A Study for Comparative Evaluation of the Methods for Image Processing Using Texture Characteristics

MARIANA JURIAN, IOAN LITA, FLORENTINA ENESCU, DANIEL ALEXANDRU VISAN
Electronics, Communications and Computers Department
University of Pitesti
Str. Targul din Vale, Nr.1, Pitesti
ROMANIA
m_jurian@yahoo.com, lita@upit.ro, visan@upit.ro, http://www.upit.ro

Abstract: - In this paper a comparative study has been made regarding certain methods of image processing by the texture characteristic, to find the optimum method for detecting color texture. The study is based on the experiments. There are two main points: the quality of the detection and the response time.
For the experiments have been used the co-occurrence matrix and the iso-segments matrix of the gray or color levels. These methods are based on processing the image at a pixel level and the making of matrix that contain certain spatial positions of pixels. The resulting matrix was analyzed and, based on the existing information, the characteristics vectors associated to the matrix was determined. Each method was studied by analyzing the pixels of the image files in certain situations and directions and at certain distances.
The co-occurrence methods had better results for the queries based on water, wood and grass textures and on the ones based on sand, ruble and clouds, better results were obtained using the iso-segment matrix

Key-Words: - texture, co-occurrence, iso-segments, pixel, propinquity, grain, contrast, directionality, regularity, roughness, line-likeness**.**

1 Introduction

The spatial and fractal characteristics are two fundamental elements of the models used in human interpreted image analysis. The textural characteristics contain information regarding the spatial distribution of the tone values within a band. Color and texture elements are always present within an image, although one property can be more dominant than the other. While trying to describe this fact, one can notice that when a discrete gray color characteristic of a small area from an image has a small variation, the predominant characteristic of that area is the color. In exchange, when a higher variation occurs, the predominant characteristic of that area will be the texture [13].

The texture is described in linguistic terms by words such as roughness, contrast, fineness, regularity, words that do not have a clear mathematical correspondent.

Nowadays, texture based image analysis has become an important and highly useful research field. Texture is exposed in many of natures surfaces so a successful viewing system must be able to work with the textured world around it. The importance of texture perception is analysed from two points of view: one considers the human viewing system and the other, the practical applications that are present on different artificial systems. It is very important how the human viewing system relates to texture because this is the standard used to compare the performance of the algorithms used to detect texture.

The methods used in texture analysis are being utilized in many areas such as medical image processing, automated surface inspection, remote notification and others.

Regarding the surface inspection, there are a limited number of applications that can detect any existing problems within a surface by analyzing its texture. Such applications are the ones detecting defects in images that contain textile surfaces, carpet wear inspections, vehicle paint color and others.

Texture analysis has also been highly used in the classification of satellite received images [6]. In this case, different areas (e.g. different terrain types) have different textures that need to be identified this leading to different analysis methods [7].

2 Texture processing methods

All surfaces that describe visual templates, with homogeneity properties, have texture as a property. In other words, the texture indicates the different physical composition of a surface [11].Properties of texture: coarseness, contrast, directionality, line-likeness, regularity, roughness. For texture to be perceived, a two-dimensional matrix is obtained from the decrypting of the image file (*.jpeg, *.bmp). Textures can be represented: statistical, structural and spectral.

From the statistical point of view, textures are represented using the statistical properties of the color or gray levels, the points/pixels within the surface of the image. The most commonly used statistic representations of textures are: the co-occurrence matrix, the Tamura texture and the Wavelet transform [11].

For the experiments we have used the co-occurrence matrix and the iso-segments matrix of the gray or color levels.

These methods are based on processing the image at a pixel level and the making of matrix that contain certain spatial positions of pixels.

