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Application of the progressive wavelet correlation for image recognition and retrieval from the collection of images

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Abstract

An algorithm for recognition and retrieval of image from image collection is developed. Basis of the algorithm is the progressive wavelet correlation. The final result is the recognition and retrieval of the wanted image, if it is in the image collection. Instructions for the choice of correlation threshold value for obtaining desired results are defined. To increase efficiency is presented two phases solution. The first phase uses well-known methods of image retrieving by descriptors based on the content of the searched image. In the second phase the progressive wavelet correlation method is applied on the small number of image candidates selected in previous phase. Experiments are performed with data bases of 1000 and 10 000 images, using Oracle data base and the Matlab component Database Toolbox for operations with data bases. The algorithm is applicable to different formats of images.

Key words: discrete cosine transform, multiresolution, progressive wavelet correlation, recognition, wavelets.

1. Introduction

Images, drawings, photographs as means of communication among people, for sending and receiving messages have been part of everyday life for a long a time. The easy to use World Wide Web, the reduced price of storage devices as well as the increased calculating power allow an essential and efficient management of large quantity of digital information. All of these factors offer a number of possibilities to the designers of real image-browsing and retrieval systems.

However, image digitalization systems do not allow for an easy management of collections of images. A particular form of cataloguing and indexing is still required. The need for efficient storage and retrieval of images was recognized by managers of large collections of images long time ago and was studied at a workshop sponsored by the American National Science Foundation in 1992 [1]. Data representation, feature extractions and indexing, image query matching and user interfacing were identified as areas with a potential for improvement. One of the issues identified was the problem of locating a picture in a large and diverse collection of images.

The earliest and the most sophisticated descriptor-based image recognition engine is IBM QBIC [2]. Another set of content-based tools for image recognition and retrieving have also improved throughout the years. Examples for such tools are VisualSEEk[3], WebSEEk [4] and ImageRover [5]. ImageRover uses low resolution for image representation in six regions in order to cover particular information along with the region based descriptors. The present commercially available engines for image recognition, based on descriptors, provide no assurance that the required information from the libraries can be found. For some applications such as for example, collections of medical images or satellite images the even the smallest details can be important. Descriptor based retrieval engines cannot meet satisfactorily such requirement. Reconstruction of details here happens only to a particular level of resolution. In addition large images can contain so many details which cannot be comprised in any compact description.

An alternative approach to the problem set forth above is pixel (elements of digitalized image) based recognition and retrieval. This type of recognition involves analysis of the image. Still this requires intense computing especially when the image contains many subtle details. Despite this fact, the existence of large number of operations per image doesn't seriously restrict the application of pixel-based recognition and retrieval techniques, especially not when it comes to research and experimental purposes.

Pixel-based techniques work by locating a particular pattern in a given image library. Popular criteria for matching are the normalized correlation coefficients [6], which measure the differences between images and patterns from the library. The particular strength of these criteria is that they are insensitive to uniform differences in brightness.

Some of the work done in the area of content-based image retrieval and PWC (Progressive Wavelet Correlation) [6] are outlined in Section 2 and 3. Our proposal about applying of the combination of content-based method and PWC for recognition images stored in a database is presented in section 4. Results of experiments that use the proposed system are presented in Section 5.

2. Content based image retrieval

Content-based image retrieval (CBIR) aims at inventing techniques that support effective recognition and browsing of large image digital libraries based on automatically derived image features. A typical CBIR system views the query image and images in the database (target images) as a collection of features, and ranks the relevance between the query image and any target images in proportion to feature similarities.

Many research works have been published in the field of CBIR. However, no universally accepted model has yet been developed. The research concentrates on image segmentation based on low-level features like color, shape, texture and spatial relations. To find the semantic meanings or high-level meanings of an image, like whether it is the image of human beings or a bus or a train and so on, is still a problem. Attempts are being made to link low-level and high-level features. However, it is proving difficult for the very simple reason that there remains a vast gap between human perception and computer perception.

CBIR systems include two main sub-systems: the server subsystem and the client subsystem [7]. The server subsystem handles the processes of feature extraction, database indexing/filtering, feature matching and system learning. The client subsystem handles the process of querying.

