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Recognition of pigment network pattern in dermoscopy images based on fuzzy classification of pixels

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ABSTRACT

Background and Objective: One of the most relevant dermoscopic patterns is the pigment network. An innovative method of pattern recognition is presented for its detection in dermoscopy images.
Methods: It consists of two steps. In the first one, by means of a supervised machine learning process and after performing the extraction of different colour and texture features, a fuzzy classification of pixels into the three categories present in the pattern's definition ("net", "hole" and "other") is carried out. This enables the three corresponding fuzzy sets to be created and, as a result, the three probability images that map them out are generated. In the second step, the pigment network pattern is characterised from a parameterisation process –derived from the system specification– and the subsequent extraction of different features calculated from the combinations of image masks extracted from the probability images, corresponding to the alpha-cuts obtained from the fuzzy sets.
Results: The method was tested on a database of 875 images –by far the largest used in the state of the art to detect pigment network– extracted from a public Atlas of Dermoscopy, obtaining AUC results of 0.912 and 88%% accuracy, with 90.71%% sensitivity and 83.44%% specificity.
Conclusion: The main contribution of this method is the very design of the algorithm, highly innovative, which could also be used to deal with other pattern recognition problems of a similar nature. Other contributions are: 1. The good performance in discriminating between the pattern and the disturbing artefacts –which means that no prior preprocessing is required in this method– and between the pattern and other dermoscopic patterns; 2. It puts forward a new methodological approach for work of this kind, introducing the system specification as a required step prior to algorithm design and development, being this specification the basis for a required parameterisation –in the form of configurable parameters (with their value ranges) and set threshold values– of the algorithm and the subsequent conducting of the experiments.

1. Introduction

Dermoscopy is a widely-used technique in the early detection of melanoma. It enables the in-depth visualisation of structures, forms and colours that are not accessible through simple visual inspection, and also allows reproducibility in the diagnosis and the use of digital image processing techniques [1]. The most relevant indicators are dermoscopic patterns or structures [1], whereby a Computer Aided Diagnosis (CAD) system should deal with their recognition [2–4]. It is a complex issue as, on the one hand, from the point of view of image processing, it is a difficult problem to deal with and, on the other, its objectivation is difficult since, on many occasions, assessment by human experts is rather subjective [5]. Nonetheless, given its importance, some good methods have already been developed for many of the patterns [6–9].

One of the most relevant dermoscopic patterns is the pigment network [1], also known as the reticular pattern, whose presence is an indicator of the existence of melanin deep inside the layers of the skin. It is an important criterion for the purpose of discerning whether a lesion is melanocytic or not and an important indicator in the diagnosis of melanoma [1]. The name derives from the form of this structure, which resembles a net, darker in colour than the "holes" it forms, corresponding to the lesion's background [1]. There are two types of pigment network: typical (relatively uniform, regularly meshed, homogeneous in colour and usually thinning out at the periphery [10]) and atypical (non-uniform, with

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darker and/or broadened lines and "holes" that are heterogeneous in diameter and shape, these being the lines are often hyperpigmented and may end abruptly at the periphery [10]), the latter often being an indicator of malignancy [1]. Examples of pigment network can be seen in Figs. 3, 4, 7 and 8.

Recognition of pigment network pattern is a complex issue. On the one hand, what sometimes occurs is that there is little contrast between the network and the background. On the other, errors are common insofar as the pigment network may be confused with other dermoscopic structures such as globules or streaks, or with artefacts such as hair, ruler markings or even bubbles. Thus, and although several good methods have been described in recent years, this remains a challenging problem.

This work presents an innovative method for recognition of pigment network pattern in dermoscopy images. This method can also be used to help deal with other problems involving pattern recognition of a similar nature.

1.1. State of the art

A thorough revision of the state of the art has been conducted by the authors, which is shown in detail in [11], to which 3 recent works are added here. Numerous are the imaging techniques that have been used, as will be seen. After analyzing the most relevant works of reticular pattern recognition we can consider that the algorithms consist, roughly, of two steps.

