AUTOMATIC HUMAN IRIS COLOR CLASSIFICATION

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ABSTRACT

We present an automatic iris color classification method suitable for predicting human eye color. The proposed method combines the abilities of intra-palette merging clustering technique with a thorough measurement of the iris color using the MartinSchultz scale. Intra-palette merging ensures the minimum set of group colors suitable for correctly representing the color information within human iris images, while the iris color specification presented as an eye color chart, the accuracy of the classification method. The experimental results seem to endorse the capacity of the method to obtain an automatic classification of the iris color.

Keywords: *iris color, inter-palette merging, clusters, color space.*

1. INTRODUCTION

The human eye color is a subject of research since ancient times. The color eye is actually given by the color of the thin circular diaphragm present in the center called iris. The general iris color is a polygenic trait and is determined primarily by the amount and type of pigments present in the iris.

The research on iris color began in 1987 with the studies published by Moss et al. [1] regarding the correlation between iris color and some eye diseases. Early classification of iris color was crude, color being divided in the in two categories: light/dark or brown/blue [2]. In other studies iris color classification is based on so called color naming rule, where each class is named after the most predominant iris color. The subdivision of iris color assumes three main classes for representation: blue / green / brown, blue / brown / other or blue-grey / green-hazel / brown-black [5], [8]. This type of classification is considered to be very subjective, since the colors of the irises tested were not compared to some standard references. To overcome this situation a five class numerical grading system was introduces later. The classes are distinguished based on the predominant color (blue, gray, green, light brown, or brown) together with the amount of brown or yellow pigment present in the iris surface. This color evaluation was presented by Seddon et al. [5] as a system for iris color classification based on manual comparison of the iris photographs, with some photographs considered as standard. Because the accuracy of this technique depends on the reliability of the observer, several attempts of automatic iris color measuring were introduced. German et al. [6] presents an automatic iris color measurement system by testing the color variation in response to a certain drug. Slit-lamp photographs of various colored irises were taken under standardized conditions, scanned and analyzed using calibrated automatic iris color grading software.

The present study proposes an automatic iris classification method suitable for medical purposes. While the majority of the methods focus on providing exclusive information about the iris dominant color, only few refer to pigmentations role in the iris color classification. Along with the measurement of the dominant iris color, our method is sensitive to the pigmentation regions. The automatic classification is a two step method. First the similar colors are grouped using modified intra-palette merging technique and then based on a color ranking (dominant vs pigment) the classification is performed with the help of an Eye color chart, created by Carleton Con [9].

The paper is organized as follows: the techniques and methods used for iris color classification are presented in Section II. In Section III some of the experimental results, test and comparisons are presented briefly. Some discussions and the comments regarding the topic of iris color classification for medical purpose are delivered in the section IV.

2. METHODS USED

In this section we present detailed description of the methods and image processing techniques, with strengths and weaknesses, involved in research towards an automatic iris color classification.

The main problem of any color classification process is identifying the minimum set of color needed for a proper representation. To overcome this issue, well known in the Computer Graphics community as color palette estimation, we provide an efficient and elegant solution known intra-palette merging technique.

2.1 Modified intra-pallet merging technique

The color space selection is very important, because the information regarding the color is held in the way it is represented. Fan *et al.* [3] presents in their work a precise and useful characterization of the suitable color space for the iris color analysis. The ideal color space should have the following proprieties: 1) accurate and objective color representation. 2) uniform distance in the color space, both with respect with iris pigmentation and with respect to perceptual differences. 3) color comparisons invariant to luminance differences.

RGB color model is convenient for computer graphics mainly because of the similarities with the human visual system, but it does not satisfy the properties of a suitable color space because it is not uniform. CIE XYZ color space allows all visible colors to be defined using only positive values called chromaticities, and the Y value the luminance. The use of normalized chromaticity has the disadvantage for being non-uniform. In order to solve this weakness an approximately-uniform color spaces $L^*u^*v^*$ was created. This space meets the requirements of suitable color space and it will be used in the analysis.