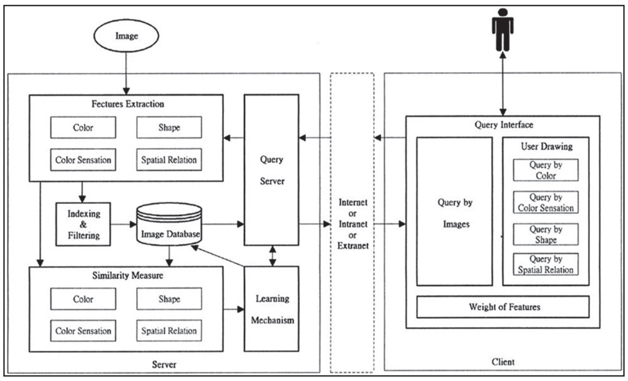

Figure 1. System Architecture of CBIR system

3. Progressive wavelet correlation

3.1 Overview

In this section we summarize the technique described in [6], [8]. The fundamental operation for recognition is the circular correlation $x \otimes y$. The j^{th} entry of the circular correlation is defined as:

$$\left(x \otimes y\right)_j = \sum_{i=0}^{N-1} x_{i+j \bmod N}\, y_i\ ,\ j = 0, 1, \dots, N\text{-}1 \quad \text{...}\ (1)$$

where x and y are column vectors of length N.

The matrix form is $x \otimes y = X\,y$

where X is left circulant matrix generated by x:

$$X = \begin{bmatrix} x_0 & x_1 & \dots & x_{N-1} \\ x_1 & x_2 & \dots & x_0 \\ \dots & \dots & \dots & \dots \\ x_{N-1} & x_0 & \dots & x_{N-2} \end{bmatrix} \quad \text{................}\ (2)$$

The notation $(P)_{i \downarrow R}$ denotes subsampling of P by taking components whose indices are equal to i modulo R. For example, if $R = 4$ and $i = 2$, the subsampling operation extracts the elements 2, 6, 10, 14, … from P. Progressive wavelet correlation using Fourier methods is based on four theorems: the Wavelet-Correlation Theorem, the Fourier-Wavelet Correlation Theorem, the Fourier-Wavelet Subband Theorem and the Fourier-Wavelet Multiresolution Theorem. To simplify the discussion all data are assumed to be one-dimensional vectors.

Wavelet-Correlation Theorem:

$$(x \otimes y)_{0\downarrow R} = \sum_{k=0}^{R-1} \left((H\ x)_{k\downarrow R} \right) \otimes \left((H\ \ y)_{k\downarrow R} \right) \text{ .... (3)}$$

where H is wavelet-packet transform. $\times$ is the Kronecker product of I_M and W, $H = I_M \times W$, where I_M is $M \times M$ identity matrix and W is an $R \times R$ matrix with property $W^T W = I_R$. The wavelet transform packet matrix H has a special structure. H is block diagonal with block size R. For instance, W can be 2×2 Haar matrix:

$$W = \left(\frac{1}{\sqrt{2}} \right) \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}. \text{ .... (4)}$$

Fourier-Wavelet Correlation Theorem:

$$(x \otimes y)_{0\downarrow R} = = F_M^{-1} \left(\sum_{k=0}^{R-1} \left(F_M \left((H\ x)_{k\downarrow R} \right) \right) .* \left(\hat{F}_M \left((H\ y)_{k\downarrow R} \right) \right) \right) \text{ .... (5)}$$

where F_M is the Fourier transform matrix of dimension M and $\hat{F}_M$ is the complex conjugate of F_M.

Fourier-Wavelet Subband Theorem:

$$F_N x = \left(T_{N,M,R} H^{-1} \right) \left(F_{M,R} H\ x \right) \text{ .... (6)}$$

where $N = MR$. The matrix $F_{M,R}$ is an interlaced Fourier transform matrix with structure $F_{M,R} = F_M \times I_R$, that is it has R interlaced copies of transform of size M. The matrix $T_{N,M,R}$ is a Fourier update matrix that transforms $F_{M,R}$ into F_N: $F_N = T_{N,M,R} F_{M,R}$.

Fourier-Wavelet Multiresolution Theorem:

$$F_{N/R,R} H_1 x = = \left(T_{N/R,N/R^2,R} \times I_R \right) U_{2,1}^{-1} F_{N/R^2,R^2} H_2 x \text{ .... (7)}$$

$$F_N x = T_{N,N/R,R} H_1^{-1} \left(T_{N/R,N/R^2,R} \times I_R \right) U_{2,1}^{-1} F_{N/R^2,R^2} H_2 x \text{ .... (8)}$$

