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A computational approach for detecting pigmented skin lesions in macroscopic images

Roberta B. Oliveira[a], Norian Marranghello[b], Aledir S. Pereira[b], João Manuel R.S. Tavares[a,*]

[a] Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial, Departamento de Engenharia Mecânica, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, s/n, 4200-465 - Porto, Portugal

[b] Departamento de Ciências de Computação e Estatística, Instituto de Biociências, Letras e Ciências Exatas, Universidade Estadual Paulista, Rua Cristóvão Colombo, 2265, CEP: 15054-000, São José do Rio Preto, SP, Brazil

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ABSTRACT

Skin cancer is considered one of the most common types of cancer in several countries and its incidence rate has increased in recent years. Computational methods have been developed to assist dermatologists in early diagnosis of skin cancer. Computational analysis of skin lesion images has become a challenging research area due to the difficulty in discerning some types of skin lesions. A novel computational approach is presented for extracting skin lesion features from images based on asymmetry, border, colour and texture analysis, in order to diagnose skin lesion types. The approach is based on an anisotropic diffusion filter, an active contour model without edges and a support vector machine. Experiments were performed regarding the segmentation and classification of pigmented skin lesions in macroscopic images, with the results obtained being very promising.

1. Introduction

Computational analysis of skin lesion images is an area of great research interest due to its importance in skin cancer prevention, particularly in achieving a successful early diagnosis (Celebi et al., 2007b; Filho, Ma, & Tavares, 2015; Scharcanski & Celebi, 2013). Such lesions, which can be classified as benign or malignant, are mainly due to abnormal production of melanocyte cells originating from factors such as excessive sun exposure. Melanocyte cells are responsible for creating the substance melanin, whose main function is to provide skin pigmentation. In the case of malignant cells, i.e. melanoma (Fig. 1a), such cells divide quickly and may invade other parts of the body. An increasing number of deaths due to melanoma have been observed worldwide, since this type of malignant lesion is the most aggressive compared to other lesion types due to its high level of metastasis (INCA, 2014). Benign lesions display a more organized structure than malignant lesions, since the former are unable to proliferate into other tissues. Seborrheic keratosis (Fig. 1b) and melanocytic nevus (Fig. 1c) are examples of benign lesions. However, these skin lesions have also been of global concern, since some types of nevi may become melanoma; moreover a melanoma may resemble a seborrheic keratosis or a nevus in its initial state.

Different non-invasive imaging techniques have been employed to assist dermatologists in diagnosing skin lesions (Smith & MacNeil, 2011). Macroscopic images, commonly known as clinical images, are normally used in computational analysis of skin lesions (Cavalcanti & Scharcanski, 2013; Wong, Scharcanski, & Fieguth, 2011), since such images may be obtained using common digital video or image cameras. Fig. 1 presents examples of macroscopic images. However, their imaging conditions are frequently inconsistent; for example, images are acquired from variable distances and/or under different illumination conditions. Furthermore, the images may have poor resolution, which may be challenging when the lesion under study is small. An additional problem with clinical images is related to the presence of artefacts, such as hair, reflections, shadows and skin lines, which may hinder adequate analysis of the imaged skin lesions.

Pre-processing, segmentation, feature extraction, and classification are fundamental steps commonly found in computational systems of image analysis. In terms of skin lesions, the image pre-processing step is an important aspect for good segmentation, i.e. identification, of the image's pigmented skin lesions. Effective approaches based on colour space transformation (Abbas, Celebi, & Garcia, 2012a), contrast enhancement

* Corresponding author. Fax: +351 22 508 1445.
E-mail addresses: roberta.oliveira@fe.up.pt (R.B. Oliveira), norian@ibilce.unesp.br (N. Marranghello), aledir@ibilce.unesp.br (A.S. Pereira), tavares@fe.up.pt (J.M.R.S. Tavares).
URL: http://www.fe.up.pt/~tavares (J.M.R.S. Tavares)

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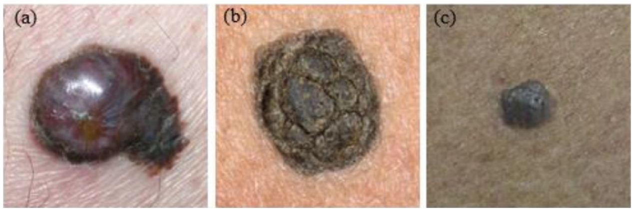

Fig. 1. Three examples of pigmented skin lesions: (a) melanoma, (b) seborrheic keratosis and (c) melanocytic nevus.

(Schaefer, Rajab, Celebi, & Iyatomi, 2011) and artefact removal (Abbas, Garcia, Celebi, Ahmad, & Mushtaq, 2013b) have been proposed for this step in order to improve the accuracy of the following segmentation step. Segmentation allows for extracting the region of interest (ROI) from the macroscopic image under analysis. Previous studies (Silveira et al., 2009; Wong et al., 2011; Zhou et al., 2010) have shown that computational methods for image segmentation may provide suitable results for the identification of skin lesions in images.