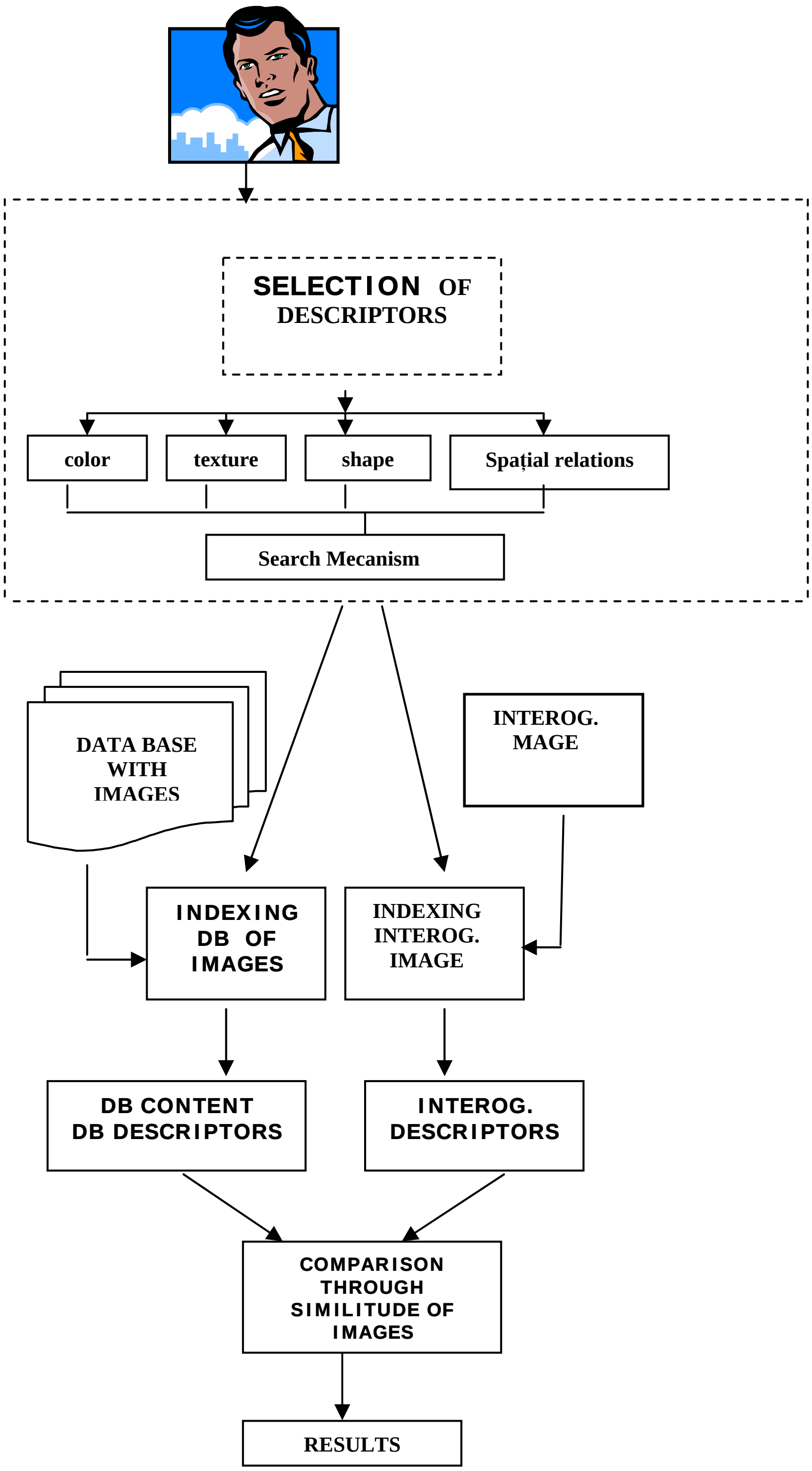


Fig.1 The algorithm of the system for indexing and finding of similar images.

The resulting matrix will be analyzed and, based on the existing information, the characteristics vectors associated to the matrix will be determined. Each method will be studied by analyzing the pixels of the image files in certain situations and directions and at certain distances.
Descriptors that are used for description of the images stored in data base and but for interrogation images that aren't in data base will be established by the user. The module named INDEXING DB OF IMAGES allows creating the descriptors calculus procedure for all images stored in data base and also allows creating a catalogue of the data base content. This catalogue determines the structure for data base description and also a series of statistical indexes calculated in correspondence with individual images. This module can work only off-line. Conversely, the module INDEXING INTERROGATION IMAGE, which realizes the same calculus functions for the same descriptors, can work on-line. The module named IMAGES COMPARISON selects from the data base the images having descriptors with sufficient similitude with descriptors of the interrogation images.

2.1 The co-occurrence matrix

Whether considering the intensity or grayscale values of the image or various
dimensions of color, the co-occurrence matrix can measure the texture of the image .
We choose one offset vector so the matrix is defined over an image to be the distribution of co-occurring values at a given offset:

$$M_t(a, b) = \text{Card } \{(x, x + t) \in R \times R| \; f(x) = a \quad (1)$$

$$f(x + t) = b \quad (2)$$

Mt(a,b) will be the number of pixel pairs from the R area (region), separated by the offset vector t, which have the value of the grayscale or color levels equal to a and b.
For an image with L grayscale or color levels, the co-occurrence matrix will be a square matrix with the dimension equal to L. To summarize the calculation , the number of gray or color levels is reduced to 8 or 16 , by a convenient technique. The difference between different textured can be made mainly by inspecting the co-occurrence matrix, by viewing it in a three-dimensional medium. Furthermore, a series of statistical indexes can be defined , indexes that characterize the distribution of the elements of the matrix.

