Image Retrieval by use of Linguistic Description in Databases

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Abstract. In this paper, a new method of image retrieval is proposed. This concerns retrieving color digital images from a database that contains a specific linguistic description considered within the theory of fuzzy granulation and computing with words. The linguistic description is generated by use of the CIE chromaticity color model. The image retrieval is performed in different way depending on users' knowledge about the color image. Specific database queries can be formulated for the image retrieval.

Keywords: image retrieval, image recognition, information granulation, linguistic description, fuzzy sets, computing with words, image databases, CIE chromaticity color model, knowledge-based system

1 Introduction

There are many publications concerning image retrieval that is a significant research area since collections of color digital images have been rapidly increasing; see e.g. a survey on image retrieval methods [8]. However, our approach differs from those presented in the literature. The main issue is the goal of image recognition and retrieval. Our aim is not to precisely recognize an object or a scene in an image but only a color that can be described within the framework of fuzzy set theory [21]. This may concern the color as well as other attributes such as amount of the color in an image (color participation or size of the fuzzy color cluster) and optionally its fuzzy location and shape. The problem formulated in this way allows to quickly retrieve an image (or images) corresponding to a fuzzy description that a user introduces into an image retrieval system. An intelligent pattern recognition system that generates linguistic description of color digital images is proposed and developed in authors' previous papers [15]-[20].

In this article, we use the method of generating the linguistic description of images in order to create specific databases that allow to quickly retrieve images responding to fuzzy queries. In addition, further image analysis can be performed by an intelligent knowledge-based system. As a result, such a system may be able to realize fuzzy inference in the direction to image understanding.

2 Color Model for Image Processing

In our approach, we employ the CIE chromaticity color model [6] in the image processing in order to produce the linguistic description (see [15]-[20] and [14]). Figure 1 presents the CIE chromaticity diagram (triangle) where the color areas, considered as fuzzy sets, are depicted and denoted by numbers 1,2, ... ,23, associated with the following colors (hues): white, yellowish green, yellow green, greenish yellow, yellow, yellowish orange, orange, orange pink, reddish orange, red, purplish red, pink, purplish pink, red purple, reddish purple, purple, bluish purple, purplish blue, blue, greenish blue, bluegreen, bluish green, green. The CIE chromaticity diagram shows the range of perceivable hues for the normal human eye.

It is worth emphasizing that chromaticity is an objective specification of the quality of a color regardless of its luminance. This means that the CIE diagram removes all intensity information, and uses its two dimensions to describe hue and saturation. The CIE color model is a color space that separates the three dimensions of color into one luminance dimension and a pair of chromaticity dimension. For simplicity, in our considerations we ignore the luminance but it can be taken into account in further, more detailed research.

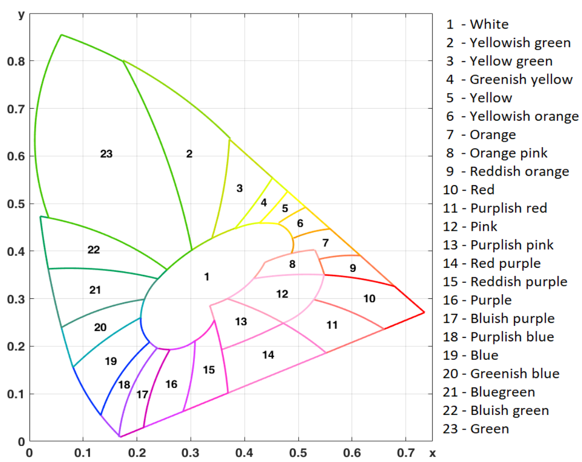

Fig. 1. The CIE chromaticity diagram

The main advantage of using the CIE color model is the fuzzy granulation of the color space, so we can employ the granular recognition system introduced in

[17] and developed in [18]. The CIE color model is suitable from artificial intelligence point of view because the intelligent recognition system should imitate the way of human perception of colors.

3 Linguistic Description of Color Images

The color granules presented in Fig. 1 are viewed as fuzzy sets with membership functions defined in [14]. Of course, according to [21] different shapes of membership functions can be employed (see e.g. [13], [11], [12]). The granular recognition system that produces the linguistic description of input images is a rule-based system (knowledge-based system) with inference using fuzzy logic [22], like e.g. [10], [2], [7]. In our approach, fuzzy granulation [23] concerns the color granules as well as location granules within an image. With regard to the shape attribute, we also consider rough granulation based on rough sets [9]; see our previous papers, e.g. [17].

