Digital image analysis of pigmented skin lesions. Early diagnosis of melanoma

Luis Coll[1], Dante Chinchilla[1], Constanza Coll[1], Fernando Stengel[1], Horacio Cabo[1]

Abstract

Objective. The purpose of this observation-based study is the automatic, objective, and operator-independent differentiation of melanoma from other pigmented skin lesions, viewed through the computer.
Methods. A videomicroscope with magnification lenses 20X and 50X and polarized light was employed, together with a computer with appropriate image analysis software. This computer viewing system allowed for the study of the amount and color distribution in images of pigmented lesions by means of RGB and HSI models. Fifty-five pigmented lesion images were included in the study, divided into two groups: melanoma (n = 16) and non-melanoma (n = 39).
Results. With reference to number of colors, 92.3 percent of non-melanoma lesions showed 4 or less colors, except blue nevi, which displayed 5 colors. In the melanoma group, 6 or more colors were detected in 88.2 percent of lesions, and 5 colors in 11.8 percent.
Cut-off point in color distribution was taken at a hue variance value of 20. 100 percent of melanoma images had higher values, in contrast to the non-melanoma group, except basal cell epitheliomas.
Conclusion. With a computer vision system for digital image processing, the number and distribution of colors may be quantified, in order to reach an automatic, objectivity and operator-independent differential diagnosis between melanoma and other pigmented skin lesions (Dermatol Argent 2008;14(3):200-206).

Key words: *melanoma, computer vision, digital image processing.*

Introduction

Color is one of the most important parameters in the A – B – C – D dermatoscopy rule for early diagnosis of melanoma (M).[1-5]
In order to enhance dermatoscopic precision and interpretation variability, multiple programs of digital image analysis are used in studying the colors of pigmented skin lesions, thus favoring differential diagnosis between M and non-melanoma lesions (NoM).
In clinical dermatology and dermatoscopy, the human eye analyzes the amount and distribution of color for the diagnosis of M.[6]
The human eye has a physical perception and a psychical description of colors, which are reproduced by the computer vision [*] through the RGB and HSI models, respectively.[7]
In 1920, Guild J and Wright WD demonstrated that addition or subtraction of the three different ratio of the light's primary colors allow us to obtain most of the colors detectable by the human eye. By this discovery it was possible to develop the RGB model, where a computer vision color image may be decomposed in the three images it comprises: red (R), green (G), blue (B).[8-9] Hereby, the HSI model is obtained, comprising three images that express hue [*] (H), saturation [*] (S), and intensity [*] (I) of the color figures perceived by a computer[9] (**Figure 1**).
By using these and other models, the colors of pigmented skin lesions can be analyzed in a good relation between human eye and computer vision, with the additional benefit of the quantification of the various variables.[10]

Reception date: 6/9/07 | **Approval date:** 19/2/08

Bioengineering Commission of the Argentine Society of Dermatology.

Correspondence
Luis Coll: Austria 1751 1º A – Autonomous City of Buenos Aires – Argentine Republic. Ph: 4824-1840 E mail: luiscoll@fibertel.com.ar

The purpose of this observation-based study is to differentiate melanoma from other pigmented skin lesions by means of the number and the distribution of colors in the digital images stored with known diagnosis, already verified by histopathology tests. The analysis was performed by an automatic, objectivity and operator-independent digital image process, by computer vision [*].

Materials and methods

A videomicroscope (Scaler Mitsubishi VMS – 110A) with a 100 W halogen light source was used as an image-capturing eye. The light radiations were transmitted by optic fiber, with a circular terminal favoring illumination uniformity. The polarized light was transmitted over the pigmented lesion (**Figure 2**). The reflected images were captured by a mini color camera with a CCD (Charge Coupled Device) favoring digitalization. Magnification lenses 20′ and 50′ were used.

A computer (Pentium IV) with a capturing plaque working with a spatial resolution of 768 ′ 576 pixels, a chromatic level of 16 million colors (24 bits ′ pixel [*]) with an appropriate software to obtain quantitative information in spatial [*] and spectral [*] resolution of each image was used as an analyzing brain. The images were analyzed with the RGB and HSI models [*].