Homogeneity:

$$O = \frac{1}{N_{nz}} \sum_a \sum_b \left(M_t(a,b)\right)^2 \quad (3)$$

N_{nz} is the number of different pairs of gray or color levels , with an offset equal to t, that are found within the considered area (region). The more times a pair is found in the certain area, the greater the value of the index - this happens usually when regularity occurs.
Local homogeneity:

$$O_{loc} = \frac{1}{N_{nz}} \sum_a \sum_b \frac{1}{1+(a-b)^2} \cdot M_t(a,b) \quad (4)$$

Contrast:

$$C = \frac{1}{N_{nz}(L-1)^2} \sum_{k=0}^{L-1} k^2 \sum_{|a-b|=k} M_t(a,b) \quad (5)$$

Each term of the co-occurrence matrix is leveled with an offset from the diagonal. Through this, we obtain an index that corresponds to the visual interpretation of the contrast and has a high value when the terms that are distant from the main diagonal have higher values (more precise, when there are numerous passes from dark pixels to light pixels).
Entropy:

$$H = 1 - \frac{1}{N_{nz} \log N_{nz}} \sum_a \sum_b M_t(a,b) \cdot \cdot \log M_t(a,b) \cdot \delta(M_t(a,b)) \quad (6)$$

The value of the entropy is low if the same pair of pixels apears frequantly and high if all the grayscale or color levels are faintly represented. This is an idicator of disorder that charaterises the texture.
Eavenness (uniformity):

$$U = \frac{1}{N_{nz}^2} \sum_a M_t^2(a,a) \quad (7)$$

Directivity:

$$D = \frac{1}{Nnz} \sum_a Mt(a,a) \quad (8)$$

The more an unique grayscale or color level apears on the translation axis, the more important uniformity and directivity are .
Correlation:

$$B = \frac{1}{N_{nz}\sigma_x\sigma_y} \sum_a \sum_b (a-\mu_x)(b-\mu_y) M_t(a,b) \quad (9)$$

In the former expression, μ_x and μ_y, are the means (average) on the lines and columns of the elements of the co-occurrence matrix, and σ_x and σ_y are the corresponding dispersions.

It is considered the the most important measures to define textures are: homogeneity, entropy, contrast and correlation.

Therefore, the co-occurrence matrix is a square matrix, with a LxL dimension, where L is the number of grayscale (for black and white images) or color (for color images) levels.

This depends on the direction on which the pixels are analyzed and the distance between two analyzed pixels. We will be studying the cases in wich the pixel orientation is at 0, 45, 90 and 135 degrees. The distance between two analyzed pixels can be any value, but of course not more than the size of the whole image, but for each of the 4 directions considered earlier, we have chosen a distance of 0, meaning that we will be analyzing adjacent pixels.

The fact that the considered distance is 0, is favorable, because this way all the pixels in the processed image will be analyzed. In case the distance is greater, some pixels will be ignored. A (x, y) pair from the co-occurrence matrix, indicates the total number of appearances within the image of a pixel pair with the grayscale or color value of x and y on the considered directions (0,45, 90,135) .

All the terms in the co-occurrence matrix are 0 initially, but incrementations are made, when pairs of pixels are found that match the values in the pixel matrix.

The construction model of co-occurrence matrix – For a better clarification of the modalities of co-occurrence matrix construction we choose a practical example where we have given the matrix

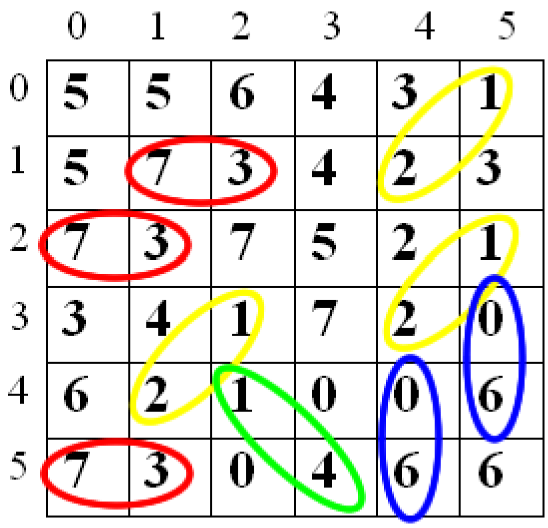


Fig. 2 The values of grey or color of the image's pixels.

with gray values (or color values) of the pixel from an small image of 6x6 resolution.

This reduced dimension of the matrix was choused for simplicity. The image, been an collection of point organized on rows and columns, every point can be localized through specification of his coordinates and is naturally to attach matrix of values to the image.

Starting to the matrix with pixels, there will be built easily the co-occurrence matrix for every of the 4 studied directions, the distance between pixels been the entire time equal with zero. This can be observed in the following pictures.

In the practical examples presented above was illustrated by surrounding with different colors the mode of construction for the co-occurrence matrix on every of the four directions: at 0 degrees (red color), at 45 degrees (yellow color), at 90 degrees (blue color) and at 135 degrees (green color).

