Color recognition of dermatoscopic images of skin neoplasms

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Abstract. The problem of determining the colors of dermatoscopic images of skin neoplasms using computer technologies is considered. Based on the proposed model, a program for recognizing the colors of the studied areas of neoplasm has been developed. The adequacy of this model was tested experimentally. This work is designed to increase the reliability of the diagnosis of skin neoplasms.

1. Introduction
Differential diagnosis of skin melanomas and nevi is an actual problem caused by a number of factors. These include, in particular, the aggressiveness and the special status of this neoplasm - the first place among other types of malignant tumors [1, 2].

Currently, digital dermatoscopes are becoming the most important for obtaining skin images. Digital dermatoscopy offers the following advantages: the independence of research, the possibility of teleconferences and teleconsultations, the convenience of storing images. The possibilities of digital dermatoscopy can significantly reduce the subjectivity of the researcher [3, 4]. In this regard, one of the most urgent tasks of oncodermatology is to improve the methods of early detection of skin melanoma using digital image recognition technologies.

The shape, location and size of the objects under study, as a rule, can be described in verbal (verbal) ways. In the case of identifying color features, there are significant difficulties. This is primarily due to the fact that specialists do not have standardized color designations, and therefore the description is characterized by arbitrariness [5].

The color assessment is determined by the characteristics of the light source, its location, orientation relative to the neoplasm, and other factors. A significant cause of errors in the visual definition of color may be the subjectivism of the researcher, which introduces discrepancies in oncodermatology practice [6]. One of the approaches to solving this problem is to create a system of samples, sometimes called color scales.

A. S. Bondartsev presented a color scale designed for working with biological objects. This scale was created to evaluate the color of plants and was of little use in determining the color of the skin of the human body. That is why G. G. Avtandilov proposed to modify the A. S. Bondartsev scale, basing it on the principle of grouping tonal shades of one dominant color [6].
The first system on the market of computer technologies in the field of color analysis was ShadeEye-EXChangeMeter (1998), which measured the spectral data of an object. The main disadvantage of this system is that the measurements were carried out on one site of the studied object, as a result of which it was necessary to perform many measurements on a large number of different sites. The ShadeScan, Spectroshade, and XRiteShade systems [7] also contribute to obtaining colorimetric data of an object that is not devoid of elements of subjectivity.

During dermatoscopy, a different number of colors can be identified. For example, there are 6 colors (white, red, light and dark brown, black and gray-blue), 4 of them are explained by the presence of melanin, white is due to regressive changes in the neoplasm, red is caused by inflammation or neovascularization. The modified Kittler pattern analysis considers 9 colors (black, blue, red, brown, gray, yellow, orange, white, magenta) [8]. Each of these colors plays a significant role in making a correct diagnosis [9].

The color in the evaluation of dermatoscopic images, as well as the structural features of the neoplasm, has an important diagnostic value. One of the most important signs of the majority of superficially spreading skin melanomas is the presence of two or more predominant colors located asymmetrically in the formation [10].

Color control with the required degree of accuracy can be effectively carried out by digital processing and computer image recognition. There is clearly not enough information in the literature on this topic.

The aim of the work is to develop a model of color analysis of skin neoplasms on digital dermatoscopic images in intelligent melanoma diagnostic systems.

2. Conceptual model of color analysis of dermatoscopic images of skin neoplasms

The conceptual model of color analysis in oncodermatology is presented in the form of a flowchart in Figure 1. The key stage is the classification of the pixels of the image of a skin neoplasm by pre-defined color groups.

When developing the model of Fig. 1, the following initial conditions were accepted. The objects under study are benign and malignant neoplasms of human skin. Dermatoscopic images are colored. The image sensor is the RDS-2 dermatoscope. The number of images of neoplasms in the dermatoscopic database is 3074. Images provided by the Central Medical Academy of the Presidential Administration of the Russian Federation. The image format is 2560×1920 pixels. The color encoding corresponds to 8 bits for each RGB color channel of the model.

A specific feature of the median filters used in the work is the pronounced selectivity with respect to the pixels of the image. Median filters with an optimally selected aperture can preserve sharp borders of image objects without distortion, eliminating abnormal outliers and interference.

When classifying the pixels of an image of a skin neoplasm, the nearest neighbor method is used, the result of which is that the pixel belongs to a certain color class.

