COLOR ANALYSIS OF THE RECONSTRUCTED COMPLEX NIPPLE-AREOLA AFTER A MASTECTOMY.

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ABSTRACT

In this paper a colour analysis of the reconstructed NAC (nipple-areola complex) after a mastectomy is performed. First, a colour segmentation algorithm based on the Live Wire method is proposed to separate the NAC from the rest of skin. And then the colour differences between the healthy and the reconstructed NAC are measured using colour-difference formulas recommended in CIE: CIELAB, CIE94 and CIEDE2000. The application domain is analyzing how the NAC is modified after applying a new reconstructed technique of areola-nipple complex, grafted after its cryopreservation. The analysis has been performed for 20 images, and good segmentation results have been obtained and quantitative colour difference in accordance with perceptual colour difference has been obtained.

Key words: colour differences, CIELAB, NAC, mastectomy

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INTRODUCTION

Breast reconstruction is surgery to rebuild a breast shape after a mastectomy. The reconstruction of the NAC (nipple-areola complex) is the final complement to mammary reconstruction. Its objective is to give a natural look, giving a symmetrical aspect when compared with the opposite complex. There are many reconstruction techniques, *e.g.* local flaps, grafting and tattoos, but no one is considered better than the others[1]. So, Virgen del Rocio Hospital of Seville decided to investigate a new reconstruction technique of NAC. Its aim is transplantation of cryopreserved nipple-areola complex. After mastectomy, the tissue is preserved by freezing at very low temperatures. The cryopreservation is an approved technique in both cell or tissue conservation[2]. The researches of Virgen del Rocio Hospital have extensive experience in cryopreservation of skin grafts taken from donors for major burn treatment[3].

How the NAC is modified after the cryopreservation, performing colour measure, is studied in this paper. To achieve this, a segmentation algorithm is developed, and colour-difference formulas recommended in CIE have been used.

The segmentation refers to the process of partitioning a digital image into multiple regions, to separate areas of interest. Choosing a completing automatic segmentation algorithm was not a good idea, because the database used did not follow an acquisition protocol. Therefore, many images present non-uniform illumination. A semi automatic algorithm where the user has to participate has been chosen. It is based in the Live Wire method[4]. The procedure consists on creating a map containing a local cost for each pixel of the image, associating low values to the contour pixels and high to the rest. After that, Dijkstra's algorithm is applied, which finds the shortest route (less weight) between pixels introduced by the user by clicking the mouse on the contour of the object to segment.

The live-wire algorithm has been used with several variants[5] and in multiple applications[6]. But only Chodorowski *et al.*[7] have applied the method to colour images.

When the healthy and reconstructed NAC are already segmented, it is necessary to analyze the colour difference between them. We have used colour difference formulas, mathematical expressions that allow us to get a representative number (ΔE) of the perceived colour difference between two colour stimuli. Its merit is that the ΔE values are highly correlated with the visually perceived colour differences[8]. In this article we study the formulas recommended by the International Committee on Illumination (CIE).

SEGMENTATION ALGORITHM

The algorithm proposed performs segmentation by tracing the contour of the object of interest between two points marked by the user. Thus, if the user consecutively clicks various points belonging to the contour, the object of interest is segmented.

The algorithm performs two steps. In the first one, the image is interpreted as a directed graph in which each pixel corresponds to a node and it is connected through its eight neighbouring pixels by branches. A cost is assigned to each branch of the graph, this cost is low for pixels belonging to the contour. These branches are called local cost map. The second step is to use Dijkstra's algorithm to find the lowest cost path that connects the two nodes (pixels) clicked by the user.

Local Cost Map (LCM)

The LCM is the matrix L(p,q) in which the cost of moving from any of the 8 neighbours pixels (q) of the pixel (p) to it, is represented.

$$L(p,q) = f_{zVDG}(q) \qquad (1)$$

The f_{zVDG} is a vector gradient edge detection function. The vector directional gradient detector (VDG) is the Sobel operator (based in the first derivate) generalized into the three-dimensional case (RGB) instead of gray scale images. Its result is an image where pixels located at edges have a high value. As we are interested in low values for pixels in the edges, we invert the output image.

Dijkstra's Algorithm

Dijkstra's algorithm finds the lowest cost path between two points belonging to the contour specified by the user. A cumulative cost map where pixel values represent the cost of going to the seed from itself by the shortest route is generated. Seed pixel is the pixel marked by the user.

COLOR ANALYSIS

To quantify colour differences, we have using three CIE formulations. All metrics are based in CIE L*a*b* colour space (also called CIELAB), developed in 1976 and considered as uniform system. This means that the same uniform changes of Euclidean distance metric in the L*a*b* colour space correspond to the same uniform changes in perceived colour.

The three coordinates of CIELAB represent the lightness of the colour (L), its position between red/magenta and green (a^*) and its position between yellow and blue (b^*).

If two points in the three-dimensional space (which represent two colour stimuli) match, then the colour difference between the two stimuli is null. As the distance between these two points (L^*_1, a^*_1, b^*_1) and (L^*_2, a^*_2, b^*_2) increases, it is reasonable to assume that the perception of chromatic difference between the two points (that represent the stimuli) also increases.