Firstly, a mask candidate to be the reticular structure is obtained. For this, usually a transformation of the image is made to the grayscale followed by different techniques: line detection [12–16], thresholding [12,17–19], spectral features –mostly high-pass filters– [15,18–25], gray level co-occurence matrix (GLCM) [21,24,26,27], local binary pattern (LBP) [16,28], snakes [13], Laws' energy masks [27,29], neighborhood gray level dependence matrix (NGLDM) [29], Markov random fields (MRF) [7,30], discrete wavelet frame(DWF) [28], steerable pyramids transformation (SPT) [8] and curvelet transformation [31]. Sometimes combined with color features [8,16,19,20,22,24,28]. In most of works, from the generated mask a post-processing process is performed using morphological techniques.

Secondly, as the main objective of most of the studies is also determining whether or not it has a reticular pattern, then most of them include morphological/structural/geometric characterisations of the pigment network [14,15,17,19–27,29,31] and, in some cases, mapping of the network structure to a graph-based estructure [20,21,25]. Sometimes chromatic features are used [8,16,19,20,22,24,28,30]. Finally, this is fed into a supervised machine learning process by performing either an empirical selection of threshold values or using a statistical function or a classifier.

Below are described the studies deemed most relevant by the authors in pigment network recognition, with a high number of images available for testing and the highest rates of reliability: 1. Sadeghi et al. [20], in which, following use of the Laplacian of Gaussian (LoG) filter and a subsequent processing, a graph structure is obtained from which a feature known as "density ratio" is calculated, which indicates the presence/absence of the pattern; 2. Barata et al. [23], in which, following use of a bank of directional filters and subsequent processing, five different morphological features are calculated, characterising the pigment network for its recognition; 3. Garcia-Arroyo et al. [24], in which a supervised machine learning process on a pixel level is carried out in order to obtain a mask with the candidate pixels to be part of the pigment network, which is subsequently processed using structural analysis, and finally making the pigment network recognition. In 4 are shown the results obtained in each of these three works and are also compared to the proposed method.

1.1.1. Contribution

Despite the importance of previous works, pigment network recognition remains a challenging problem and the proposed work attempts to address some of the shortcomings identified by the authors in the state of the art. The main contribution made by our work is the innovative design of the pattern recognition method, based on fuzzy classification of image pixels, which could also be used to deal with other pattern recognition problems of a similar nature. Moreover, it provides other improvements over other previous works, as will be commented in Section 4.1.

2. Materials and methods

2.1. Image database

The image database contains 875 images randomly extracted from the Interactive Atlas of Dermoscopy [32], used in the vast majority of important studies on dermoscopic pattern recognition. The image size is 768×512 pixels, with 10x increase and 72 ppi resolution, and is high-quality compressed in JPG format. All the images are labelled in relation to the pigment network pattern as belonging to "absent" or "present" categories, taken according to the diagnosis presented in the Atlas, carried out by expert dermatologists.

2.2. Specification of the system

In most works relating to pattern recognition from dermoscopy images, the description in medical language is provided as a specification of the system, and this is written in a language that is not deemed to be too formal. Hence, it is quite common in establishing what the method actually attempts to do to analyse the System Design section and, on many occasions, even the Results section too. To improve on this, the proposed work puts forward a new methodological approach for methods of this kind, introducing the system specification as a required step prior to algorithm design and development, being this specification the basis for a required parameterisation process which supports the design and development of the algorithm and the realisation of the experiments. This specification is carried out using the pattern' s definition itself, the exhaustive study of the dermoscopy images obtained from the database, the information provided by expert dermatologists and the labelling carried out by the latter. This new approach constitutes an attempt to formalise the design of dermoscopic pattern recognition methods in a more optimal way.

This specification can be carried out in different ways. In this work was made in the form of a set of requirements in structured natural language: 1. For an image to have a pigment network pattern, it must contain a structure of this type in some part of the lesion. This structure is a net shape, which is light brown, dark brown, grey or black in colour, the "holes" being a lighter colour than the "net". In some cases, there may be little contrast or the net is faint; 2. The texture is highly characteristic, both in "net" and "hole" type pixels; 3. This net shape comprises one or more structures in the shape of a net (subnets), with one or more cells together in each one, making a total of cells greater or equal than two; 4. Even though the mesh width of the net differs within the same lesion (particularly in atypical cases), the width is normally similar on a local scale. Likewise, even though the cells may be different sizes within the same lesion (particularly in atypical cases), they are normally consistent in size with others on a local scale; 5. On a global level for the set of images used, there is a range for such sizes corresponding to the characteristics of the images being studied (in the event of these changing, the ranges would also change); 6. There are some images in which it is very difficult to discern the pattern, even for a human expert. In addition, due to