Iris color evaluation through multispectral systems

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RESUMEN:

En este trabajo se hace un estudio de las herramientas multiespectrales en la aplicación de la medición del color en iris humanos, prótesis oculares y lentes de contacto cosméticas. Con el análisis estadístico de los valores CIELa*b*, las diferencias de color CIEDE2000 y las gamas de color las muestran se clasifican en tres grandes grupos: marrón, azul y verdes. Así mismo, se analiza la reproducción que de los iris humanos hacen las prótesis y las lentes de contacto. Los resultados muestran que los iris humanos utilizados en este estudio son predominantemente marrones y que la reproducción del color hecha por las prótesis es aceptable mientras que no es así en el caso de las lentes de contacto. Además, se plantea como perspectiva el incluir el análisis de no sólo los valores colorimétricos promedio, sino también el análisis de la distribución espacial del color.

ABSTRACT:

In this work a study of multispectral tools in color measurement of irises, prostheses and cosmetic colored contact lenses is performed. With the statistical analysis of CIELa*b* values, the CIEDE2000 color differences and color gamuts, the samples are classified in three major groups: brown, blue and green. In the same way, the irises color reproduction made by prostheses and contact lenses is analyzed. The results show that brown irises are predominant into the set of samples utilized and the irises color reproduction in prostheses is closer than in contact lenses. Besides, we set out as perspective, to include the analysis of not only mean colorimetric values, but also the analysis of color spatial distribution.

Keywords: Color, multi-spectral systems, iris, gamut.

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1. Introduction

Iris color has been studied in just some works[1-5]. Some of these studies have been subjective observations[1,2] and few have attempted quantitative measurements using standard color instrumentation[3-5]. This shows that quantitative iris color measurement is a task neither ended nor easy. Although irises have such variability in color and texture that make them suitable for irises identification applications[6] and implicitly set exact color measurements as almost impossible ones, increasing the accuracy in quantitative color and spectral reflectance characterizations are desirable for other several applications[7-9]. Thus, some recent works have been implementing new colorimetric elements like color image processing and multispectral systems to face these studies[5,10-12]. Following this tendency this work classifies, through an automatic algorithm, a set of samples composed by 106 human irises, 68 ocular prostheses and 17 cosmetic colored lenses in three different groups: brown, blue and green. This algorithm evaluates some criteria over the CIELa*b* coordinates of each sample. These coordinates are obtained by means of an optimized and calibrated multispectral system product of former works[5,10-15].

Statistical analyses, color differences and gamut comparisons are performed as a first approach to the color characterization of samples as well as the comparison of prostheses and contact lenses accounting their color characteristics in respect to irises. In that way, we attempt to obtain objective color data that could assist prostheses and contact lenses producers in their goal of reproducing iris. Task that nowadays is performed by trial and error with subjective comparisons[16].

With this work we show the different gamuts of the three major groups resulting from the proposed classification. It clearly shows the group of brown color as the most populated for the irises and prostheses samples. In the same way, color gamuts and color differences show the color proximity between irises and prostheses and also the differences with the contact lenses. It reveals that contact lenses are clearly influenced by the eye utilized in the measurement procedure, so is needed a different treatment for its complete characterization.

This paper is structured as follows: in the second section a brief description of the system, methods and statistical tools used are presented. The results and comparison are shown in the third section and, in the last section, the conclusions of this work are presented.

2. Experimental setup and methods

2.a. Experimental setup

The system utilized in this work is the result of former studies that have yielded an optimized experimental setup with its necessary computational tools[5,11-15,17]. This multispectral system (Fig. 1) consists of a 12 bit depth cooled CCD monochrome camera (QImaging QICAM Fast1394) with 1.4 megapixels (1392 × 1040), an objective zoom lens (Nikon AF Nikkor 28–105 mm), and a color RGB tunable filter attached to the CCD camera.