The formation of reference colors in the classification of images was carried out using RGB, XYZ, Lab, HSV color models. The values of the coordinates of the reference colors of these models were determined experimentally. The color characteristics of the Kittler dermatoscopic algorithm are based on 9 colors. For which, according to the results of the analysis of the studied images from the dermatoscopic knowledge base, the values of each of the components of all four color models were obtained. Based on the obtained values, the average values of the components of the color models for nine colors were calculated. The results of the study are presented in Tables 1 and 2.
**Figure 1.** Conceptual model of color analysis of dermatoscopic images of skin neoplasms.

**Table 1.** Template colors RGB and XYZ in the color analysis model.

| Color | R    | G    | B    | X    | Y    | Z    |
|-------|------|------|------|------|------|------|
| Black | 34.72| 14.84| 12.78| 1.15 | 0.89 | 0.62 |
| White | 214.01| 199.96| 200.04| 59.89| 60.96| 65.04|
| Red   | 170.42| 54.94| 63.04| 19.81| 12.63| 7.37 |
| Brown | 100.56| 43.12| 19.92| 6.87 | 4.96 | 1.33 |
| Yellow| 199.88| 148.36| 93.76| 38.32| 36.21| 18.17|
| Orange| 180.08| 112.34| 65.32| 26.52| 22.7 | 9.09 |
| Blue  | 105.44| 103.62| 146.8 | 20.23| 18.94| 36.13|
| Violet| 135.28| 90.44| 122.44| 20.35| 16.93| 24.68|
| Gray  | 144.24| 123.74| 123.11| 25.95| 25.78| 26.71|

**Table 2.** Template colors of Lab and HSV in the color analysis model.

| Color | L    | a    | b    | H    | S    | V    |
|-------|------|------|------|------|------|------|
| Black | 7.01 | 9.09 | 4.67 | 0.24 | 0.65 | 0.14 |
| White | 81.72| 5.24 | 1.91 | 0.39 | 0.12 | 0.86 |
| Red   | 41.26| 46.82| 22.77| 0.77 | 0.71 | 0.67 |
| Brown | 25.26| 24.09| 26.42| 0.05 | 0.8  | 0.39 |
| Yellow| 65.34| 13.93| 35.28| 0.08 | 0.52 | 0.78 |
| Orange| 53.81| 22.58| 36.51| 0.07 | 0.64 | 0.71 |
| Blue  | 45.38| 12.44| -22.43| 0.65 | 0.35 | 0.59 |
| Violet| 44.34| 23.36| -9.27 | 0.73 | 0.39 | 0.56 |
| Gray  | 53.63| 8.57 | 4.07 | 0.44 | 0.25 | 0.58 |
As a measure of similarity (proximity r), the Euclidean metric was used, represented by the formula 1 of the color distance in three-dimensional space:

\[ r = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \]

x1, y1, z1 are the color coordinates of the first point in three-dimensional space, x2, y2, z2 are the color coordinates of the second point in three-dimensional space.

The smallest value is selected from the pairwise calculated distances, according to which the pixel is assigned the color value of the nearest reference class.

The conceptual model of color analysis can be analytically represented by a tuple:

\[ CA = <I_{in}, F, PQ, KN, C, I_{out}> \]

where CA is the color analysis of dermatoscopic images of skin neoplasms; I_{in} is the original image, F is noise filtering, PQ is getting pixel coordinates; KN is searching for the nearest neighbor in the space of reference colors; C is assigning a pixel to a color class; I_{out} is displaying a color map on the screen in different color models.

3. Experimental study

The purpose of the experiment is to test the effectiveness of the proposed model for recognizing 9 colors corresponding to the color palette of the Kittler algorithm. In this regard, a C++ program was written in the Qt development environment that implements a model for color analysis of images of skin neoplasms. As a sample of images for the experiment, 3074 images of skin neoplasms were used (website telederm.ru). Previously, images of two or more dermatoscopic colors were selected from the knowledge base. The results of the experimental study confirmed the recognition of the palette of the studied 9 colors. An example of the experiment is shown in Fig. 2 and 3.

![Figure 2](image)

**Figure 2.** An example of color analysis in the Lab color space: a) the original image, b) the Lab color map.
4. Conclusion
The article is devoted to color recognition of dermatoscopic images of skin neoplasms. A model of color analysis of skin neoplasms on digital dermatoscopic images in intelligent melanoma diagnostic systems has been developed. A conceptual model of color analysis in oncodermatology has been developed according to the color palette of the Kittler algorithm. The model includes operations of preliminary noise filtering, classification of the studied image pixels by reference colors and output of a color map of the image of a neoplasm. The conducted experiment on a sample of 50 images (25 - melanoma and 25 - benign neoplasm) confirmed the adequacy of the proposed model.

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