On the selected color model, the unique colors and their presence expressed in pixels are determined. Together they form a pair of attributes that successfully describe the color characteristics inside the input image image [7]. The result is described as:

$$F = \{\{C_i, p_i\}, i = 1, 2, \ldots, N\} \quad (1)$$

where N represents the total number of unique colors inside the image, C_i is the color feature vector and p_i represents the color presence in pixels. The unique color feature vector is very useful for the intra palette merging process.

The intra-palette merging was originally presented by Ka-Man Wang et *al.* [8]. This method, known as a pixel clustering technique, ensures two by two similar colors merging into a new group color. The description of the method is presented briefly:

Let any two random given colors form the feature vector: $C_i = [L_i, u_i, v_i]$ and $C_j = [L_j, u_j, v_j]$. The Euclidean distance d between the two given colors is computed using:

$$d(C_i, C_j) = \sqrt{(L_i - L_j)^2 + (u_i - u_j)^2 + (v_i - v_j)^2}, \quad (2)$$

where [L, u, v] are the color components from the color space.

Two colors are considered to be similar if the Euclidean distance d, between their color components is smaller then a given threshold Th. If two colors are classified as similar, a new color C_n is generated and replaces the two original colors.

The obtained color $C_n = [L_n, u_n, v_n]$ is computed using the following formulas:

$$L_n = \frac{(L_i \cdot p_i + L_j \cdot p_j)}{(p_i + p_j)}, u_n = \frac{(u_i \cdot p_i + u_j \cdot p_j)}{(p_i + p_j)}, \quad (3)$$

$$v_n = \frac{(v_i \cdot p_i + v_j \cdot p_j)}{(p_i + p_j)},$$

where p_i, p_j represents each color presence inside the image.

During the merging process each pair of colors from the feature vector is analyzed. If the Euclidean distance between the two analyzed colors is smaller then the given threshold, a new merged color is computed as described in Eq. (3). The new weighted color, obtained by merging, replaces the two original colors. The process stops when there are no similar color left in the color feature vector. In this way the number of colors is reduced significantly to a minimum set of color groups.

In the present analysis a modified version of the intra-palette merging technique is presented. The final version of the implemented color grouping algorithm is described as follows:

Modified Intra-palette Merging Algorithm:

1. *Determine Euclidean distances between all colors within the feature vector F, and store results as a i-by-i matrix, $i = 1 \ldots N$. Each line and column values holds the order number of colors, from the feature vector, for which the Euclidean distance is computed.*
2. *Find all the Euclidean distances smaller then the given Threshold and the unique pair of colors which satisfy this condition.*
3. *Merge each pair of colors to a new color as described in Eq. (3) and replace both original colors with the new color.*
4. *Perform operations from 1 to 3 until there are no colors with Euclidean distance smaller then the given Threshold.*

We have used this modified algorithm because it allows the automatic threshold estimation and reduces the computational time needed for color merging by processing all color pairs 2-by-2 simultaneously.

The threshold for the original intra-palette merging technique is provided manually by the user. To overcome this drawback we follow a very simple argument to estimate the threshold directly from the input data. We assume multiple color variations within iris images and by calculating the Euclidean distances between colors we determine all those variations. Using histogram to visualize colors variations we proved wrong. There are few bins on the histogram, suggesting a reduced number of distinct colors, each bin holding similar color pairs with Euclidean distances alike grouped around a local minima, as seen in Figure 1. The bin holding the most alike Euclidean distances is of interest because it suggests the value of the threshold.

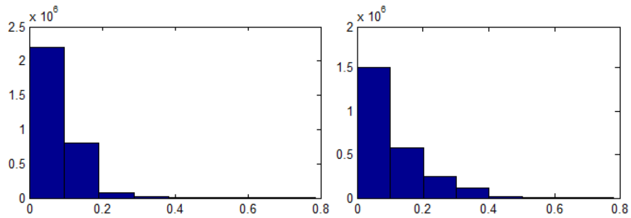

Figure 1*: Typical histograms of Euclidean distances computed for two different images.*

Remark that the method is completely automatic, in the sense that the user does not need to specify any calibration parameters at all. The the threshold parameter is automatically determined by the algorithm.

