New Superpixels for Chronic Ulcers Segmentation

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Abstract. Chronic ulcers are usually the result of prolonged pressure on the skin and underlying tissues. These are chronic wounds with a very broad clinical presentation, ranging from superficial skin loss to progressive destruction of fatty tissue, muscle and bone. These lesions are usually very common during periods of hospitalization and in the elderly. Prevalence in Spain at 2013 is from around 7% and 8% in hospitals, 7.9% and 9,1% in primary care and 12,6% and 14,2% in Social Health Centers. In most cases, the methods of analysis in use today are rudimentary, leading to errors and using invasive techniques, uncomfortable for patients. Often, it's extremely difficult to monitor wound evolution according to treatment and healing process accurately with the common health systems. The great social and economic relevance of these wounds in the clinical field is almost as evident as the opportunity it presents for the creation of a digital tool that contributes to the improvement of this situation. For this reason, development of algorithms for its assessment is proposed as the main theme of this work. This paper discus about how improve the wound assessment using new computer vision techniques, in particular Superpixel (SP) segmentation in order to segment healthy skin and wound area and give some comparative measures respect to manual methods.

Keywords. Wound assessment, Pressure ulcers, chronic wounds, chronic ulcers, area, dimension, super pixels

1. Introduction

When it comes to managing and improving the quality of life in patients with chronic wounds or pressure ulcers, assessment, prevention and treatment are the most important issues taken into account when addressing solutions [1], [5], [9]. Is an adverse and constant event in public health because it poses an additional pathological problem that generates a longer stay, deterioration in quality of life, increased morbidity and other socioeconomic consequences for countries and their health systems [2]. In 2019 study indicates that in the United States, 2.5 million cases are treated annually at a cost of 11.6 billion to the health system [3]. In addition to the immense economic costs, patients with chronic wounds have a 5 times higher mortality rate [3] The main goal of the wound assessment scales is to objectify the main characteristics of a wound, in the assessment phase, setting for each wound her severity and obtaining an overall assessment result. Resvech scale 2.0 [10] identifies a number of characteristics based on size, tissue

distribution, depth involvement, edge status and signs of infection. This paper discus about how improve the size detection using new computer vision techniques. Discover in an image what is wound and what is healthy skin, as well as the exact calculation of its contour. The Superpixel [7] technique will be analyzed as a contour detection tool. Superpixel is a technique that groups different similar neighboring pixels taking into account the color and spatial characteristics of similarity between them. The use of Superpixels in object detection has long been used [8] [7]. It is necessary to find the optimum value of the algorithm's operating variables, adapting it to the characteristics of the images, wound and chronic wounds. In addition, a polynomial regression technique has been implemented to find the optimal number of Superpixels (segmentation) and the Sigma value (Gaussian filter).

2. Methods

With the aim of ensuring and accrediting the performance of Superpixels in the wound measurement process, a validation procedure based on the objective comparison of samples is considered. The professional will take a photograph of the wound and, by means of an application on a digital tablet, will draw the contour manually. Subsequently, the Superpixel method is applied to the photograph and the result obtained is compared with the manual contour [6]. Hospital de la Santa Creu de Vic has collaborated in this project. Without any change in the clinical practice, the professional obtained the anonymous samples and processed them with the aforementioned application.

2.1. Participants

In the framework of this project, 100 patients with age of (mean + - std) 75 years +- 5 years of which 75% women and 25% men were enrolled at Hospital de la Santa Creu de Vic. In 15% of cases, patients are hospitalized and 85% have been seen in an outpatient clinic or at home. All participants signed an informed consent form that has been approved by the local ethics committee.

2.2. Data collection

The data collection has been made with Samsung Galaxy Tab A tablets, without the use of additional flash, and with a normalized resolution (694 × 694 pixels). A specific app has been developed to this purpose. All data are collected during the healing process without modifying the health practice.

2.3. Manual contour

Using the same application to acquire data, the health professional has drawn using digital pencil corresponding contour over the photo. As will be seen in the results, a lack of precision will be noted here.

2.4. Contour detection with Superpixels Analysis

The SP algorithm will run automatically and unassisted, calculating the different blocks of Superpixels. In this section it will be noted that the adjustment of the different operating variables of SP is necessary to obtain an optimum result.

N_segments: indicate the approximate number of segmentations.

Compactness: comparation between color and proximity to group pixels in SP.

Max_iterations: maximum number of iterations of the k-means method.

Sigma: Gaussian filter to blur the image.

Enforce_connectivity: variable that indicates whether the segments are joined or not.

First, an estimation study is performed using the assignment of N_segments and Sigma manually and fixedly. After the review of the results that will be obtained, the use of a polynomial regression will be proposed for the most efficient calculation for each situation: Has been used 50, 100 and 200 N_segments and 1, 3 and 5 values of Sigma, getting the best results using 100 SP and Sigma 3. The images not segmented properly are selected to reprocess them with SP with different values: 150, 200 and 300. Taking into account the diversity of wound typologies, and her resolution, a polynomial regression is proposed for the calculation of the N_segments and Sigma values.