Before each capture, the system was calibrated by using a color chart (Color Checker Gretab Macbet) and white patch test, following the method by Haeghen et al.[11]

The color quantification analysis was performed by transformation of a real color image in the RGB model at other segmentation [*] by color, by means of Gray Level Quantization [*], SCT/Center [*] (Spherical Coordinate Transform), and PCT/Median [*] (Principal Components Transform), thus obtaining image segmentation by colors in three dimensions through the clustering technique [*].

The color distribution analysis was performed with the HSI model by obtaining variance values in the H (hue) and I (intensity) bands. The Ganster et al. method, which proposes a standardization of pigmented lesions images due to the different skin types, was used. It consists in subtracting the mean value of intensity and hue of the non-pigmented skin from the total of the image. This, in turn, allows for image segmentation to obtain variable values.[4] Total data was stored in electronic calculation sheets. Fifty-five pigmented lesions with known diagnoses checked by histopathologic studies were studied. The analyzed images were: 16 superficial extensive-type melanomas (n=15) and lentigo maligna melanoma (n=1), showing Breslow between thin (< 0.75mm) to 2mm.

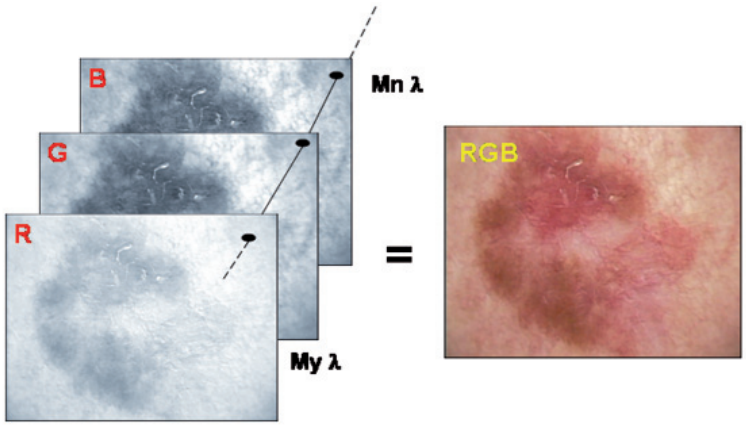

Figure 1. *Superficial extensive melanoma. Breslow 0.6mm.* ***(R)*** *red band,* ***(G)*** *green band,* ***(B)*** *blue band. Addition of the bands forms the original image in RGB. Each band is formed by the skin penetration level of each wavelength (λ).*

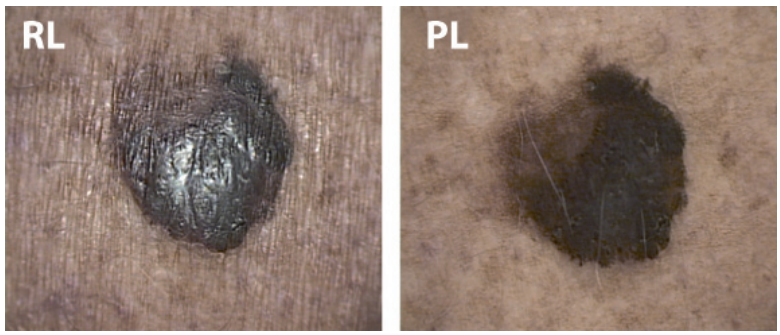

Figure 2. *Melanoma. Breslow 0.72mm.* ***RL:*** *Random light image.* ***PL:*** *Polarized light image.*