In [19] and [20], the process of producing the linguistic descriptions of color digital images based on the fuzzy color granules, determined in the CIE color model, is explained. Figures 2 and 3 present results of classification pixels of two images into fuzzy color granules of the CIE diagram.

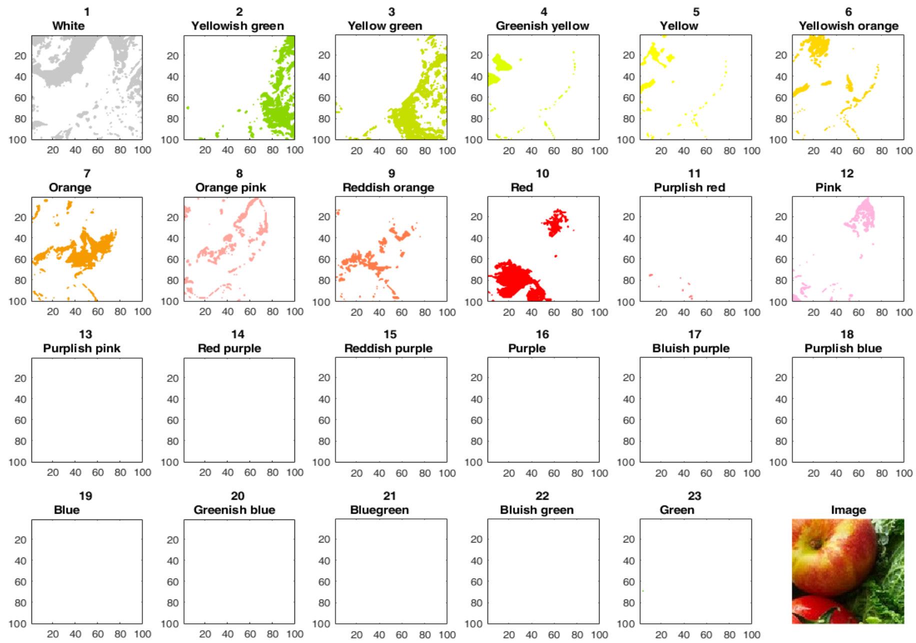

Fig. 2. Color granules in input image 1

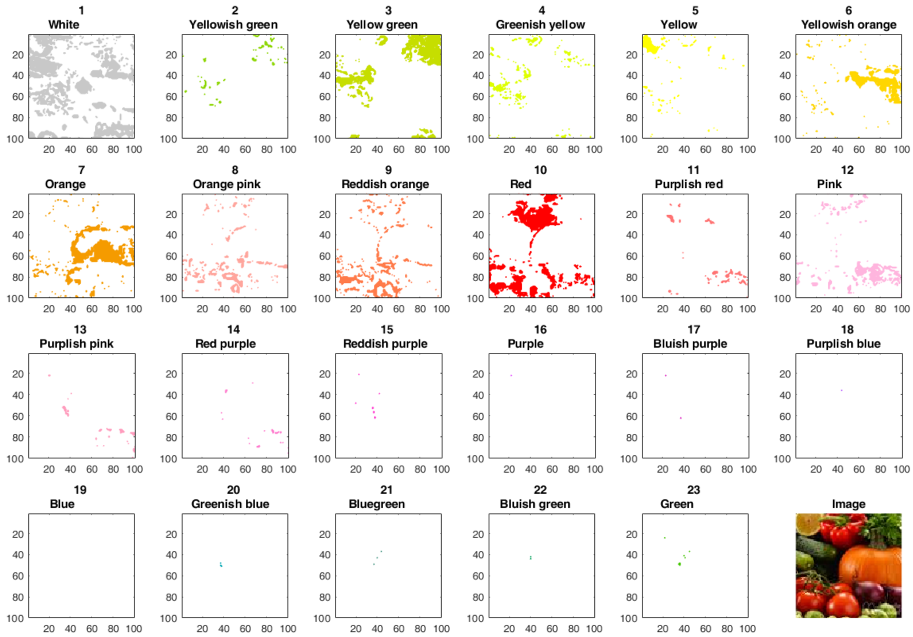

Fig. 3. Color granules in input image 2

Then, histograms portrayed in Figs. 4 and 5, respectively, illustrate participation rates of particular colors (fuzzy color granules) in both images. It should be emphasized that values of the participation rates are viewed as fuzzy numbers, and measured by use of the fuzzy unit P (fuzzy set with the membership equal 1 only for p); see e.g. [13]. Thus, value p is the kernel of the fuzzy number P that denotes the participation rate of every color granule, assuming that each of them participates in the image with the same rate. This fuzzy number is applied as the unit of participation of particular colors in an image.