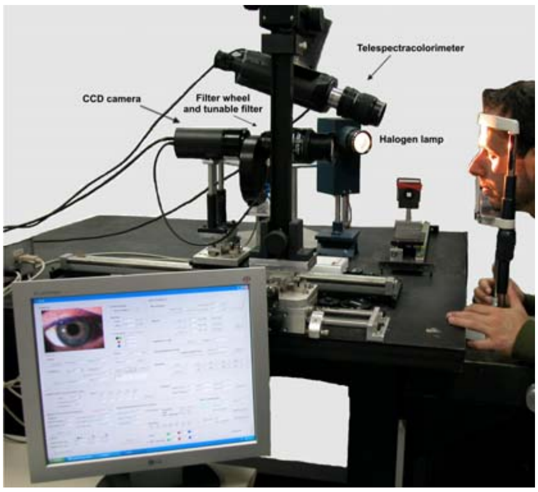

Fig.1. Multispectral experimental setup.

Furthermore, there is an illumination system composed of an adjustable halogen lamp (Philips 15V 150 W) attached to a stabilized dc power supply (Hewlett Packard 6642A) and a focusing lens, allowing illumination of the analyzed iris with a 45° angle of incidence and providing a rather uniform luminous field on the eye.

2.b. Methods

With the described system, we measured the mean digital output levels of the samples, i.e. irises, prostheses and contact lenses, corresponding to two square areas of approximately 1×1 cm on the iris (Fig. 2), which presented a rather uniform coloration. At the same time, the corresponding averaged spectral reflectances in the visible range (380 – 780 nm) of those zones were also measured using a spectrophotometer (Photo Research PR-650).

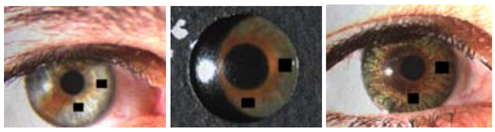

Fig. 2. Image of an iris, a prosthesis and a coloured contact lens, with the corresponding 2 analyzed areas.

Thus, from these digital levels we obtained the colorimetric L*a*b* or XYZ tristimulus values following some former steps. Basically these steps involve:

- System optimization: the selection of the best set of filters. For our system an RGB tunable filter had been determined as the best solution.
- Image preprocessing: flat-field correction applied in order to both correct the camera response and the nonuniformity of the illumination.
- Training set calibration: tests with different training sets for spectral profiles reconstruction. A subset of real irises has been used as the final training set.
- Reconstruction of spectral reflectances profiles: tests of different reconstruction algorithms. Moore-Penrose pseudoinverse algorithm had been selected because of its accuracy and implementation simplicity.
- With those spectral reflectances profiles and the illuminant D65 the XYZ and CIELa*b* values are obtained.

The reasons and details of the former procedures are deeply explained in REFs[5,11-13,17].

TABLE I

Statistical CIELa*b* values for the irises samples.

	a* Irises	b* Irises	L* Irises
Mean	6,33	14,97	27,57
Std. Dev.	5,77	8,77	8,65
Min	-6,43	-5,47	10,88
Max	23,65	29,76	47,64
Volume		6670	

The automatic classification of the samples is performed based on statistical descriptors extracted from their CIELa*b* values. The table I shows the main descriptors for the group of samples coming from real irises. With it we can identify the ranges in each colorimetric coordinates, their dispersions and besides, we can analyze volumes, namely, color gamuts.

3. Results and comparison

With the analysis we built boundaries in the CIELa*b* space for the separation of the samples which give us the following gamuts when they are applied to the irises samples (Fig. 3).