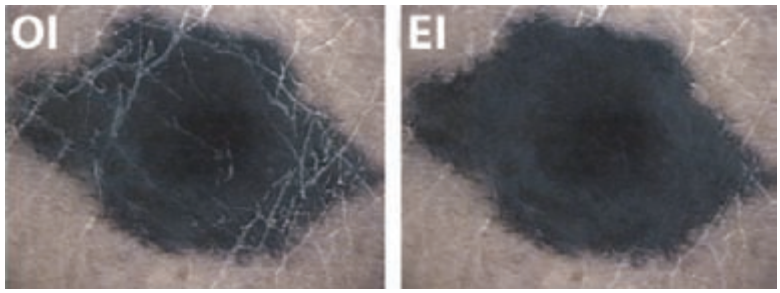

Figure 3. *Blue nevus.* ***OI:*** *Original image.* ***EI:*** *Pixel extrapolation image. Pixel extrapolation favors hair and scale elimination in the images.*

In addition, junctional nevi (n=8), blue nevi (n=6), compound nevi (n=5), Spitz nevi (n=3), seborrheic keratoses (n=6), and basal cell epitheliomas (n=11) were studied.

The algorithm below was followed for all analyzed images:

- **Capture of images**: the pigmented lesions studied had been captured after system calibration by the method of Haeghen et al.[11]
- **Preprocessing**: in most images, median (3 ′ 3 matrix) filters were performed in order to reduce noises [*]. In images with hair or intense scaling, a pixel extrapolation [*] was used, producing a minimal modification of variable values of the pigmented images (**Figure 3**).
- **Segmentation**: the computer automatically separates the pigmented lesion from the rest of the skin or the different color ar-

TABLE 1. AMOUNT OF COLORS IN THE NOM GROUP.

Amount of colors	n	1	2	3	4	5	6 or more
Junctional nevus	8	-	3	2	3	-	-
Blue nevus	6	-	3	1	2	-	-
Compound nevus	5	-	1	2	2	-	-
Spitz nevus	3	-	1	2	-	-	-
Seborrheic keratosis	6	-	1	-	5	-	-
Basal cell epithelioma	11	-	3	2	3	3	-
TOTA L	39	0	12	9	15	3	0
Percent (%)	100	0	38.8	23.0	38.5	7.7	0

TABLE 2. AMOUNT OF COLORS IN THE M GROUP

Amount of colors	n	1	2	3	4	5	6 or more
Fine (<0.75mm)	12	0	0	0	0	2	10
Thick (0.75 to 2mm)	3	0	0	0	0	0	3
Lentigo MM	1	0	0	0	0	0	1
Total	16	0	0	0	0	2	14
Percent (%)	100	0	0	0	0	11.8	88.2

TABLE 3. COLOR HUE AND INTENSITY DISTRIBUTION IN THE NOM GROUP.

NoM lesions		Color distribution		Intensity distribution	
Type of lesion	n	Hue	H variance	Intensity	I variance
Junctional nevus	8	13.7	4.3 ± 1.7	85	334.1
Blue nevus	6	17	30.7 ± 10	79.8	140.3
Compound nevus	5	5.7	5.4 ± 0.7	112.5	412.2
Spitz nevus	3	1.3	9.3 ± 5.6	80.3	224.7
Seborrheic keratosis	6	10.7	6.8 ± 1.5	92.8	327.7
Basal cell epithelioma	11	5.5	8.3 ± 5.1	96.4	276.6

TABLE 4. COLOR HUE AND INTENSITY DISTRIBUTION IN THE MM GROUP

MM lesions		Color distribution		Intensity distribution	
MM subtypes	n	Hue	H variance	Intensity	I variance
Fine (<0.75mm)	12	14.3	70.1 ± 49	91.5	483.4
Thick (0.75 to 2mm)	3	8.2	76.4 ± 52.9	91.0	552.9
Lentigo MM	1	29.4	36	80.9	166.2

eas, according to the analyzed variable. As for colors, images were segmented by: Gray Level Quantization, PCT/ Median and SCT/Center in the RBG model; then converted into 8 bits of grays to detect the different color types by thresholding. Color distribution analysis was performed in the HIS model by global thresholding, to obtain hue and intensity values.