Figure 6 presents trapezoidal membership functions of fuzzy sets VS, S, M, B, VB denoting $Very\ Small$, $Small$, $Medium$, Big, $Very\ Big$, respectively, as linguistic values of color participation (p_rate) in an input image. It is obvious that the p_rate axis corresponds to the vertical axes in the histograms (Figs. 4 and 5); the unit value p is employed in all the axes.

In the next section, the database table (Table 1) that shows the participation of colors in different images has been produced by use of the fuzzy unit P. In this table, the linguistic values depend on the fuzzy numbers expressed by means of the unit P. Fuzzy numbers are described in [5], and applied in many problems (see e.g. [3]). Values indicated by the histograms and expressed by the unit P are described by linguistic labels according to the membership functions of fuzzy sets presented in Fig. 6.

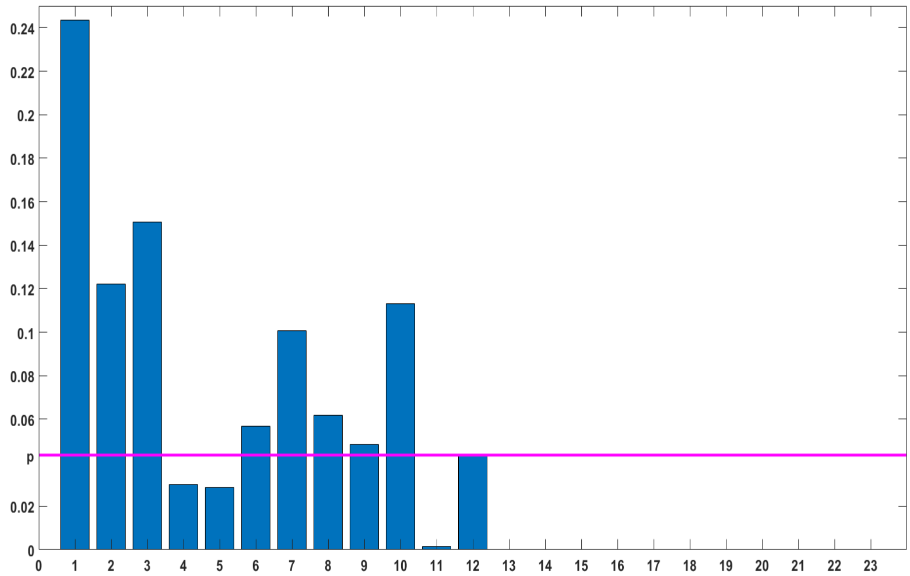

Fig. 4. Histogram of color participation in input image 1

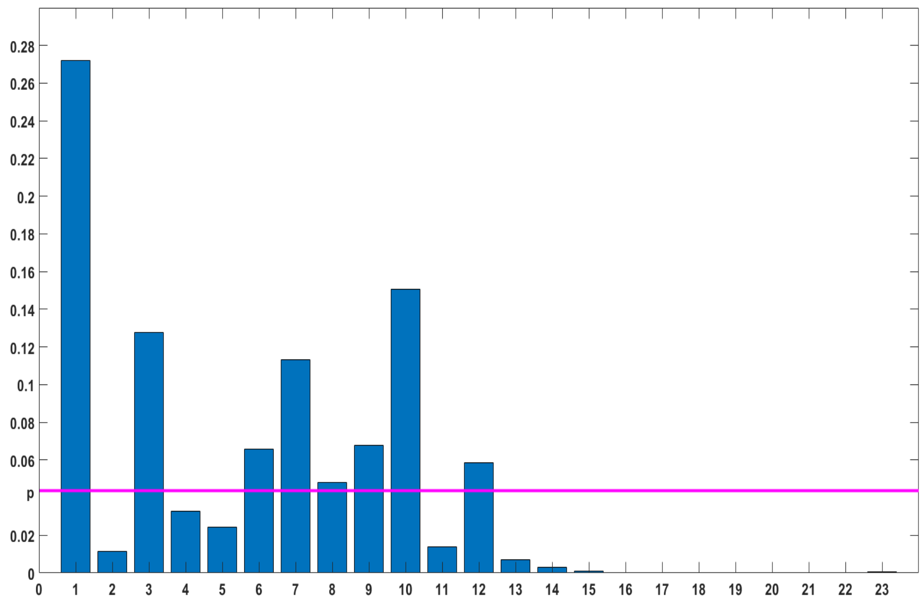

Fig. 5. Histogram of color participation in input image 2

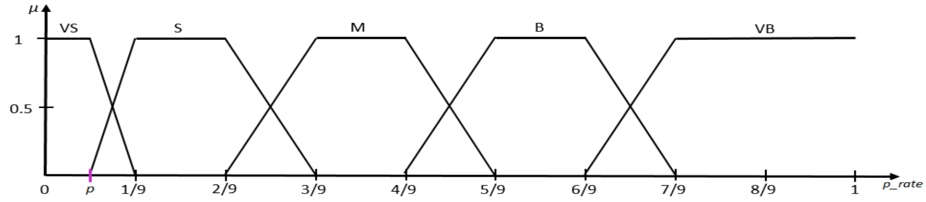

Fig. 6. Fuzzy sets of color participation rate

4 Databases for the Linguistic Description of Images

Table 1 is a database table that includes data concerning participation of particular colors, C_1, C_2, ..., C_{23}, in images from an image collection. Values of the data corresponds to the percentage of pixels belonging to the color granules.

More detailed data, concerning the color participation in particular locations of the images can be included in a hierarchical database and also in the form of a multidimensional cube. This means that Table 1, in addition to the values that denote the participation rates of colors in the images, may also contain two-dimensional tables of the color participations in parts of the images. This refers to the macropixels, introduced and employed in [15]-[20]. The fuzzy macropixels indicate locations within an image LU,...,RD (see Fig. 7). The macropixels can be of different size, as Fig. 8 illustrates. Semantic meaning of the location names is explained later in this section, when referred to Fig. 10.