2.2 The Classification of the Iris Color

In the second stage of this research we focused on the classification of group colors provided with the intra-palette merging technique. The automatic classification method deals with both the dominant color and the amount of pigment present on the surface of the iris. The classification is performed hierarchically:

- First, the group colors obtained using the intra-palette merging techniques receive a name according to their color components location within the u^*, v^* chrominance plane.

- Next the group colors are ordered by the amount of pixels that belong to each group and the ranking color vs pigment is performed. According to the assign names and the pixel presence a ranking dominant vs pigment is realized.
- Finally the classification iris color classification is realized based on a the description from the Eye Color Chart created by Carleton Con [9].

The first step ensures that each group color obtained from the image, is correctly identified and receives the appropriate name according to its color components values from the u^*v^* chrominance plane. Iris can be light (green, blue and hazel) or dark (brown and black) when reffered to its overall color and can have brown, yellow or white pigmentation regions within its surface. By analyzing the u^*v^* chrominance plane (Figure 4) one can see that the regions of blue, green and brown can be easily approximated as follows. All blue color variation are obtained for $u^* \in [0, 0.223]$ and $v^* \in [0, 0.625]$. The green ones for $u^* \in [0, 0.223]$ and $v^* \in (0.625, 1]$. And the brown color variations for $u^* \in (0.223, 1]$. We have grouped the colors variation from yellow to brown and red to pink as one brown region because such colors are different than blue and green and on the iris surface often appear as pigment regions.

The group colors list is ordered according to the number of pixels belonging to each group group color. The first name represents the most frequent color in the image and the last one the less frequent. The colors blue and green are grouped together because are considered light colors while brown color is considered dark. The most frequent group color will be considered dominant and the less pigment.

Finally an automatic classification can be performed. In the classification we used the description of colors presented in the work of Carleton Con, an anthropologist who studied the variations of different human facial characteristics according to development of the human species [9].

The eye color classification is presented as a chart as follows:

- **Light eyes:** eyes light and light mixed.
  - **- Light**: Gray, blue, green.
  - **- Light mixed**:
    - a. Very light-mixed (blue with gray or green with gray).
    - b. Light mixed (light or very light-mixed with small admixture of brown pigment).
- **Mixed eyes:** Mixture of light eyes (blue, gray or green) with brown pigment when light and brown pigment are the same level.
- **Dark eyes:** eyes dark and dark mixed.
  - **- Dark mixed**: Brown with small admixture of light pigment.
  - **- Dark mixed**: Brown and very dark brown (almost black).

To be able to ensure the automatic classification, according to the specification from the above eye chart, we used the color naming and the ranking dominant vs pigment properties generate in the first two steps of the method. If the percentage of the pigment is low (less than 30) and the dominant color is blue or green the iris is classified as light. If the percentage of pigment is between [10, 30] and the dominant color is blue or green the iris is classified as light pigment migration. If the percentage of pigment is between [30, 50] and dominant color is blue or green the iris is classified as pigmentation migration backgrounds. If the percentage of pigment is above 60) and dominant color is blue or green the iris is classified as multiple pigment migration. If the dominant color is brown and the pigment percentage low the iris is classified as dark.

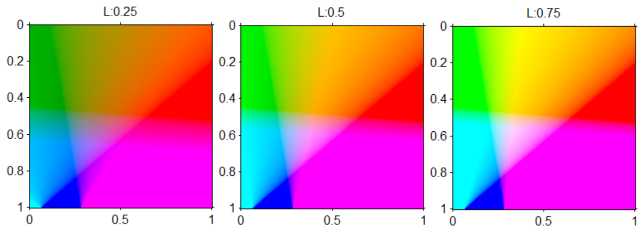

Figure 2*: Visibe color variation within CIE u*v* chrominance color plane (u* is represented on x axis and v* on y axis). Influence of the luminance value variation upon those colors: 1) Luminance = 25, 2) Luminance = 50, 3) Luminance = 75.*

3. EXPERIMENTAL RESULTS

In the experiments were used 40 eye iris images from the evaluation database. The iris was extracted from the input eye images using the method presented in [10]. The extracted iris images are 265 pixels wide, 265 pixels height and are stored on 24 bit RGB color format.