where $N = MR^2$. H_2 is a coarse transform matrix that is block diagonal with block of size R^2 with the structure $H_2 = I_{N/R^2} \times (W_1 \times W_1)$ and operates on R^2 subbands, each of length N/R^2. W_1 is an $R \times R$ wavelet filter matrix with property $W_1^T W_1 = I_R$. H_1 is a fine transform matrix that is block diagonal with block size N/R with structure $H_1 = I_{N/R} \times W_1$. There is an update matrix $U_{2,1}$ that refines H_1 into H_2, $H_2 = U_{2,1} H_1$. The matrix $U_{2,1}$ is block diagonal with block of size R^2 with the following structure:

$$U_{2,1} = I_{N/R^2} \times (W_1 \times I_R) \text{ .... (9)}$$

3.2 Method for image recognition

JPEG compression is based on the discrete-cosine transform (DCT) [6]. The matrix C_8 is an 8×8 DCT matrix that is used to create transforms of 8×8 subimages in a JPEG representation of an image.

The multiresolution recognition process relies on the factorization of the DCT matrix C8 = $V_{8,4} V_{4,2} V_2$, where V_2 and $V_{4,2}$ are matrices built from Kronecker products of W and the identity matrix.

The matrix $V_2 = I_4 \times W$ consists of 4 interlaced copies of W and is of size 8×8. The matrix $V_{4,2}$ has a structure $V_{4,2} = I_2 \times (W \times I_2)$.

If we write $C_8 = V_{8,4} V_{4,2} V_2$ where $V_{8,4}$ is a matrix whose coefficients we want to compute, then

$$V_{8,4} = C_8 V_2^{-1} V_{4,2}^{-1} \text{ .... (10)}$$

obtain the last expression by multiplying both sides by $V_2^{-1} V_{4,2}^{-1}$. The matrix $V_{8,4}$ satisfies equation $V_{8,4} = V(W \times I_4)$. The inverse of V is given by (11), where $\gamma(m) = \cos(2\pi m / 32)$.

The matrix H is an $N \times N$ matrix with the structure $I_M \times C_8$ where $N = 8M$. It produces the JPEG transform of a vectors of length N. Let x be image stored as a JPEG transform of a vector Hx with an instance of a pattern y with JPEG transform Hy. The algorithm consists of three incremental steps, each of which quadruples the number of correlation points. The process can be halted at any stage if the intermediate results indicate that the correlation will not result in a match.

The three incremental steps are:

1. *Coarse correlation* – Generate the Fourier transforms $F_{M,8}H\,x$ and $\hat{F}_{M,8}H\,y$. Multiply the transforms point by point and partition them into eight subbands of length M. Add these eights vectors and take the inverse Fourier transform of the sum. Every eighth point of the correlation is generated.

2. *Medium correlation* – Multiply $F_{M,8}H\,x$ by $(T_{2M,M,2}\times I_4)(I_M\times((W\times I_4)V^{-1}))$ $\hat{F}_{M,8}H\,y$ by $(\hat{T}_{2M,M,2}\times I_4)(I_M\times((W\times I_4)V^{-1}))$. Multiply the resulting vectors point by point and partition them in four subband of length $2M$. Add the subbands and you will create a single vector of length $2M$. Taking the inverse Fourier transform of size $2M$ yields the correlation at indices that are multiples of 4 mod 8 of the full correlation.

3. *Fine correlation* – Multiply the x and y transform from the preceding step by $(T_{4M,2M,2}\times I_2)$ $(I_M\times V_{4,2})$ and $(\hat{T}_{4M,2M,2}\times I_2)(I_M\times V_{4,2})$, respectively. Multiply the resulting vectors point by point and partition them in two subbands of length $4M$. Add the subbands and you will create a single vector of length $4M$. Take the inverse Fourier transform of size $4M$ to obtain the correlation at indices that are multiples of 2 mod 8 and 6 mod 8 of the full correlation.

4. *Full correlation* – Multiply the x and y transform from the last step by $I_{8M,4M,2}(I_M\times V_2)$ and $\hat{T}_{8M,4M,2}(I_M\times V_2)$, respectively. Multiply the resulting vectors point by point and take the inverse Fourier transform of size $8M$ to obtain the correlation at odd indices.

Figure 2 is a flow diagram showing the steps performed for an image recognition according to the PWC method.