Table 1. Database table: Participation of color

File of Image	Participation of C_1	Participation of C_2	...	Participation of C_{23}
Image 1	0.24	0.12	...	0.00
...	...	...	...	...
Image 2	0.27	0.01	...	0.00
...	...	...	...	...

Such a multidimensional model of the data table can be considered as an OLAP cube (see e.g. [4]); OLAP stands for OnLine Analytical Processing. As a matter of fact, in our case, this multidimensional cube is viewed as a fuzzy data model (see e.g. [1]).

Figure 9 illustrates how to create a three-dimensional cube that represents an image. The cube is composed of every matrix $\mathrm{M_{C\_1}}, \mathrm{M_{C\_2}}, ..., \mathrm{M_{C\_23}}$, of membership values of particular color granules from the CIE diagram (Fig. 1). Based on the matrix cube the visualizations shown in Fig. 2 have been generated and also put in form of the corresponding cube as we see in this figure.

It should be emphasized that OLAP cubes are used in data warehouses for analytical processing of the data. OLAP cubes consist of facts, also called mea-

Fig. 7. Locations in image 1

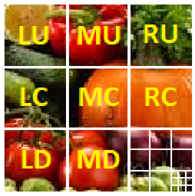

Fig. 8. Locations in image 2

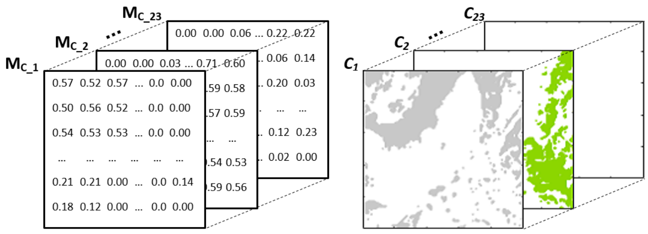

Fig. 9. Multidimensional cubes of color granules in image 1

sures, categorized by dimensions (in general, it can be more than three dimensions). An OLAP cube provides a convenient way of collecting measures of the same dimensionality. The useful feature of an OLAP cube is that the data can be contained in an aggregated form. Special operations allow to slice, dice, drill down/up, roll-up, and rotate an cube in order to navigate, select, and view particular subsets of the data. In this way we can easily analyze specific parts od the data. Especially, the drill down and up enable to navigate among levels of data ranging from the most summarized (up) to the most detailed (down). A slice is a subset of a multidimensional cube corresponding to single value for one or more numbers of the dimensions.