Can be observed that exists 4 co-occurrences matrixes (fig. a, b, c, d) corresponding to the 4 directions specific to the image pixels. For example, for co-occurrences matrix at zero degrees, when the pixels are inspected on horizontal direction, were surrounded only the pairs of pixels with values 7 and 3. Can be observed that exists a number of three pairs in the entire matrix of pixels, so in the co-occurrence matrix will be stored at position (7,3) the value 3 (the number of pixels). The value 3 is stored in co-occurrence matrix on the position indicated by the values of the pair pixels. The procedure is continued in identically for all the other pixel pairs and is generated the co-occurrence matrix for zero direction. In an similar way proceed at 45 degrees, when in the example pictures were surrounded with yellow all pixel pairs having values 2 and 1. These are also three in all matrix of pixels, thing that is reflected in the co-occurrence (for 45 degrees) matrix by storing the value 3 in position (2, 1). At 90 degrees were surrounded with blue the pixel pairs having values 6 and 0 that can be observed that they are in number of 2 on this direction. In consequence in the co-occurrence matrix attached to the vertical direction of analysis of the image, namely at (6, 0) position it was stored number 2 (the number of pixel pairs with values 6 and 0).

Finally, for the last direction taken into consideration, at 135 degrees, exists an single pair of pixels with values 4 and 1, marked in the figures with green color (in the matrix with the values of pixels). In consequence, in the co-occurrence matrix, at the direction of 135 degrees will be stored value 1 corresponding to position (4, 1). The presented example was given for an single matrix of pixel values.

	0	1	2	3	4	5	6	7
0	1	0	0	0	1	0	1	0
1	1	0	0	0	0	0	0	1
2	1	2	0	1	0	0	0	0
3	1	1	0	0	2	0	0	1
4	0	1	1	1	0	0	1	0
5	0	0	1	0	0	1	1	1
6	0	0	1	0	1	0	1	0
7	0	0	1	3	0	1	0	0

a) The co-occurrence matrix (0 grades)

	0	1	2	3	4	5	6	7
0	2	0	1	0	0	0	0	0
1	0	0	0	0	0	1	0	1
2	0	3	0	1	0	0	0	0
3	0	1	0	2	1	0	0	0
4	1	0	0	1	0	0	0	1
5	0	0	1	0	0	1	0	0
6	0	0	0	0	1	0	1	0
7	0	0	2	0	1	0	1	1

b) The co-occurrence matrix (45 grade)

	0	1	2	3	4	5	6	7
0	0	2	1	0	0	0	0	1
1	0	1	0	1	0	0	0	1
2	0	0	2	1	1	0	0	0
3	0	1	1	0	0	0	1	2
4	1	0	0	1	1	0	0	0
5	0	0	0	0	1	1	0	0
6	2	0	0	1	0	0	1	0
7	0	0	0	1	0	1	1	0

. c) The co-occurrence matrix, 90 grade

	0	1	2	3	4	5	6	7
0	0	1	2	0	0	0	0	1
1	0	0	1	1	1	0	0	0
2	0	0	0	1	2	1	0	0
3	0	0	0	1	0	2	1	0
4	0	1	0	0	0	0	1	1
5	0	0	0	1	0	0	0	0
6	2	0	1	0	0	0	0	0
7	0	0	0	0	0	1	0	2

d) The co-occurrence matrix, 135 grade

Fig. 3. An example presenting the construction model of co-occurrence matrix.

In the case when are studied color images, then will be used three such matrixes of pixels, one for red values of pixels, other for green values of color pixels and other for values corresponding to the blue component of the color pixels.
For each of these three matrixes of values will be built 4 co-occurrence matrixes corresponding to the 4 directions of analysis of the pixels:

```
Program sequence:
    a)  co-occurrence matrix
        creation
  public void createCom(int cul, int
  dir) {
        int r, c;

        long com=new
  long[256][256];
        for(r=0; r<256; r++)
          for(c=0; c<256; c++)
            com[r][c]=0;

        if(dir==0) {
           for(r=0; r<h; r++)
             for(c=0; c<w; c++) {
               if(c+1<w)
  com[pixels[r][c][cul]]
  [pixels[r][c+1][cul]]++;
             }
           }
           // … the same for other
  dirrections
  }
```

2.2 The iso-segment matrix

An iso-segment of grayscale or color levels, also called range or run-length, is a linear multitude of consecutive pixels that have the same grayscale or color level orientated on a certain direction. The length of an iso-segment is the number of pixels that form it [4].For a fixed orientation (direction) θ, an iso-segment matrix can be determined: the elements $M_\theta(a, b)$ represent the number of segments that have a given length equal to b, formed from pixels of a given grayscale or color level, and orientated on the