The feature extraction of skin lesion images is usually based on methods used by dermatologists in their clinical routine diagnosis. Of these methods, the ABCD rule is mostly used, being a criteria based on the Asymmetry, Border, Colour and Diameter characteristics of the lesion under study (Abbasi et al., 2004). The asymmetry criterion may be examined by dividing the region of the lesion into two sub-regions by an axis of symmetry, in order to analyse the similarity of the area by overlapping the two sub-regions along the axis. The lesion is considered symmetric when the two sub-regions are highly similar, which is prevalent in benign lesions. Otherwise, the lesion is considered asymmetric which is associated with malignant lesions. The border criterion corresponds to the measure of the regularity of the lesion's shape. According to this criterion, a border of regular shape is associated with benign lesions while a border of irregular shape is associated with malignant lesions instead. The colour criterion consists of analysing the tonality variation of the pigmented skin lesions in order to identify the malignant lesions, which usually present non-uniform colours. The diameter criterion is associated with the size of the lesion and is defined by the greatest distance between any two points of the lesion's border. As such, a diameter equal to or greater than 6 (six) millimetres may indicate malignancy. Texture analysis may also be performed for image-based examination of skin lesions, since it assists in discriminating benign from malignant lesions by assessing the roughness of their structure (Cavalcanti & Scharcanski, 2013).

Several computational solutions (Celebi et al., 2007b; Iyatomi, et al., 2010) have been proposed for extracting features from pigmented skin lesions in images in order to represent them according to certain criteria. Then, the classification step consists of recognizing and interpreting the information about the pigmented skin lesions based on these features. Hence, computational classifiers are important tools to assist the computational diagnosis of skin lesions in macroscopic images (Celebi et al., 2008a; Iyatomi, et al., 2008; Maglogiannis & Doukas, 2009).

The objective of this work was to develop a novel computational approach based on the ABCD rule and texture analysis for the identification and classification of pigmented skin lesions in macroscopic images, in order to provide information that may assist dermatologists in their diagnosis. In this approach, an anisotropic diffusion filter (Barcelos, Boaventura, & Silva, 2003) is applied to reduce the noise present in the image under study. Then, the active contour model without edges (Chan & Vese, 2001) is employed in the segmentation of the lesion in the pre-processed image. Afterwards, features related to the asymmetry, border, colour and texture of the lesion are extracted from the segmented image. Finally, the features are used as input to a support vector machine (SVM) classifier (Burges, 1998) to classify the skin lesion.

This paper is organized as follows: a review of the computational methods that have been applied to classify pigmented skin cancers and other skin lesions is provided in Section 2. A novel approach for detecting and classifying skin lesions in dermoscopy images is proposed in Section 3. The results and their discussion are provided in Section 4. Finally, conclusions drawn and proposal for future studies are in the last section.

2. Related studies

Computer-aided diagnosis (CAD) systems for skin lesions in images have been proposed in order to assist dermatologists, predominantly in the early assessment of skin cancer. In these systems, image filters are commonly applied to pre-process the input images in order to increase the accuracy of the segmentation step. A median filter, which is a non-linear image filtering algorithm, has been applied often to smooth images of skin lesions as well as to remove artefacts, preserving the border of the lesion, which is imperative to assure adequate segmentation (Celebi et al., 2007b, 2008b; Silveira et al., 2009). An anisotropic diffusion filter has also been regularly used for smoothing skin lesion images, particularly to remove artefacts with good results and without losing relevant information about lesions (Barcelos & Pires, 2009). Based on set theory, morphological filtering (Gonzalez & Woods, 2002) enables removing image noise (Norton et al., 2010; Silveira et al., 2009), and may also be used to enhance skin lesions in images (Beuren, Janasieivicz, Pinheiro, Grando, & Facon, 2012), as well as to include areas with borders of low contrast in previously detected lesion regions (Norton et al., 2010, 2012).

Algorithms of image segmentation have been developed based on several techniques to assist the diagnosis of skin lesions from images (Oliveira et al., 2016). From these, threshold-based algorithms have been widely used, mainly because of their simplicity. Thus, thresholding algorithms, such as the Otsu (Celebi et al., 2007b; Celebi, Wen, Hwang, Iyatomi, & Schaefer, 2013; Norton et al., 2010, 2012), type-2 fuzzy logic (Yuksel & Borlu, 2009) and the Renyi entropy method (Beuren et al., 2012), aim to establish the threshold values in order to separate the regions of interest (ROIs) in the input images. However, these techniques may reveal some problems; for example the segmented lesions tend to be smaller than their real size, and the segmentation process may lead to highly irregular lesion borders (Yuksel & Borlu, 2009).

Algorithms based on active contour models (ACM) have been frequently proposed for the segmentation of skin lesions in images (Abbas et al., 2012a; Silveira et al., 2009; Zhou et al., 2010). In these algorithms, initial curves move toward the boundaries of the objects of interest through appropriate deformation. The algorithms of active contour may be classified as edge- or region-based models (Zhang, Song, & Zhang, 2010) according to the technique used to track the curves movement. Additionally, mixed models have been also adopted, see, for example, Li, Xu, Gui, and Fox (2010). The edge-based models include classic parametric models (Kass, Witkin, & Terzopoulos, 1988), gradient vector flow (GVF) (Xu & Prince, 1998) and geometric (or geodesic) active contours (GAC) (Paragios & Deriche, 2002). However, classic parametric models and GVF have difficulty in dealing with topological changes and large curvatures. On the other hand, GAC models, such as level-set-based algorithms, do not present such problems. The region-based active contour model proposed by Chan and Vese (2001) has been used in the segmentation of skin lesions (Silveira et al., 2009) due to its advantages relatively to other segmentation algorithms based on ACM (Chan & Vese, 2001), such as: (1) the initial curve may be defined more freely in the input image, (2) the inner contours are automatically detected without the