In case of our example, we can slice a particular matrix M_{C_i}, for i=1,2,...,23, from the cube presented in Fig. 9. In addition, we can drill down (or up) to analyze specific regions of an image (location indicated by macropixels of different size); see Fig. 10. It should be emphasized that in our case, the dimensions: color granules and two-dimensional space of an image (composed of pixels) have values considered as fuzzy sets, i.e. fuzzy color granules and fuzzy macropixels (see [15]-[20]).

Figure 10 presents two fuzzy histograms that portray participation of pixels of the same color granule (C_2 – yellowish green) in locations determined by macropixels of different size (big and small). This concerns image 1; see Figs. 2, 7, and 9. Let us notice that color C_2 is mostly visible at the right side of the picture (Righ Upper - RU, Right Central - RC, and Right Down - RD macropixels), and also (but much less) in the Left Down - LD and Middle Down - MD macropixels. This corresponds to Fig. 7 where color Yellowish green does not exist in locations LU - Left Upper, MU - Middle Upper, LC - Left Central, and MC - Middle Central.

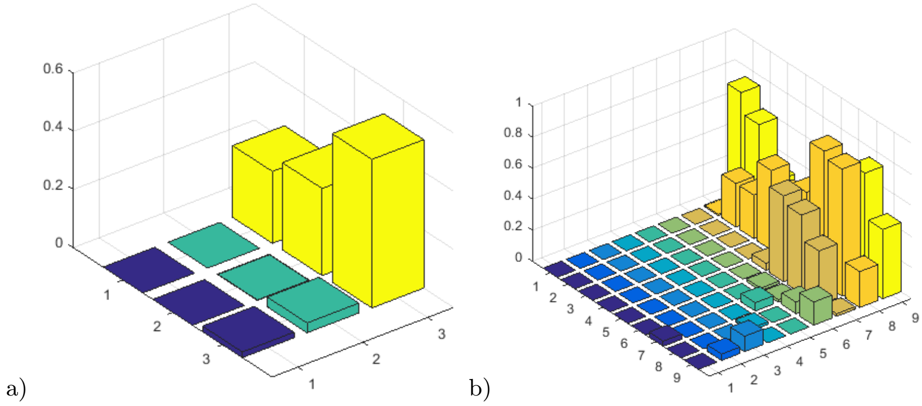

Fig. 10. Color C_2 in image 1, in locations of macropixels: a) big size b) small size

The three-dimensional cube considered so far represents a single image described by data concerning participation of particular colors in the image and smaller regions (location determined by fuzzy macropixels). This data model can be viewed as a part of an OLAP cube that contains data concerning a collection of images. Figure 11 illustrates the multi-dimensional cube composed of the data of the form depicted in Fig. 9, for many digital color pictures. By use of the OLAP operations, it is easy to analyze an image base with regard to colors and locations in a set of the pictures. An example of image retrieval based on the data that can be aggregated in such a cube is considered in Section 5.

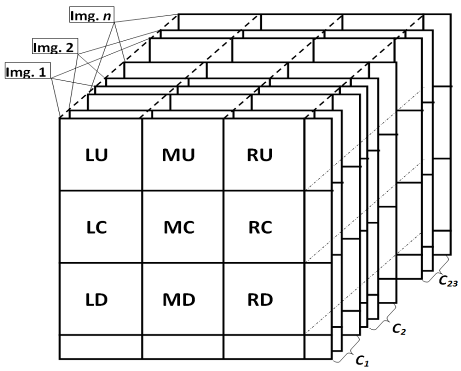

Fig. 11. Multidimensional data model of a collection of images

5 An Example of Image Retrieval by use of the Database

Figure 12 portrays several images from the base of color digital pictures employed to illustrate our approach to image retrieval. As a matter of fact, only data concerning the color participation in images without the localization as shown in Figs. 7 and 8 is presented in this section. Of course, by use of the multidimensional data model of the form of OLAP cube, as shown in Fig. 11, the image retrieval procedure can be extended to analyze color participation in particular regions indicated by the fuzzy macropixels (see Figs. 7 and 8). Data in the cube depicted in Fig. 11 are viewed as hierarchical granulated cubes, enabling to navigate within more aggregated and more detailed levels. This refers to the deeper granulation of an image area by smaller macropixels as shown in Fig. 8 and also in Fig. 10 b).