θ direction. The resulting matrix has L lines and a number of columns equal to the maximum segment length on the given direction (N_θ).
The aspect of this matrix is specific to a certain texture.
The number of segments:

$$N_{iz} = \sum_{a=1}^{L-1} \sum_{b=1}^{N_\theta} M_\theta(a,b) \qquad (10)$$

Short ranges proportion:

$$RF_1 = \frac{1}{N_{iz}} \sum_{a=0}^{L-1} \sum_{b=1}^{N_\theta} \frac{M_\theta(a,b)}{b^2} \qquad (11)$$

Long ranges proportion:

$$RF_2 = \frac{1}{N_{iz}} \sum_{a=0}^{L-1} \sum_{b=1}^{N_\theta} b^2 M_\theta(a,b) \qquad (12)$$

The heterogeneity of the grayscale or color levels measures the range dispersion between the levels:

$$RF_3 = \frac{1}{N_{iz}} \sum_{a=0}^{L-1} \left(\sum_{b=1}^{N_\theta} M_\theta(a,b) \right)^2 \qquad (13)$$

The heterogeneity of the range length:

$$RF_4 = \frac{1}{N_{iz}} \sum_{b=1}^{N_\theta} \left(\sum_{a=0}^{L-1} M_\theta(a,b) \right)^2 \qquad (14)$$

Range percentage:

$$RF_5 = \frac{N_{iz}}{N_{reg}} \qquad (15)$$

The iso-segment matrix, is an LxN matrix, where L is the number of grayscale (for black and white images) or color (for color images) levels, and N the maximum length of the segments (ranges of pixels with the same grayscale or color level value) within the image. This matrix depends on the same parameters as the co-occurrence matrix. We will be studying the cases in which the pixel orientation is at 0, 45, 90 and 135 degrees. The distance between two analyzed pixels can be any value, but of course not more than the size of the whole image, but for each of the 4 directions considered earlier, we have chosen a distance of 0, meaning that we will be analyzing adjacent pixels.
The fact that the considered distance is zero, is favorable, because this way all the pixels in the processed image will be analyzed. In case the distance is greater, some pixels will be ignored. The A(x, y) pair from the matrix, indicates the total number of appearances within the image of the pixel ranges with the grayscale or color value of x and the range value of y on the considered direction (0, 45, 90, 135). The pixels with the same grayscale or color value will be counted and this values will be written in the matrix.
All the terms in the matrix are zero initially, but incrementations are made, when ranges of pixels are found that have the same grayscale or color level.
The construction methods of iso-segment matrix – For a better understanding of the modalities for the construction of iso-segment matrix were choused also an practical example in which we have given the matrix with grey or other color values of the pixels contained in an small image with an 6x6 resolution (choused for simplicity). The image, been an collection of points organized on rows and columns, every pixel can be localized specifying the line and column on which is situated. In this case iti is naturally to create an matrix of values attached to the image. Starting from this matrix containing values of pixels, will be easily built the iso-segments matrix according with algorithm and for every of the four studied directions, the distance between pixels been all the time equal to zero, as can be observed from the figures. For a better understanding, were indicated through surrounding notation (with different color) few particular examples for every of the four directions taken into consideration, namely: at 0 degrees with red color, at 45 degrees with yellow color, at 90 degrees with blue color and at 135 degrees with green color. Can be observed that exist four matrixes of iso-segments corresponding to the four directions of inspection for the image's pixels.
As example, for iso-segments matrix at zero degrees, meaning the situation in which pixels are inspected on horizontal direction, in the pixel's matrix there were surrounded with red color only the segments having pixels with value 6. Thus, in the proposed example are 3 such segments with length 1 and one segment of length 2 (two pixels with value 6). In the iso-segments matrix afferent to the direction zero, will be introduced value 3 (number of segments with value 6 and length 1) in position (6, 0) or will be introduced value 1 in position (6, 1) respectively the number of segments with value 6 having length 2.

	0	1	2	3	4	5
0	5	5	6	4	3	1
1	5	7	3	4	2	3
2	7	3	7	5	2	1
3	3	4	1	7	2	0
4	6	2	1	0	0	6
5	7	3	0	4	6	6

Fig. 4 The values of gray or color of the pixels from the analyzed image

	0	1
0	2	1
1	4	0
2	4	0
3	6	0
4	4	0
5	2	1
6	3	1
7	5	0

	0	1	2
0	0	2	0
1	4	0	0
2	4	0	0
3	3	0	1
4	4	0	0
5	2	1	0
6	3	1	0
7	3	1	0

	0	1	2
0	4	0	0
1	2	1	0
2	1	0	1
3	6	0	0
4	2	1	0
5	2	1	0
6	3	1	0
7	5	0	0

	0	1	2
0	4	0	0
1	4	0	0
2	4	0	0
3	4	1	0
4	4	0	0
5	4	0	0
6	5	0	0
7	2	0	1

a) 0 degrees b) 45 degrees c) 90 degrees d) 135 degrees

Fig. 5. The iso-segments matrixes.