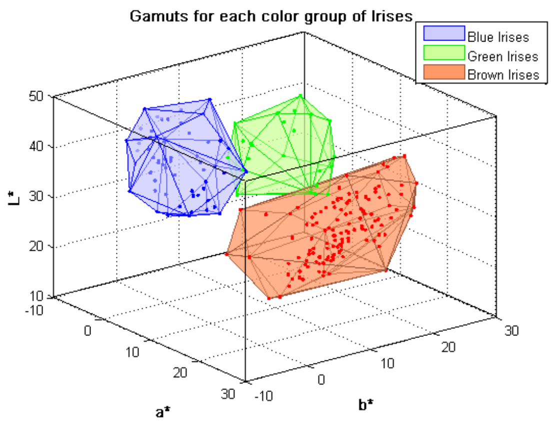

Fig. 3. CIELa*b* volumes for the proposed classification in real irises.

As can be seen, this separation shows the brown group as the biggest and most populated one. Similar results are obtained in prostheses and contact lenses. Using this classification we can compare the samples by colors and analyze the color reproduction in prostheses and colored contact lenses with respect to real irises. In addition, utilizing the CIEDE2000 formula for calculating the color differences we found the nearest pair for each iris in the other two sets of samples, prostheses and colored contact lenses, helping us to conclude how they replicate real irises.

Fig. 4 has an example showing how the volumes of each sample belonging to the group of blue color overlap. It is clear how for these blue subsets the prostheses and irises overlap much more between them than with the contact lenses. This behaviour gets repeated when this comparison is performed again in the other two groups of colors.

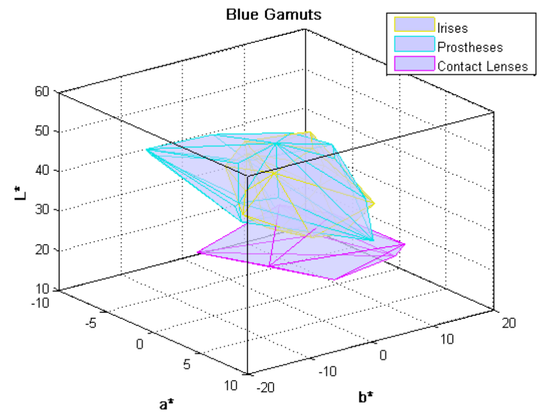

Fig. 4. Comparison of blue gamuts.

This is a first approach that shows how prostheses and irises are more similar between them. The same conclusion is evident when we use the data extracted from color differences, the mean values and the dispersion of the minimum color differences between contact lenses samples and irises are bigger than between prostheses and irises (TABLE II). It shows that prostheses are a better representation of the irises than the contact lenses regarding to their mean color values. It can be said that taking into account how the gamuts of each color group are represented by the prostheses or contact lenses, the prostheses cover almost completely the gamuts of the irises for each color group, it means that is very likely to find some close representation of a desired iris in the set of prostheses, at least regarding to their bulk color appearance. But, on the other hand, it sets the need of more accurate color analysis, not only including mean colorimetric values for a determined region, but including a color distribution analysis taking advantage of the obtained data over the whole image through the multiespectral system.

TABLE II

CIEDE2000 minimum color differences with respect to real irises. Irises-Prostheses(I-P), Irises-Lenses(I-L).

	ΔE_{00} I-P	ΔE_{00} I-L
Mean	2.28	4.47
Std. Dev	1.02	3.95

4. Conclusion and perspectives

This work shows the results of an automatic algorithm to classify a set of samples composed by 106 real irises, 68 prostheses and 17 colored contact lenses in color groups: brown, blue and green. This classification shows the brown group as the most populated one and with the biggest volume in the CIELa*b* color space. This classification allows us a deeper analysis of the irises color reproduction through the representation of gamuts in each color group and the observation of their overlapping. The overlapping shows us how the prostheses are very close to the irises regarding their gamuts. Moreover, with the analyses of the color differences utilizing the CIEDE2000 formula, the same behaviour is observed. Thus, we can state that the prostheses make a good representation of the irises colors at least concerning to their mean color values. The next step will be to include the analysis of spatial color distribution to classify and compare the samples taking advantage of the multi-spectral data. In addition, a close study of the influence of the eye in the contact lenses measurement is intended to be done.