However, it has been demonstrated that Euclidean distance ΔE^* is not an accurate measure of magnitude of perceived colour difference between two stimuli. So, CIE had to recommend two new standards for colour difference measurements, CIE94 and CIEDE2000.

Colour difference formula ΔE_{ab}^*, CIE 1976 (CIELAB)

Colour differences are measured in the CIELAB space as the Euclidean distance between the coordinates for the two stimuli. This is expressed in terms of CIELAB ΔE^*_{ab}, which can be calculated using Equation 1. It can also be expressed in terms of lightness, chroma, and hue differences.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (1)$$

Colour difference formula ΔE_{94}^* (CIE 1994)

In 1994, CIE recommended a new equation, it was called CIE 1994 with symbol ΔE_{94}^* and abbreviation CIE94, to improve the uniformity of colour difference measurements. Use of the CIE94 equation is preferred over a simple ΔE_{ab}^* CIELAB[9].

$$\Delta E_{94}^* = \sqrt{\left(\frac{\Delta L^*}{k_L S_L}\right)^2 + \left(\frac{\Delta C_{ab}^*}{k_C S_C}\right)^2 + \left(\frac{\Delta H_{ab}^*}{k_H S_H}\right)^2} \qquad (2)$$

$$S_L = 1 \qquad (3)$$

$$S_C = 1 + 0.045 C_{ab}^* \qquad (4)$$

$$S_H = 1 + 0.015 C_{ab}^* \qquad (5)$$

The parametric factors, k_L, k_C and k_H are used to adjust the relative weighting of the lightness, chroma and hue components, respectively, to account for any deviations from the reference viewing conditions. Under a set of reference conditions established by CIE in 1995, their values are 1.

Colour difference formula ΔE_{00}^* (CIEDE2000)

Effects of non-uniformity in the space for small colour differences in different ranges and different directions have been tested. CIEDE2000 tries to correct them. While the CIEDE2000 equation certainly performs better than CIE94 for some data sets, its added complexity is probably not justified for most practical applications[10].

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)} \qquad (6)$$

RESULTS

The segmentation has been tested on 20 images, with good results. On average, 8 points have been required for achieving these optimal results. Examples of segmented NACs are shown in Figure 1.

Fig1. Examples of segmented NACs

Colour information is extracted from features of the distance image. The distance image is the image whose pixels values are the difference between their colour in the original image in L*a*b* space, and the colour taken as a reference also in L*a*b* space. Those pixels that have a colour very similar to reference in the new image will have a gray level close to black and the pixels that appear near white will be those with different colour.

The colour difference is calculated using the three distance metrics previously noted, CIELAB, CIE 1994 and CIEDE2000. In Figure 2 an example of NACs image is shown. And in Figure 3 the distance images of this reconstructed NAC are shown, taken as the colour reference the mean of pixels values in L*a*b* of the healthy NAC. Mean and variance of pixels values in these distance images give colour information. The results data for the full NAC are shown in Figure 4. In the same way, a comparison between reconstructed nipple and healthy nipple, both from Figure 2, are show in Figure 5. The values in Figure 5 are bigger than in Figure 4, because colour differences are higher between nipples than between NACs.

Fig 2. Image of a reconstructed NAC and healthy NAC.

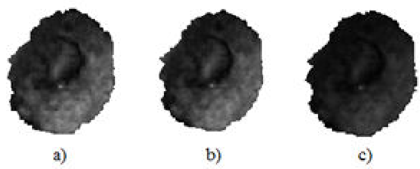

Fig 3. Colour distance images of reconstructed NAC formed by calculating a) CIELAB distance b)CIE94 distance c)CIEDE2000, regarding healthy NAC.

	CIELAB	CIE 94	CIE 2000
Mean	8.0304	7.2411	6.3450
Variance	17.4753	16.4407	11.6619

Fig 4. Mean and Variance of colour distance images of reconstructed NAC regarding healthy NAC (Figure 3).

	CIELAB	CIE 94	CIE 2000
Mean	15.7456	14.9868	12.9533
Variance	16.4705	14.9090	10.1668

Fig 5. Mean and Variance of colour distance images of reconstructed nipple regarding healthy nipple.

We conclude that mean values below 3, represent tissues with similar colours, values around 5-7 represent perceptible colour difference but acceptable; and if values are bigger, the tissues to compare have very different colours. Two observers have evaluated perceptual colour difference of 20 images giving the highest value when images to compare have very different colour. A correlation coefficient of 0.885, has been obtained, between the mean of 20 distance images using CIEDE2000, and their evaluation.

CONCLUSIONS

A quantitative study of how the nipple-areola complex is changed when is grafted after a mastectomy has been performed. A segmentation algorithm has been proposed and experimental results evidence

Its good performance, as shown in Figure 1. Furthermore, a quantitative measure of the perceived difference between the reconstructed and the healthy skin have been performed. To this aim, the color distance measures proposed by CIE have been used. A 0.886 correlation coefficient between perceived measures according to two observers and distance measures according to CIE distance show that the proposed distances agrees with perceived distances.

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