3. Comparative studies upon detecting texture on sand images

3.1 Experiment conditions

Based on the experiments, a comparative study has been made regarding certain methods of image processing by the texture characteristic, to find the optimum method for detecting color texture.

There are two main points: the quality of the detection, the response time.

In order to carry on with this study, the fallowing conditions were presented:

- A test database with synthetic images was created.
- Each image from the database was processed before the interrogation was made.
- An interrogation image was selected and a human observer assigned the relevant images to the selected interrogation.
- Each of the relevant images was used at a time to query the database. The precision and re-appeal represent an arithmetic mean of the resulting values, in the case where each image passes as the interrogation image.
- To compare the results, of each experimental query, a precision and re-appeal chart was made.

The procedure continued in similar manner for all the other iso-segments and it is building the iso-segments matrix for direction zero. An similar method is used at 45 degrees, when, in the example figures were surrounded with yellow the segments with value zero of the pixels that are 2 of length 2 (2 pixels of value zero), thing that is reflected in the iso-segments matrix for 45 degrees direction by storing the value 2 in position (0, 1). This means that exists 2 iso-segments of length 2 with pixels of value zero, on 45 degrees direction.

At 90 degrees there were surrounded with blue the pixels segments having value 2, observing that on this direction exist only segment of length 1 (an single pixel having value 2) respectively 1 of length 3 (3 pixels of value 2). These observations are registered in the iso-segments matrix attached to the vertical direction of analysis of the image's pixels. The registration is made at positions (2, 0) and respectively (2, 2) where was stored values 1 and 1 respectively. Finally, for the last considered direction, at 135 degrees, there exist marked with green color the segments with value 7 of the pixels from the matrix with values. As consequence, in the iso-segments matrix, at direction 135 degrees, will be stored values 2 and 1 in positions (7, 0) and (7, 2) respectively, namely exists: an single iso-segment of 3 pixels length with value 7 and two iso-segments with length 1 pixel having value 7.

The presented example emphasized the situation of an single matrix of pixels values, but in the case of color image processing will exist 3 such matrixes of pixels, one for red values of the pixels from image, other for green values and other for blue values. For each of this 3 matrixes of values there will be realized 4 iso-segments matrixes corresponding to the 4 directions of inspection for the pixels from image

In the following section will be presented an part from the software function through was built the iso-segments matrix. Namely, will be presented only the case in which the direction of inspection of the image's pixels is zero degrees, meaning the horizontal direction.

The program sequence responsible with the construction of iso-segments matrix is:

```
public void createIzo(int cul, int dir) {
int r, c, k, m;
if((cul<0)||(cul>2)) return;
if((dir<0)||(dir>3)) return;
if(dir==0) l=w;
else if (dir==2) l=h;
else { if(h>w) l=w; else l=h; }
izo=new long[256][l];
for(r=0; r<256; r++)
            for(c=0; c<l; c++) izo[r][c]=0;
    if(dir==0) {
      for(r=0; r<h; r++) {
     c=0;
     while(c<w) {
            k=0;
            if(c==w-1);
            else {

while(pixels[r][c][cul]==pixels[r][c+k+1][cul]) {
                        k++;
                        if(c+k+1>=w) break;
                  }
            }
   izo[pixels[r][c][cul]][k]++;
c=c+k+1;
        } } }
    // …
}
```

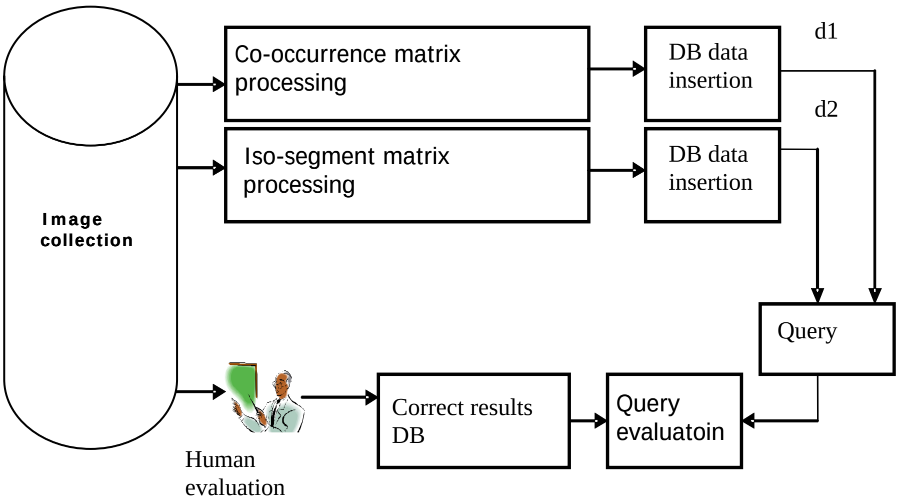


Fig.6 The presentation of the experiment steps.