We begin this section with an detailed example of how automatic intra-palette merging technique determines the group color within an iris input image. In Figure 3 an input iris image is presented. The unique colors stored in the image's feature vector are merged together by pairs and as result we end up with a minimum set of color groups, Figure (3b). The group colors are arranged in descending order based on the number of pixels belonging to each color, the most frequent being in the top of the list while the less frequent at the bottom. On the image feature vector there were 13720 unique colors which merged towards 7 group colors. The degree of similarity between colors is controlled by the automatic generated threshold obtained from the maximum

Figure 3*: Exemplification of inter-palette merging procedure. a) original eye iris image (265x265 pixels), b) minimum set of group colors presented in a descending order according to their pixels presence, (white the background), c) the Euclidean distance histogram.*

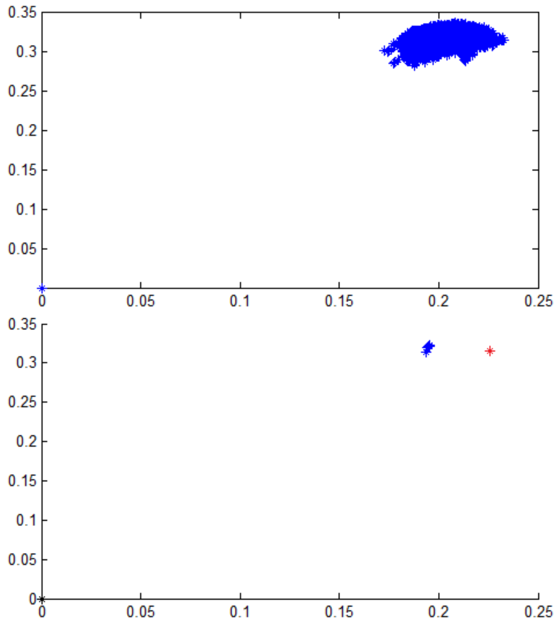

Figure 4*: Color representation using the u^*v^* components: a) unique colors from the image feature vector, b) dominant colors and the color name assignment.*

bin of the Euclidean distance histogram, (Figure 3c). The location of this bin provided a threshold value equal with 0.0512.

Figure 4 presents the spatial distributions of unique vs group colors within the u^*v^* chrominance plane. The results, Figure 4b, illustrates both the reduction of the colors and the migration of similar colors towards the corresponding central group color. Note that dominant colors were named according to the ranking presented in Subsection 2.2. 7 group colors with values $u^* \in [0, 0.223]$ and $v^* \in [0, 0.625]$ are blue and 1 with $u^* \in (0.223, 1]$ is brown. Based on the pixels presence and color naming, according to the eye chart the analyzed iris image is classified light mixed (54.3% blue dominant color, 15.4% brown pigment, 30.3% background). At the end we present the overall automatic classification results for all 40 eye analyzed iris images. Of all 40 images, 28 irises were green and blue and 12 were brown. The light irises present different variation of pigment while the brown ones were with no pigmentation at all. For all the brown ones the proposed method identified the dominant color correctly and ranked them as brown irises. For the blue and green irises the dominant color was identified correctly and the amount of pigment was precisely predicted. 17 irises were classified as light pigmented 7 irises with pigment migration backgrounds and 4 irises with multiple pigment.

Regarding the color naming (blue, green brown) the assigned representatives are not always right. While the brown is easily differentiated from blue and green, green and blue can easily been mixed up especially if their u^*v^* components are close tho the separation intervals.

On the experiments we observed that many of the images from the data set had white balance issues. Those errors proved to be low enough for the tested images and the proposed method provided correct results without the necesity of preliminary white balance correction.

4. CONCLUSION

The aim of this work was to develop an automatic iris classification tool intended for medical purposes. This classification meets ophthalmological requirements concerning the iris color and offers accurate results, realistic running times and low user interaction for parameter settings. The experimental results claim the efficiency and accuracy of the method. As future work this method will be integrated in a human iris analysis system, which can provide information about patients state of health based on their iris color and texture particularities

5. AKNOLADGEMENT

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