Fig. 12. Part of the image base used in the example of image retrieval

Table 2 contains linguistic values obtained according to the membership functions depicted in Fig. 6 that describe color participation in the images included in this base. Two first rows of this table contain the linguistic values describing participation of particular colors in images 1 and 2. Of course, the table includes linguistic values for every image from the collection, much more than only seven presented.

Table 2. Database table with linguistic values of color participation in images

Im.	$\mathbf{C}_1$	$\mathbf{C}_2$	$\mathbf{C}_3$	$\mathbf{C}_4$	$\mathbf{C}_5$	$\mathbf{C}_6$	$\mathbf{C}_7$	$\mathbf{C}_8$	$\mathbf{C}_9$	$\mathbf{C}_{10}$	$\mathbf{C}_{11}$	$\mathbf{C}_{12}$	$\mathbf{C}_{13}$	$\mathbf{C}_{14}$	$\mathbf{C}_{15}$	$\mathbf{C}_{16}$	$\mathbf{C}_{17}$	$\mathbf{C}_{18}$	$\mathbf{C}_{19}$	$\mathbf{C}_{20}$	$\mathbf{C}_{21}$	$\mathbf{C}_{22}$	$\mathbf{C}_{23}$
1	S	S	S	VS	VS	VS	S	VS	VS	S	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS
2	S	VS	S	VS	VS	VS	S	VS	VS	S	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS
3	M	VS	S	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS
4	VS	M	S	VS	VS	VS	VS	VS	VS	S	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS
5	S	VS	VS	B	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS
6	S	VS	VS	VS	VS	VS	VS	S	VS	S	VS	B	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS
7	M	VS	S	VS	VS	VS	VS	VS	VS	VS	VS	S	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS	VS
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

The image retrieval is performed by use of the data in Table 2 and fuzzy IF-THEN rules of the following form, e.g.:

$$\textbf{IF } c_1 \text{ is S } \textbf{AND } \ \mathrm{c}_2 \text{ is VS } \textbf{AND } \ \mathrm{c}_3 \text{ is S } \textbf{AND } \ldots \textbf{ THEN } \text{Im. 2} \tag{1}$$

$$\textbf{IF } c_4 \text{ is B } \ \textbf{THEN } \text{Im.5} \tag{2}$$

$$\textbf{IF } c_{12} \text{ is B } \textbf{ THEN } \text{Im.6} \tag{3}$$

where c_1, c_2,..., c_{12} are linguistic variables corresponding to fuzzy color granules C_1, C_2,..., C_{12}, respectively.

An inference process that employs fuzzy logic and the fuzzy IF-THEN rules produces outputs (image or images) matching an user's query. Since descriptions of images are included in database tables the SELECT instruction used in the SQL language can be employed, e.g. SELECT FROM Table 1 WHERE Color is greenish yellow AND participation is Big. It is worth emphasizing that in our approach the fuzzy queries are employed (see e.g. [24]). In our example, an answer to this query is image 5 as the output.

6 Conclusions and Final Remarks

The image retrieval approach presented in this paper is very useful when a problem is formulated as follows: Find a picture (or pictures), from an image collection, including color described with regard to names of the color granules (see Fig. 1 and Figs. 2 and 3) located in regions (indicated by names as in Figs. 7, 8, and 11) of size defined by fuzzy linguistic values (as shown in Fig. 6). There are situations requiring quick retrieval of pictures including an object that can be recognized by its color, size, and (optionally) location, approximately defined. For example – a wanted person who escapes with a yellow bag.

When the data describing images by use of the linguistic values are contained in the form of a multidimensional cube (OLAP), as illuatrated in Fig. 11, we can analyze the color pictures in the direction of image understanding. It is worth noticing that deeper granulation of an image area (as shown in Fig. 8) allows to inference concerning shapes of objects by means of macropixels of various size.

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