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Dermoscopic assisted diagnosis in melanoma: Reviewing results, optimizing methodologies and quantifying empirical guidelines

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ABSTRACT

Early diagnosis is still the most important factor to deal with skin cancer, a disease that challenges physicians and researchers. It has benefited from computer-aided diagnosis methods that successfully combine dermoscopy, Digital Image Processing, and Machine Learning techniques. This paper aims to approximate medical professionals working with dermoscopy to these methods, to join the challenge of melanoma early detection. Accordingly, a proposal for extracting, selecting and combining texture and shape features from dermoscopic images is presented. The Feature Selection task is added to the learning process to potentiate the quality of classification models. Three classical Machine Learning algorithms were applied to differentiate melanoma from non-melanoma images. The models are evaluated by standard performance measures and a multi-criteria decision analysis method. This is the first time such method is used in melanoma diagnosis. As a result, we found a decision tree that performs well and allows the explicit representation and analysis of the knowledge learned from the images. In addition, the competitiveness of our decision models in comparison with literature approaches reviewed in this work encourages further applications of Machine Learning and Feature Selection to assist computer-aided diagnosis.

1. Introduction

Starting from the simple Laennec's stethoscope to the most recent technology among image advances in medical practice, the improvements regarding medical devices always combined the existence of a practical problem and the development of technology to answer these specific needs. This historical beginning note aims to reflect the valuable dialog between Medicine and Engineering in clinical derived technological improvements, establishing the interdisciplinary approach as a successful strategy to the final goal of improving health care assistance.

Cancer, a major worldwide challenge in basic and clinical research, has gained even more visibility and control with this dialog [1]. Despite important advances in this field to understand the genesis and the control mechanisms, an early diagnosis is still a strong tool for treatment management and prognosis. This is also the case in skin cancer [2].

Epidemiology of skin cancer is frightful. The American Society of Cancer shows that the occurrence of new cases of skin cancer each year is higher than the combined incidence of breast, prostate, lung and colon cancers [3]. Also, it is reinforced in [4] that over the past three decades, more people have had skin cancer than all other cancers combined.

When a histological study of the skin is performed, it is possible to describe three main layers: epidermis, dermis, and hypodermis. The upper layer is itself divided into five more sublayers. Among other types of cells with several functions present in the skin, the melanocytes are specialized cells located in the basal layer of the epidermis. After sun exposure in physiological conditions, these particular cells produce a brown/dark pigment known as melanin. The presence of this pigment

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allows one to classify skin lesions as melanocytic (when it is present) or non-melanocytic (otherwise).

Regarding the classification of skin cancer, it is possible to identify three types according to the origin of the process at the skin layer. Basal Cell Carcinoma (BCC) originates from the basal layer of the epidermis and is the most common type of skin cancer. BCC usually appears on the face, neck or back, presenting a slow-growing locally invasive, thus not presenting metastases.

Spinous Cell Carcinoma (SCC) has its origin in the middle layers of the epidermis (spine layer) and is the second most common type of skin cancer. In this case, the lesion usually is fast growing and is more aggressive than BCC.

Malignant melanoma (or simply melanoma) is the third skin cancer type and the most dangerous one. It is also present in other organs where melanin exists, such as eyes, gastrointestinal tract and meninges. Unlike the two previous cases where the chronic sun exposure is a risk factor, here the acute sun exposure can trigger the carcinogenic process. This fact puts forward the importance of sun exposure prevention campaigns.

The melanoma diagnosis is established after the excision of the lesion and subsequent histological study. The Breslow thickness, the microscopic ulceration, and mitotic rate have been used since 2010 to determine clinical stages of melanoma and to define treatment and prognosis [5].

Due to the central role of early diagnosis in skin cancer, a detailed exam of the skin in suspicious lesions is crucial. Hence, the use of digital image processing techniques is the natural approach to avoid the subjectivity of the human eye assessment and to provide an accurate way to quantify important clues to assist a focused diagnosis. Several protocols have been used in dermatology practice. The ABCD rule, 7 point check-list, and the Menzies method are the most known among them [6].

The use of dermoscopy in skin analysis is a practice with documented results in terms of clinical outcomes, when compared with the naked eye examination, by reducing the dermatological surgery workload of false-positive lesions. As a result, it leads to cost savings, reduced morbidity, and less scarring [7]. Also in terms of cost-effective assessment, dermoscopy decreases the number of excised benign lesions and the early detection of melanomas [8,9].