- **Parameter extraction**: the color amount value was obtained by thresholding each image in 8 bits of grays. In the case of several images of the same lesion, average shade was

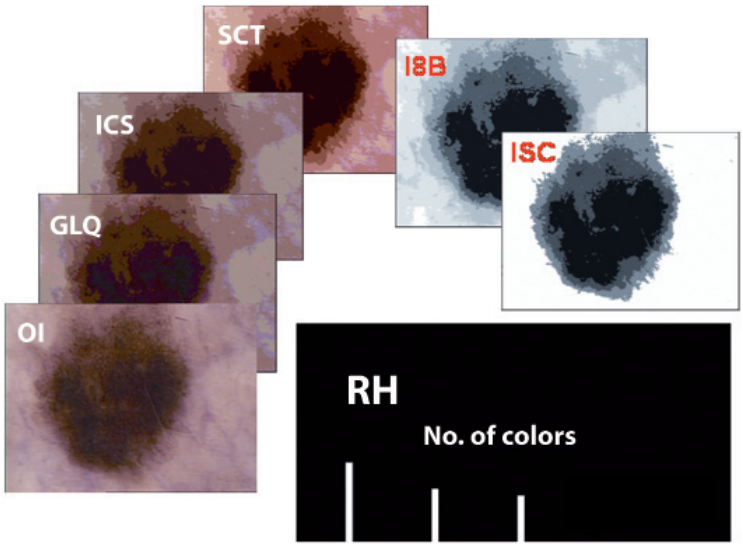

Figure 4. *Junctional nevus. Number of colors: 3. Segmentation algorithm for color quantification.* ***OI:*** *original image.* ***GLQ:*** *Gray Level Quantization.* ***PCT:*** *image after PCT/median.* ***SCT:*** *image after SCT/center.* ***I8B:*** *image in 8 bits.* ***ICS:*** *image in complete segmentation.* ***RH:*** *resulting histogram. The latter informs the number of colors comprising the image.*

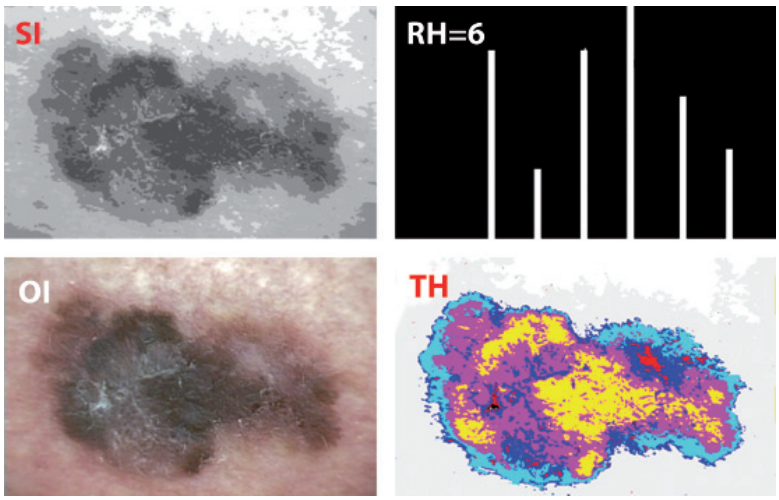

Figure 5. *Melanoma. Breslow 1.2mm.* ***OI:*** *original image.* ***SI:*** *segmented image.* ***RH:*** *resulting histogram.* ***TI:*** *thresholding image with false colors; the latter enables a qualitatively appreciation of lesion asymmetry.*

extracted. Hue, intensity, and variance values of each of the former variables were obtained in color distribution, in engineering units.

- **Collection of data**: recorded in electronic calculation sheets.
- **Statistical analysis of data**: assessed by Mann-Whitney's U test, with 95 percent confidence interval (95 percent CI) and $p<0.05$.

Results

The analyzed images of pigmented lesions were separated in two groups: no melanoma (NoM) and melanoma (M).

The amount of colors detected in the NoM group was 4 or less in 92.3 percent of lesions, and 7.7 percent showed 5 colors. The latter belonged to the basal cell epithelioma subgroup. Average of colors in junctional nevi was 2.9 (95 percent CI: 3.5-2.3), blue nevi 2.8 (95 percent CI: 3.6-2.0), compound nevi 3.2 (95 percent CI: 3.9-2.5), Spitz nevi 2.7 (95 percent CI: 3.4-2.0), seborrheic keratosis 3.7 (95 percent CI: 4.3-3.1) and basal cell epithelioma 3.5 (95 percent CI: 4.2-2.8) (**Table 1**).

