.

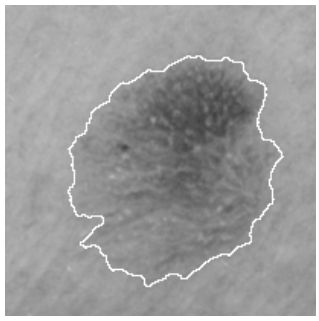

Figure 4: Detected lesion border (marked white)

A complete overview of our proposed segmentation scheme is given in figure 5.

PRELIMINARY RESULTS

The segmentation scheme was tested on 25 macroscopic lesion images. As mentioned before ΔT was set to 5. Labelled regions with less than 1000 pixels are suppressed.

Considering these parameters 80 % of the lesion borders were visually successfully detected. From the remaining 5 lesions 2 has a ΔT which was chosen slightly too low. For 1 lesion ΔT was chosen slightly too high.

The last 2 lesion images were taken from moles which are elevated and therefore the images covering strong shadows which have influence on the detection of the borderline.
In summary all lesions could be detected. But only 5 by manipulating the constant ΔT.

The smoothness of the boundary can be controlled by the used filter which is applied to the intensity image (see Fig. 2). A more smoothed boundary can be archived by choosing a median filter with a greater scale, for example 7x7 or 9x9.

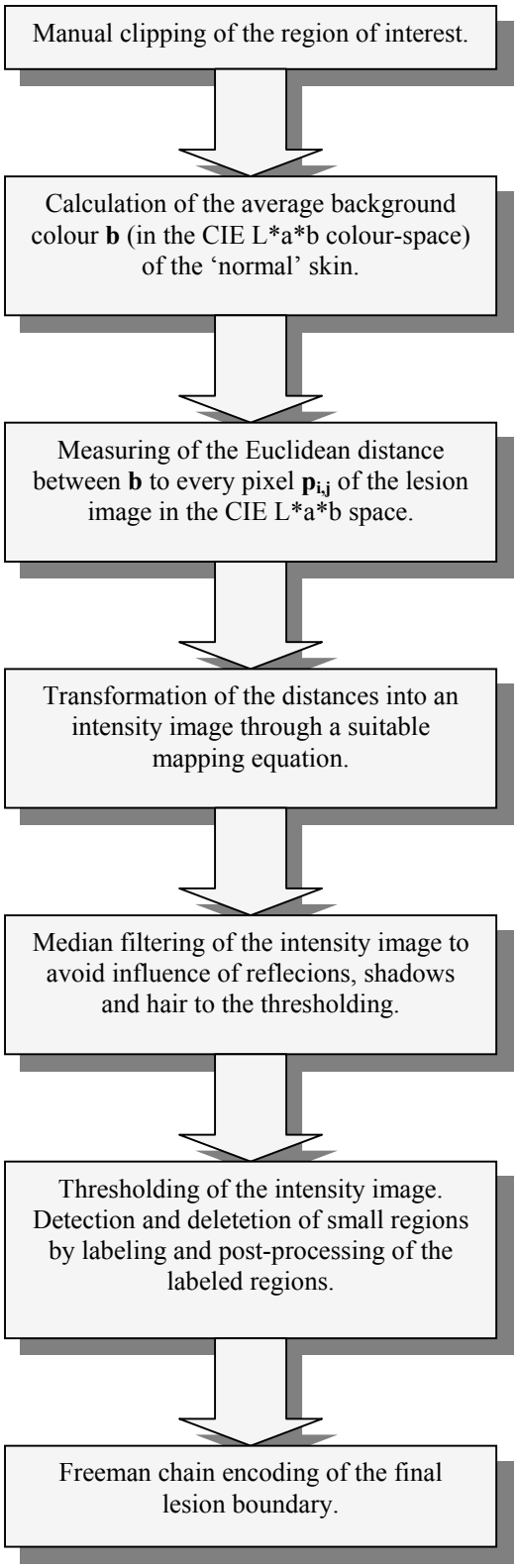

Figure 5: Overview of the segmentation scheme

CONCLUSIONS AND FUTURE WORK

We have presented a segmentation scheme which provides a fast and robust technique for the detection of the boundary of pigmented skin lesions in digital macroscopic images.

Further tests on a wide range of lesion images are necessary. Tests with dermatoscopic images should also be applied.
The preliminary tests have shown that the detection of the threshold *T* should be revised by more sophisticated techniques.
Our segmentation scheme is currently a supervised detection method. One major aim for the future will be to develop the scheme further to an unsupervised segmentation scheme. Therefore the first step of our scheme, the manually clipping of the lesion, should be replaced by an automatic lesion localisation method.

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