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Computational methods for the image segmentation of pigmented skin lesions: A review

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ABSTRACT

Background and objectives: Because skin cancer affects millions of people worldwide, computational methods for the segmentation of pigmented skin lesions in images have been developed in order to assist dermatologists in their diagnosis. This paper aims to present a review of the current methods, and outline a comparative analysis with regards to several of the fundamental steps of image processing, such as image acquisition, pre-processing and segmentation.

Methods: Techniques that have been proposed to achieve these tasks were identified and reviewed. As to the image segmentation task, the techniques were classified according to their principle.

Results: The techniques employed in each step are explained, and their strengths and weaknesses are identified. In addition, several of the reviewed techniques are applied to macroscopic and dermoscopy images in order to exemplify their results.

Conclusions: The image segmentation of skin lesions has been addressed successfully in many studies; however, there is a demand for new methodologies in order to improve the efficiency.

1. Introduction

Pigmented skin lesions, which may be classified as benign or malignant, are mainly caused by an abnormal production of a group of cells in some specific regions. Benign lesions have a more organized behaviour than malignant lesions, since the former do not proliferate into other tissues. Nevus, such as melanocytic, blue, halo, sptiz and dysplastic (Fig. 1a), and seborrheic keratosis (Fig. 1b), are examples of benign lesions. In

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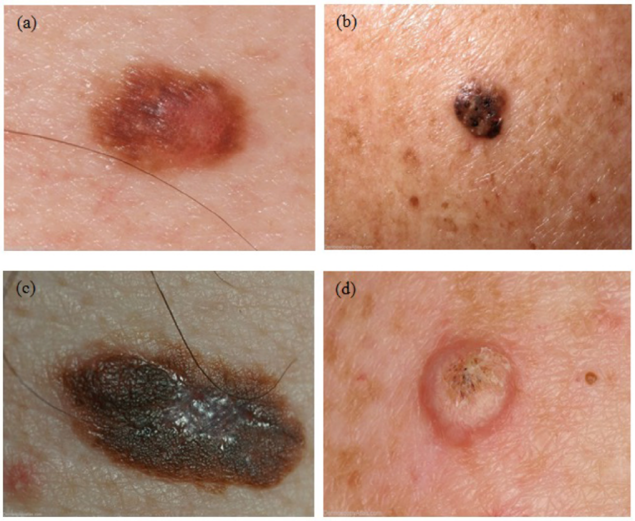

Fig. 1 – Four examples of skin lesions: (a) dysplastic nevus, (b) seborrheic keratosis, (c) melanoma, and (d) squamous cell carcinoma (images publicly available in [1]).

the case of malignant lesions, i.e., skin cancer, the cells split quickly, and may invade other parts of the body. Indeed, these cells do not die as generally occurs with normal cells. Skin cancer may be divided into two categories: melanoma (Fig. 1c) and non-melanoma (Fig. 1d). Basal cell carcinoma and squamous cell carcinoma are two examples of non-melanoma skin cancer (NMSC) and are the most common of all skin cancers. Moreover, these types of cancer have a higher chance of cure than melanoma, since they have a reduced capacity to spread (metastasis) to other parts of the body. Melanoma is the most aggressive form of skin cancer and the one with the highest mortality rate due to its high levels of metastasis [2].

Melanoma was the 19th most common cancer worldwide in 2008, with an approximate estimation of 200,000 new cases, and with the highest incidence rate in Australia/New Zealand, Northern America and Northern Europe, and the lowest in South-Central Asia [3]. Table 1 presents recent data regarding skin cancer in the United States of America (USA), the United Kingdom (UK) and Brazil, according to gender. In the USA, 76,100 new cases of melanoma were estimated to be diagnosed in 2014 [4]. This estimate does not include NMSC, since this form of skin cancer is not required to be reported to cancer registries.

Table 1 – Number of new cases of skin cancer, according to gender, in the USA, UK and Brazil.

Country	Type of skin cancer	Year	Number of new cases	
			Male	Female
USA[a]	Melanoma	2014	43,890	32,210
UK[b]	Melanoma	2010	6201	6617
	Non-melanoma		55,747	43,802
Brazil[c]	Melanoma	2014	2960	2930
	Non-melanoma		98,420	83,710

[a] Estimated number, based on 1995–2010 incidence rates.
[b] Confirmed cases in 2010.
[c] Estimated number in 2014 and valid also for 2015.

For the same year, 9710 deaths from melanoma were estimated. Another interesting point concerns melanoma incidence rates, which have increased during the last 30 years; for example, the incidence rates from 2006 to 2010 have increased by 2.7% per year. In the UK, melanoma was the 15th most common cancer in 2010, with approximately 12,800 new cases of this disease [3]. As a result, melanoma was the 18th most common cause of death from cancer in the UK. In 2011, there were 2209 deaths from melanoma, and 590 deaths from NMSC in the UK. Of these deaths from melanoma, 59% of the deaths were male patients, and 41% of the deaths were female patients. In Brazil, NMSC will be the most common form of cancer, since approximately 182,000 new cases are estimated in 2014 and 2015 [5]. Although NMSC has a lower mortality rate, it has a higher incidence than melanoma.

Recently, there has been a great interest in the development of computer-aided diagnosis (CAD) systems for the detection and analysis of pigmented skin lesions from images [6–9], which can assist the dermatologist in preventing the development of malignant lesions. Particularly, CAD systems may be used to monitor benign skin lesions, in order to prevent the development of malignancy. Moreover, malignant lesions may be diagnosed at an early stage, during which the patient has a higher probability of cure, and more favourable conditions for being properly treated.

On the other hand, there is also a great interest concerning the image segmentation step of the CAD systems. This step allows for a better representation of the lesion under study, and extraction of its features. Image segmentation has, therefore, a critical role in the effectiveness of the CAD systems. Previous studies [10–15] have shown that computational methods for image segmentation may provide suitable results for the identification of skin lesions in images. Frequently, the images under analysis are pre-processed for image enhancement and artefact removal, so that more robust segmentations may be achieved [16,17]. An overview of lesion border detection methods, which addresses the pre-processing, segmentation and post-processing steps, is presented in Celebi et al. [18]. In addition, the authors also discuss performance evaluation issues and propose guidelines for future studies. However, they primarily focus on dermoscopy images of pigmented skin lesions, and the segmentation methods were classified according to the images to be segmented. In this review, we introduce some of the most relevant solutions that have been developed to assist the diagnosis of skin lesions from images, including those concerning the steps of image acquisition, pre-processing and segmentation. In particular, we comprehensively review the computational techniques that have been suggested for the image segmentation of pigmented skin lesions. In the following sections, these techniques are classified into five classes according to their segmentation principle, specifically, based on edges, thresholding, regions, artificial intelligence techniques, and the ones based on active contours. In addition, several of the reviewed techniques are applied to macroscopic and dermoscopy images, in order to exemplify and discuss their applications.

The paper is organized as follows: in Section 2, a review of the current state-of-the-art concerning the image segmentation of pigmented skin lesions is provided. In addition, smoothing and segmentation results by using several methods