In the M group, 88.2 percent showed 6 or more colors, and 11.8 percent showed 5 shades. Total average of the three subgroups was 5.8 ± 0.3 (95 percent CI: 5.9-5.7) (**Table 2**).

Cut-off value taken in color distribution analysis was 20 for the hue variance of the analyzed images. 84.6 percent of NoM lesions showed a lower value and the remaining 15.4 percent showed a higher value. The latter belong to a blue nevi subgroup (**Table 3**).

In the M group, 100 percent showed a value higher than 20 for hue variance. Statistical analysis of this group with the various subgroups of NoM was statistically significant ($p<0.05$), except the blue nevi subgroup (**Table 4**).

Intensity variance or brilliance was not statistically significant between groups NoM and M.

Discussion

Clinical and/or dermatoscopic diagnosis of non-nodular M is favored by the presence of multiple colors and the asymmetrical colors distribution, in contrast to most other pigmented skin lesions.[3,6]

There is good correlation between human eye and computer vision systems in detecting colors of skin lesions.[3,12,13]

Dermatoscopic diagnosis of M by skilled people increases sensitivity between 10 to 30 percent, compared to the naked eye. In turn, the accuracy of the digital image analysis systems is similar to experts in epiluminescence. Multiple works demonstrated a sensitivity of 80 and 100 percent in computer vision methods for diagnosis of M.[13-17]

Digital image analysis systems reproduce human vision and provide the benefit of shade quantization enabling the determination of the amount and color distribution in pigmented skin lesions. This technology may obtain said values by two three-dimensional color representation models: RGB (red, green, and blue), and HSI (hue, saturation, and intensity). The former reproduces the physical perception, and by addition or subtraction of said shades makes it possible to obtain most of the colors perceived by the human eye. The latter transcribes the psychical description. The hue reports the dominant wavelength in the perceived image. Saturation pro-

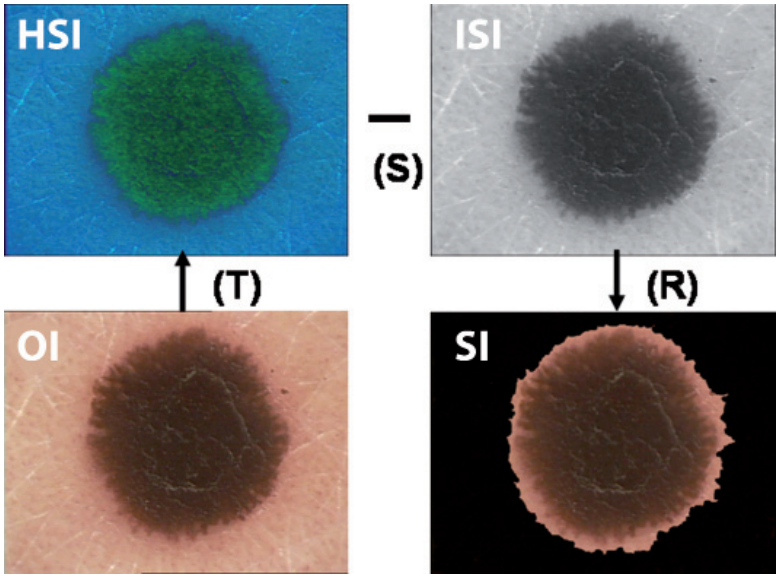

Figure 6. *Spitz nevus. Original image OI is transformed (T) in HSI. Due to the different skin types, standardization of images by subtraction (S) of average value of surrounding skin from the pigmented lesion in ISI (I strip images) is done. Resulting (R) is the segmented image SI, to obtain variable values.*

vides the amount of white in the color. The intensity or brightness is the energy of the perceived light.[9]

In this work, the amount of color was acquired from images using the RGB model. To such effect, transforms allowing for obtaining the colors comprising the images by reflex energy were used. Such mathematical calculations add the benefit of segmentation of various colors by the clustering technique. The latter is performed by automatic aggregation by the computer of pixels with similar color values (**Figure 4**). 92.3 percent of NoM lesions showed 4 or fewer colors, and the remaining 7.7 percent showed five shades. Said values are similar to those found in other research work. We must take into account that we do not discriminate size, localization, gender or age of the patient, skin color, atypia, evolution time, and type of pigmented lesions.