Currently, it is established the advantage of combining dermoscopy with a detailed physical examination of the skin. The dissemination of digital technology in hospitals, joining with the good performance of image processing algorithms, empower the use of Machine Learning (ML) techniques in an integrated and broadly disseminated strategy of Computer-Aided Diagnosis (CAD), as the next natural step in dermoscopy practice. The use of CAD in Medicine began around 1980 [10] and since then, the successful application has proved the relevance of its use [11]. This is the case in the emergency triage [12], related to the automatic detection of polyps in colonoscopy [13–15] and calcifications in mammography [16] as well as in chest imaging [17]. In these successful cases, the low number of false positives indicates high sensitivity levels, being determinant to the adherence of the medical community to these tools, avoiding to waste time in classifying bad hits.

Although the number of CAD publications increased in the last decades, the comparison of results between pieces of work is an awkward task. This limitation is due to some methodological constraint, such as redundancies, sampling, under and overfitting, as well as due to the absence of some of the standard metrics to evaluate the performance of the classifiers in terms of Sensitivity, Specificity, and Accuracy, as discussed in [18].

In this work, the use of ML in dermoscopy to assist diagnosis of melanocytic images is addressed. In particular, the extraction and selection of classical texture and shape features are followed by the use of three ML algorithms. Afterward, the performance of these algorithms in the classification problem melanoma *versus* non-melanoma is evaluated. This strategy of using the most promising features and well-known classification algorithms for this particular challenge accomplishes two objectives. First, the use of conventional algorithms will approach those who apply digital techniques only as a user. Second, it is aligned with the major goal of setting optimized algorithms and parameters to achieve high levels of sensitivity and specificity. Moreover, this strategy will put forward these tools in the track of its use as a truly CAD strategy in dermoscopy.

2. Review on melanoma classification results

The starting point for this work is the optimization of classic techniques in ML in dermoscopy, as well as establishing a way to evaluate its performance. In order to assess the obtained results, it is mandatory to perform the state of the art in what refers to the classification results within recent publications enrolling ML methodologies and to evaluate the dependence of these different approaches in the performance of the classifiers.

With the purpose of literature comparison, a comprehensive review of 13 papers studying the melanoma classification issue on dermoscopy images, published in the last five years (2013–2017), was conducted. Table 1 compares our proposal with the approaches reported in the 13 papers. This table also defines new abbreviations regarding method names. The following criteria were considered:

- Image set size (M + NM): number of images, including Melanoma (M) and Non-Melanoma (NM) cases, used in the study;
- #Features: number of single descriptors or descriptors categories belonging to a collection;
- Feature categories: categories of the dermoscopy image descriptors;
- Dimensionality reduction method: Feature Selection or feature construction[1] method applied in the study;
- Classification algorithm(s): supervised ML algorithm(s) used to induce classifiers;
- Performance measure(s): measures considered to evaluate the performance of classifiers;
- Evaluation strategy: sampling method adopted to estimate the ML algorithm(s) performance;
- Statistical test(s): test(s) employed to verify the occurrence of significant differences among classifiers.

A classification method based on a local image descriptor, widely known as Bag-of-Features, was evaluated in [19] to differentiate melanoma from benign lesions. The paper compares distinct strategies to extract regions of interest and achieves results showing that texture-based detectors generally outperform the dense sampling strategy.

With the same purpose, a Bag-of-Features model was also applied in [20] and [21] to identify the role of different descriptors. In the first study, the authors investigated a new feature set based on color keypoint detectors and Color-SIFT. Their outcomes evidenced that the color extensions of SIFT are more discriminative than the SIFT variation computed in the luminance images. In the second study, the authors compared different local texture and color descriptors. The obtained results indicated that the latter feature type outperformed the former one. Another characteristic of these studies is that both of them dealt with the class imbalance problem in the selected dermoscopic images. To do so, the authors have created artificial instances by repeating the feature values of melanoma cases and adding Gaussian noise.

In [22], the applicability of color constancy was analyzed by using two color-based approaches. The idea was to reduce the influence of the acquisition devices and settings on the color features extracted from the

[1] Feature construction, *a.k.a* feature extraction by the data mining community, builds new and more expressive features from the existing ones by mapping the input dimension space into another one usually smaller.

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