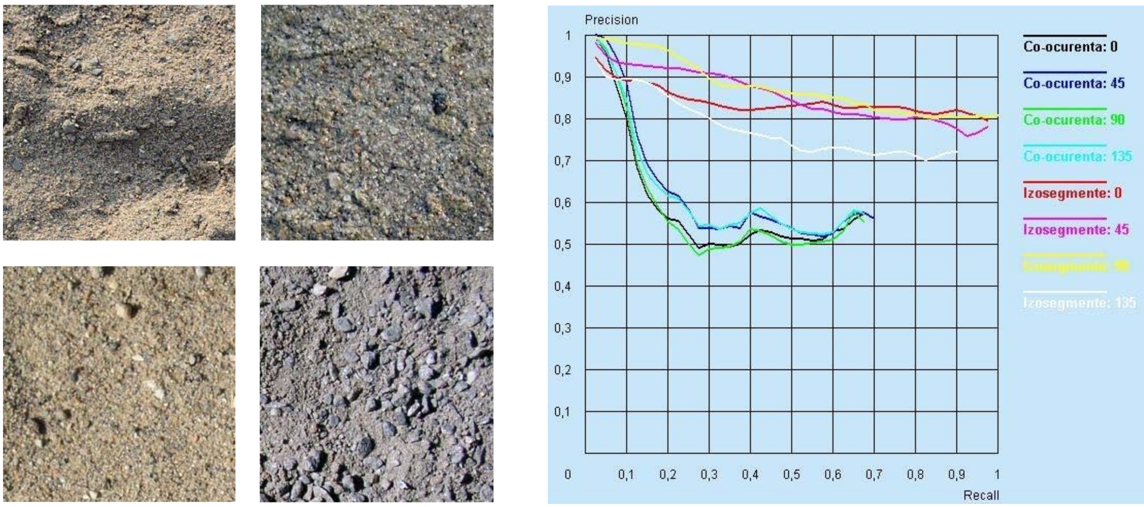
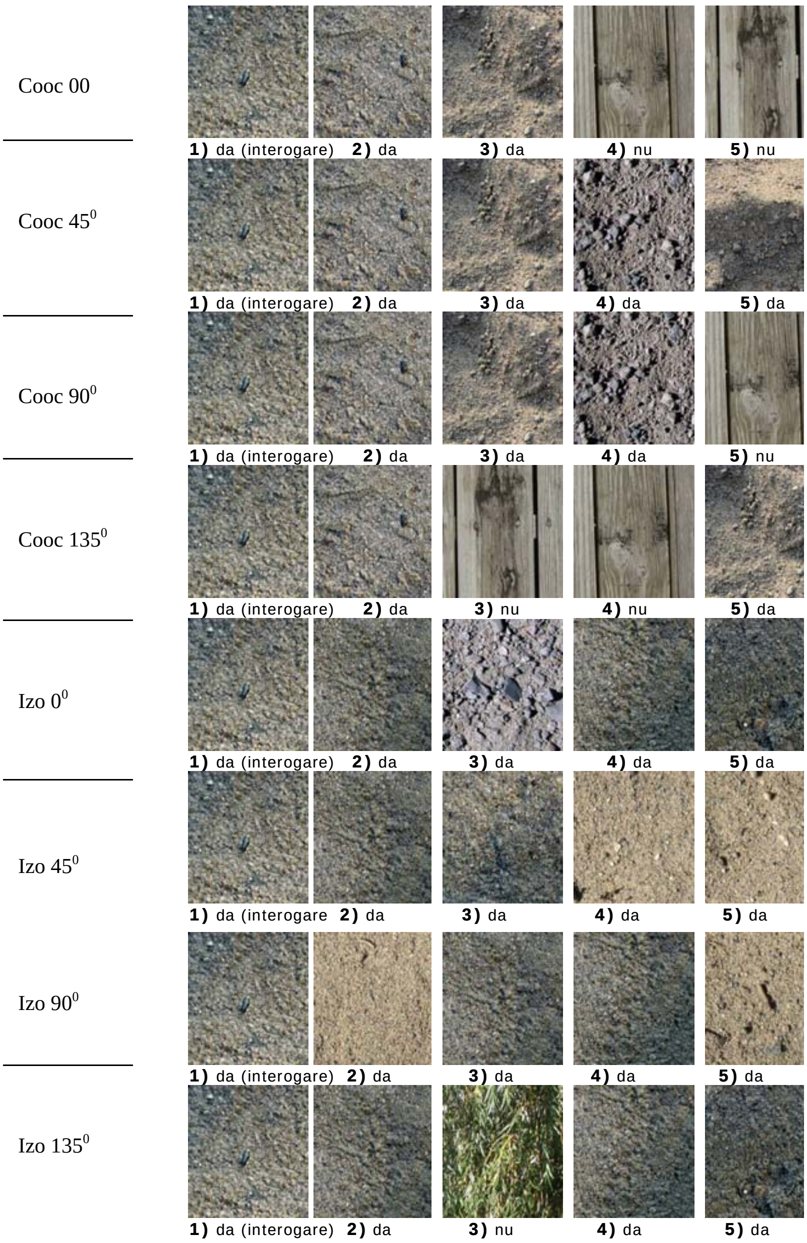


Fig.7 The sand texture experiment.