Lesions of this group showing more than 4 colors (n = 3) belong to the subgroup of basal cell epithelioma.[18]

In 88.2 percent (n = 14) of M lesion images, 6 (six) or more shades were found, and 11.8 percent (n = 2) showed 5 (five) colors. Values are similar to those identified by Argenziano G, et al.[12] Lesions with lesser amount were seen in the fine subgroup (<0.75mm).

By means of a histogram, each area may be painted with fake colors, which allows appreciation of lesion symmetry (**Figure 5**).

Color distribution was performed in the HSI model. Due to the various types of skin, image standardization is performed by subtraction of average value of intensity and hue of the skin surrounding the pigmented lesion, in bands I and H, which in turn allows for image segmentation. Color distribution quantization was performed through the hue and intensity variance values. The latter were not statistically significant (**Figure 6**).

Cut-off point of the analyzed image hue variance used is value 20. In the NoM group, 84.6 percent showed lesser values and 15.4 percent, higher. The latter belong to the blue nevi subgroup. In the M group, 100 percent of analyzed lesions showed a higher value. Consulted work shows similar results, although most of them use standard deviation of hue. In this work, we analyze variance to obviate working with negative numbers.[5,19]

Image standardization, multiple segmentation methods, system calibration, analysis of color amount and distribution, allowed for differentiation of melanoma from other pigmented lesions in the population were analyzed automatically, objectivity, and in an independent-of-operator-way by computer vision.

References

1. MacKei R.M., Fleming C., McMahon A.D. and Jarrett P. The use of dermatoscope to identify early melanoma using the three – colour test. British Journal of Dermatology 2002; 146:481-484.
2. Claridge E., Cotton S., Hall P., Moncrieff M. From colour to tissue histology: Physics – based interpretation of images of pigmented skin lesions. Medical Image Analysis 2003; 7:489-502.
3. Pellacani G., Grana C., Seidenari S. Automated description of colours in polarizad – light surface microscopy images of melanocytic lesions. Melanoma Res 2004; 14:125-130.
4. Ganster H., Pinz A., Röhrer R., Wildling E., et al. Automated Melanoma Recognition. IEEE Transactions on Medical Imaging, 2001; 20(3):233-238.
5. Tomatis S., Bono A., Bartoli C., Tragni G., et al. Image Analysis in the RGB and HSI colour planes for a computer – assisted diagnosis of cutaneous pigmented lesions. Tumori, 1998; 84:29–32.
6. Langley RGB, Barnhill RL, Mihm MC, Fitzpatrick et al. Neoplasias: melanoma cutáneo, in Fitzpatrick TB, Freedberg IM, Eisen AZ et al. Dermatología en Medicina general. Ed. Panamericana. Buenos Aires 2005; 1029-1065.
7. González JJ. Adquisición de Imágenes. González JJ. Visión por Computador. Paraninfo. Spain. 2000; 20-37.
8. Marmo W, Panichelli V, Fuga GC. La spettrofotometria cutanea. Seidenari S. Diagnostica non invasiva in dermatologia. EDRA srl. Milano. 1998; 218-243.
9. González RC, Woods RE. Mejora de la imagen. González RC, Woods RE. Tratamiento digital de imágenes. Addison – Wesley Iberoamericana S.A. USA. 1996; 175-273.
10. Pellacani G., Grana C., Seidenari S. Automated description of colours in polarizad – light surface microscopy images of melanocytic lesions. Melanoma Research 2004; 14:125-130.
11. Haeghen YV., Naeyaert JMA., Lemahieu I. An Imaging System with Calibrated Color Image Acquisition for use in Dermatology. IEEE Transactions on Medical Imaging. 2000.19;7: 722-30.
12. Argenziano G., Fabbrocini G., Carli P. et al. Epiluminescence microscopy for the diagnosis of doubtful melanocytic skin lesions. Comparison of the ABCD rule of Dermoscopy and a new 7 – point checklist based on pattern analysis. Arch Dermatol 1998; 134:1563-1570.
13. Blum A, Luedtke H, Ellwanger U, Schwabe R et al. Digital image analysis for diagnosis of cutaneous melanoma. Development of a highly effective computer algorithm based on analysis of 837 melanocytic lesions. Clinical and Laboratory Investigations. British Journal of Dermatology 2004; 151:1029-1038.
14. Sidenari S, Pellecani G and Pepe P. Digital videmicroscopy improve diagnostic accuracy for melanoma. J Am Acad Dermatol 1998; 39:175-181