2.5. Comparation

For comparison, the contour drawn by the professional and the SP blocks forming the wound have been used. Different characteristics have been extracted from each of the samples, both the number of pixels inside the wound and the Hausdorff distance calculation [11]. With this comparison we can determine what degree of efficiency the algorithm will have.

3. Results

Once this method is implemented, it is necessary to explore the parameters and determine which are best for proper wound segmentation. Considering that ulcers have different shapes and colors, it would be interesting to further develop an automatic method that chooses the correct number of parameters for each image. Therefore, the first step is to process the original data set with Superpixels. Specifically, the parameters used have been 50, 100 and 200 Superpixels and with 1, 3 and 5 as sigma. The conclusion of this first processing is that the parameters that best segment in general all data are 100 SP and sigma 3 (Table 1). This is because it has been the set of parameters that best segmented the wounds without being excessive the number of relevant SP. 200 SP is also good, but the selection of useful super pixels (wound) is more laborious. 50 SP worked well with some large wounds or wounds that cover a large part of the image. It is important to keep in mind the wide variety of wound shapes, colors and sizes being evaluated. Although these values generalize well the detection of ulcer contour, they are ineffective in some cases. Specifically, it happens in those ulcers that cover an important part of the image, both for its size or how the photograph was taken, and in ulcers of reduced size.

Table 1. Initial dataset

Processed Images	N_segments
72	100
7	150
19	200
11	300

A wound that has been well segmented with a specific SP number will probably be well segmented with a larger number. Therefore, all wounds that had been included in the 100 SP label (72) have been reprocessed with the values 150, 200 and 300 in order to further equalize the label distribution. This means that despite increasing the number of Superpixels with which the wound will be segmented, those concretes that make up the wound area are a reasonably small number. This is a point so that a vector drawn (DV) by means of the user-application interface can be selected. Subsequently, using the

same data set, a polynomial regression has been implemented in the hope of obtaining a model that fits better.

$$Y = \theta_0 + \theta_1 x + \theta_2 x^2 \quad (1)$$

In this case, Y is the number of Superpixels for correct segmentation. X and X2 are the polynomial characteristics extracted from the number of pixels of the ROI, which is automatically obtained by DV. However, the line of the model that best fit the data was a grade 3 polynomial regression. Therefore, from the number of ROI pixels 3 characteristics will be obtained instead of two as shown in Equation 1.

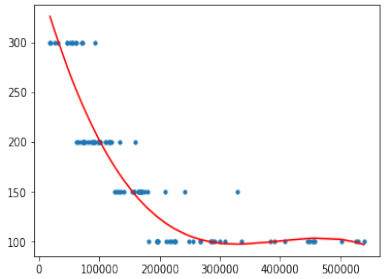
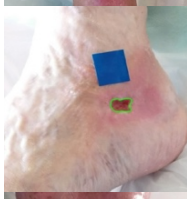
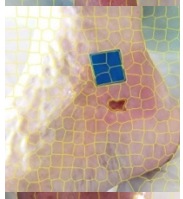
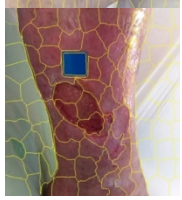


Figure 1. Polynomial Regression Model with Number of Superpixels as a Y axis and ROI as a X axis.

The results are more promising as can be seen without regression model. The highest value obtained is 326 and the lowest is 97. These values, unlike the linear regression models, are very close to the desired ones (300 and 100 respectively). Furthermore, in this case the MSE is 24.95 and the R2 is 0.8629. Here it is possible to corroborate the improvement of the model with respect to the previous ones given the considerable decrease of the error and the increase of the coefficient of determination. Then, the predictions of the regression have been used to segment the wounds with the proper number of SP in each case and were obtained just 4 bad segmentations of the 100 images in the initial dataset. The implementation was tested in the 100 images and only in 5 the obtention of the ROI fail.

Table 2. Sample images as well their manual contour, Superpixel contour, and number of SP segments. Finally, on Results the number of count pixel accuracy (number of pixels comparation in %), and Hausdorff distance calculation.

Original image	Manual contour	SP Contour	SP Segments	Results
				SP: 87,15% Dist: 26,93p
				SP: 97,78% Dist: 14,76p
				SP: 102,44% Dist:31,32p

4. Conclusions

As far as segmentation is concerned, Superpixels has proven to be a very powerful method. In phase of test, practically a very good segmentation has been obtained (very close to 100%), even taking into account that the quality of the images is not optimal. It has been concluded that in most cases the segmentation is more reliable with SP than using manual methods. This is because the automatic system is much more accurate than human vision and manual tracing. As next steps we propose the evaluation of the size of the marker that appears in each photograph in order to approximate the perimeter and the area in units of measure. Also implementing new variants of Superpixels as mentioned in [12]. We can conclude that this approximation of Superpixels can improve the measurement process dramatically being a non-intrusive alternative front manual method.

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