Fig.8 Relevant image



4 Conclusion

For different studied images, one can not specify which method is better, because for some nature images superior results were obtained using the co-occurrence method while for others, satisfying results were obtained using the iso-segment matrix.
The co-occurrence methods had better results for the queries based on water, wood and grass textures and on the ones based on sand, ruble and clouds, better results were obtained using the iso-segment matrix.
A very important finding is that despite of the analysed direction, and the number of relevant images, for any of the experiments based on the synthetic images, the co-occurrence methods give almost identical results for all the four directions of analysis. The iso-segments methods have essential differences between the cases. Although there were differences between the different directions of analysis, one can not say that a certain direction was generally better than the other.
To summarize, this are the main points: all methods gave good results on the nature images, the co-occurrence methods were almost direction independent and the iso-segment methods frequently gave different results when analyzing different directions, the two methods came out with almost equal results for a great number of relevant images
The final complexity for the making of the co-occurrence algorithm is:

$$O(h*(w-1)) \qquad (16)$$

This is a square complexity when h=w-1;
Where, h and w are the height and width of the image.
The final complexity for the making of the iso-segment algorithm is:

$$O(h*(w/lm)*lm)=O(h*w) \qquad (17)$$

Where:

l_m is the average length of a segment;
h,w the height and width of the image;

In this case, the complexity given by the assigning the variables is:

$$O(256*l_{Max}+i_1), \qquad (18)$$

Where:

l_{Max} is the maximum length of a segment
i_1 is the neccesary time to assign the other variables.

There is a greater complexity in creating the iso-segment matrix algorithm. More databases were created, with samples of water, soil, grass and others. This database allows the research of the soil and water image characteristics.

References:

[1] Bernd Jahne, *“Digital Image Processing”*, Berlin, New York, Springer Verlag, 2002
[2] John C. Russ *“The image processing handbook”* 5th ed, CRC Press and Taylor&Francis Group, LLC, 2007.
[3] Pratt, William K., *“Digital Image Processing”*, Third Edition, John Wiley & Sons, Inc., 2001.
[4] R.C. Gonzales, R. E. Woods, *“Digital Image Processing”*, Prentice Hall, Inc, New Jersey, 2008.
[5] Steve Mann, *“Intelligent Image Processing”*, ISBN: 0-471-40637-6 Copyright John Wiley&Sons, Inc., 2002.
[6] R.C. Gonzales, R. E. Woods, *“Digital Image Processing”*, *Prentice Hall*, *Inc*, New Jersey, 2002.
[7] C. Vertan, V. Buzuloiu,*”Temporal Enhancement and Color Based Motion Detection in Image Sequences*”, Proc. Of OPTIMU‘ 98, pp. 715-718, Braşov, Romania, 14-15 May, 1998.
[8] A.L. Baert, E. Neri, D. Caramella, C. Bartolozzi *“Image Processing in Radiology: Current Applications (Medical Radiology / Diagnostic Imaging)”*, Springer, 2007.
[9] Geoffrey Hutson, *“Colour Television”*, McGraw-Hill Book Company, Berkshire, 1990.
[10] Fl. Enescu, M. Jurian, L. Bănică ” Algorithms and Methods for Images Processing that Contain Synthetic Structures”, Scientific Bulletin on Mathematic and Informatics, Piteşti, 2008.
[11] Fl. Enescu, *”Algoritmi şi metode de prelucrare a informaţiei distribuite prin mijloace multimedia”*, Doctoral Thesis, University of Pitesti, Romania, 2008.
[12] D. Popescu, R. Dobrescu, M. Nicolae, V. Avram, *“Algorithm based on medium co-occurrence matrix for image region classification”*, 7th WSEAS Int. Conf. on Signal Processing, Computational Geometry & Artificial Vision, August 2007, pp. 123-128.
[13] N. Koutsoupias, “Visualizing WEB navigation patterns with factor analysis”, 7th WSEAS International Conference on Applied Informatics and Communications, August 2007, pp. 380-385.
[14] W.Y. Wang, M. C. Lu, C. T. Chuang, J. C. Cheng, “Image-Based Height Measuring System”, 7th WSEAS Int. Conf. on Signal Processing, Computational Geometry & Artificial Vision, August 2007, pp. 147-152.