15. Nachbar F., Stolz W., Merkle T., Cognetta AB, et al. The ABCD rule of dermatoscopy. J Am Acad Dermatol 1994; 30:551-559.
16. Sober AJ and Burstein JM. Computerized Digital Image Analysis: An Aid for Melanoma Diagnosis. The Journal of Dermatology. 1994; 21:885-890.
17. Mayer J. Systematic review of the diagnostic accuracy of dermatoscopy in detecting malignant melanoma. Med J Aust 1997; 167:206-210.
18. Seidenari S., Pellacani G. and Grana C. Computer description of colour in dermoscopic melanocytic lesion images reproducing clinical assessment. British Journal of Dermatology 2003; 149: 523-529.
19. Landau M, Matz H, Tur E, Dvir M et al. Computerized system to enhance the clinical diagnosis of pigmented cutaneous malignancies. International Journal of Dermatology 1999; 38:443-446.

[*] Glossary

- **Clustering technique.** Procedure to assemble pixels by common features; e.g., color, intensity, closeness, etc.
- **Computer vision.** Its purpose consists of the expression of the human eye vision in computing terms.
- **Digital image processing.** Transformation of an image to obtain one of better quality, and extract information.
- **Gray Level Quantization.** Computer calculation enabling segmentation (separation) of an image in its color components. It searches details of the image and places it in one point.
- **H band.** Images comprising HSI, RGB, or other models are defined as bands. The H bands is the image of the hue comprising the HSI model.
- **Histogram equalization.** A histogram is the graphical representation of the frequency with which the levels of gray appear in an image. The X axis informs the gray scale, while the Y axis informs the amount of pixels in each gray level. The equalization is a uniform distribution of grays in the histogram.
- **Hue (H).** A chromatic attribute describing a pure color or the dominant wavelength in a source of light perceived by an observer.
- **Intensity (I) or brightness.** It is the energy transmitted by the light.
- **Median filter.** Mathematic calculation enabling softer images, in order to reduce noise.
- **Noises.** Spurious effect of an image as a result of the capture and digitalization process, due to unwanted electrical stimuli.
- **PCT/Median.** Computer calculation enabling segmentation (separation) of an image in its color components, based on statistical properties of images.
- **Pixel extrapolation.** This function enables transfer of pixel values from one area of interest to another not desirable.
- **Pixel.** Each point of a digital image. Acronym of picture element.
- **RGB and HSI models.** Specifications of a three-dimensional coordinates system, and of a subspace of this system, where each color is represented by one single point.
- **Saturation (S).** Measure of dilution of a pure color in white light.
- **SCT/Center.** Computer calculation enabling segmentation (separation) of an image in its color components. It has the advantage of de-coupling color from brightness information.
- **Segmentation.** Subdivision of an image in its parts or objects of interest; e.g., separates a pigmented lesion from normal skin.
- **Spatial resolution.** Amount of lines horizontally and vertically represented on a screen.
- **Spectral resolution.** Degree of details of the grayscale.
- **Thresholding.** A segmentation form based on an image histogram.