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Features identification for automatic burn classification

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ABSTRACT

Purpose: In this paper an automatic system to diagnose burn depths based on colour digital photographs is presented.

Justification: There is a low success rate in the determination of burn depth for inexperienced surgeons (around 50%), which rises to the range from 64 to 76% for experienced surgeons. In order to establish the first treatment, which is crucial for the patient evolution, the determination of the burn depth is one of the main steps. As the cost of maintaining a Burn Unit is very high, it would be desirable to have an automatic system to give a first assessment in local medical centres or at the emergency, where there is a lack of specialists.

Method: To this aim a psychophysical experiment to determine the physical characteristics that physicians employ to diagnose a burn depth is described. A Multidimensional Scaling Analysis (MDS) is then applied to the data obtained from the experiment in order to identify these physical features. Subsequently, these characteristics are translated into mathematical features. Finally, via a classifier (Support Vector Machine) and a feature selection method, the discriminant power of these mathematical features to distinguish among burn depths is analysed, and the subset of features that better estimates the burn depth is selected.

Results: A success rate of 79.73% was obtained when burns were classified as those which needed grafts and those which did not.

Conclusions: Results validate the ability of the features extracted from the psychophysical experiment to classify burns into their depths.

1. Background

A burn injury is the result of an energy transfer that destroys skin and adjacent tissues. For a successful evolution of a burn injury it is essential to initiate the correct first treatment as soon as possible [1]. This first treatment depends on burn severity assessment. Main factors that determine the severity of burns are burn surface area, depth and location.

There are three main types of burn wounds [29]: superficial dermal burn, deep dermal burn and full-thickness burn. On the other hand, there is a two-group classification essential for

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a plastic surgeon: those burns that require excision and those that heal spontaneously.

(1) A burn does not need graft when it heals spontaneously. Superficial dermal burns type belongs to this group. These burns involve the epidermis and the superficial part of the dermis (papillary dermis). Blisters and a reddish colour are trademark characteristics. These burns heal spontaneously by epithelialisation within 21 days.
(2) A burn needs graft when it does not heal spontaneously. Deep dermal burns and full thickness burns belong to this type. Deep dermal burns are characterized by the early (within hours) development of extensive blisters, which usually rupture early to expose deep damaged dermis. The exposed reticular dermis may be pale in colour (pink-whitish) due to damage to dermal blood vessels, or red due to extravasation of red blood cells from damaged vessels. Full thickness burns destroy both layers of skin (epidermis and dermis) and may penetrate more deeply into underlying structures. These burns have a dense white, waxy or dark brown appearance. Both kinds of burns are referred to a surgeon.

A false-positive assessment and the patient faces needless surgery, a false-negative one and the patient faces increased length of stay, risks contracture, and hypertrophic scar formation [30].

In this paper, we focus our effort on burn depth estimation, specifically we will classify the burn into the two-groups classification described above. The determination of burn depth is around 50% for inexperienced surgeons as reported by Hlava et al. [2]. The clinical estimates of burn depth rise to the range from 64 to 76% for experienced surgeons [3,4]. As the cost of maintaining a Burn Unit is very high, it would be desirable to have an automatic system to give a first assessment in local medical centres or at the emergency, where there is a lack of specialists [17]. If a patient with burn wounds arrives at a medical centre without Burn Unit, a telephone communication is established between that local medical centre and the closest hospital with Burn Unit, and the non-expert doctor describes subjectively the colour, shape and other aspects considered important for burn characterization. The result in many cases is the application of an incorrect first treatment (very important for the correct evolution of the wound), or unnecessary displacements of the patient, involving high sanitary cost and psychological trauma for the patient and family.

These statistics, together to the fact that a burn patient is usually initially treated in a primary health centre, justify the utility of a computer-aided diagnosis (CAD) tool in the clinical practice. Procedures and systems for computer-aided diagnosis [5–7] have gained increasing acceptance in medicine. However, the extension of the CAD concept to the analysis of colour images of skin lesions is being developing at a slower pace due to difficulties in translating human colour perception into objective rules that may be analysed by a computer.

One of the main characteristics in the assessment of the depth of a burn wound that physicians take into account is colour; therefore, an image-acquisition system must preserve this property to the highest accuracy possible. In the related bibliography, there are works trying to evaluate burn depth by using thermographic images [8–12], terahertz pulsed imaging [13], polarization-sensitive optical coherence tomography [14], reflectance spectrometer [15], laser Doppler flux measurements [16], and spectrophotometric intracutaneous analysis scope (SIAscope) [32], which is a novel portable imaging device based on Doppler perfusion imaging system. There are also very interesting works that, modelling the human skin and studying the transfer of heat through the skin, can predict the damage of it if exposed to high temperatures [33–35]. The main disadvantages of all these methods are the complexity and cost of the image acquisition system. For example, thermal images can give very interesting information about the heat distribution and the composition of deep layers of the skin, while photographic images give only the visual information, but as in Acharya et al. work is stated [31], the infrared camera should be placed in a temperature-controlled room with a maintained humidity, which does not constitute an affordable image acquisition system in local medical centres. There are also some other interesting references dedicated to the estimation of chronic wounds and scars based on digital photography, near-infrared images and reflectance spectrophotometry [40–42].

The aim of the proposed system is to be used in local medical centres and at the emergency. In this sense, as has been stated in Roa et al. work [17], the technical requirements of the acquisition system are to be cheap, easy to use and fast. Therefore, we concluded that a digital photographic camera could be a good option to get an affordable image-acquisition method. Previous attempts to automatically assess burn depth from digital photographs have been published with encouraging results [20].

Section 2 is devoted to describe the algorithm, Section 3 exposes the results and Sections 4 and 5 state the discussion and the conclusions of the paper, respectively.

2. Methodology

2.1. *Hypotheses*

The hypotheses of the methodology are:

(1) In order to estimate the depth of a burn, physicians diagnose based on colour and texture characteristics of the burn. Superficial dermal burns are reddish and with a wet appearance; deep dermal burns have pink-whitish colour; and full thickness burns are characterized by a beige-yellow colour or dark brown colour.
(2) In the literature, an extensive number of works that deal with the extraction of colour and texture descriptors can be found. Specific colour spaces (such as $L^*a^*b^*$) are more suitable to translate human colour perception into measurable quantities [38]. There exist many different texture descriptors that can represent different types of texture, such as statistical moments, coocurrence matrix, features based on Fourier spectrum, etc. [39].
(3) There are many classification methods that taking a feature vector as input give the class it belongs to. Among these classifiers [39], the most popular ones are artificial