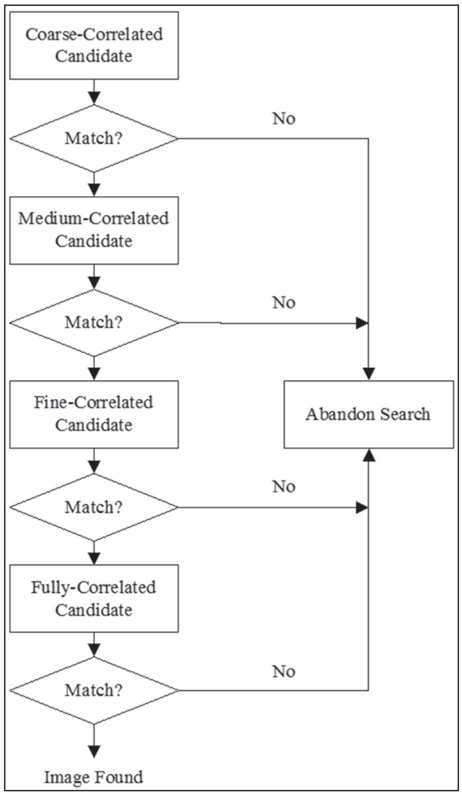

Figure 2. Flow diagram of PWC method

$$V^{-1}=\begin{bmatrix}1 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\ 0 & \gamma(2)\gamma(7) & 0 & \gamma(5)\gamma(6) & 0 & \gamma(3)\gamma(6) & 0 & \gamma(2)\gamma(1)\\ 0 & \gamma(6)\gamma(1) & 0 & \gamma(3)\gamma(2) & 0 & -\gamma(5)\gamma(2) & 0 & -\gamma(6)\gamma(7)\\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0\\ 0 & \gamma(2)\gamma(1) & 0 & -\gamma(3)\gamma(6) & 0 & \gamma(5)\gamma(6) & 0 & -\gamma(2)\gamma(7)\\ 0 & 0 & \gamma(6) & 0 & 0 & 0 & \gamma(2) & 0\\ 0 & 0 & \gamma(2) & 0 & 0 & 0 & -\gamma(6) & 0\\ 0 & -\gamma(6)\gamma(7) & 0 & \gamma(5)\gamma(2) & 0 & \gamma(3)\gamma(2) & 0 & -\gamma(6)\gamma(1)\end{bmatrix} \quad \text{......................................} (11)$$

We investigate what happens in the two-dimensional case. Let the image size be N by N. In step 1, we have 64 subbands of length $N^2/64$. We perform one step of the inverse 2D JPEG transfer function, and one 2D step of the forward Fourier transform function. The next step includes adding the 64 subbands point by point to create a 2D array of size $N/8$ by $N/8$. Taking the inverse Fourier transform, we obtain the correlations at points that lie on a grid that is coarser than the original pixel grid by a factor of 8 in each dimension. In step 2, we obtain 16 subbands of size $N^2/16$ by adding the 16 subbands point by point, and taking the Fourier inverse. We will obtain the correlation values on a grid that is coarser than the original grid by a factor of 4 in each dimension. In step 3, we obtain 4 subbands of size $N^2/4$. Finally, in step 4, the full resolution is obtained.

Formulas for calculating normalized correlation coefficients that measure differences between images and patterns are given in [6]. Normalized correlation coefficients can be computed from the correlations described above. The normalization is very important because it allows for a threshold to be set. Such a threshold is independent of the encoding of the images.

The normalized correlation coefficient has a maximum absolute value of 1. Correlations that have absolute values above 0.9 are excellent, and almost always indicate a match found. Correlations of 0.7 are good matches. Correlations of 0.5 are usually fair or poor. Correlations of 0.3 or less are very poor. There is a tradeoff between the value of the threshold and the likelihood of finding a relevant match. Higher thresholds reduce the probability of finding something that is of interest, but they also reduce the probability of falsely matching something that is not of interest.

4. Proposed system for image recognition

4.1 Practical implementation of PWC

The progressive wavelet correlation provides guidelines on how to locate an image in the image library. To make this method practical, we must first decide how to store the images. The initial choice is to store them in a disk file system. This can be seen as the quickest and simplest approach. A better alternative that should be considered is to store those images in a database. Databases offer several strengths over traditional file system storage, including manageability, security, backup/recovery, extensibility, and flexibility.

We use the Oracle Database for investigation purposes. There are two ways of storing an image into the Oracle Database. The first one is the use of Large Objects – LOB, and the second one is the use of Oracle *inter*Media. To store images into the database we use the BLOB datatype. After creation of one BLOB column defined table we also create a PL/SQL package with a procedure for loading images (named load). This procedure is used to store images into the database. The implementation of the progressive wavelet correlation in Matlab and the connection between the algorithm with the database are the next steps. The Database Toolbox is part of an extensive collection of toolboxes for use with Matlab.

Before the Database Toolbox is connected to a database, a data source must be set. A data source consists of data for the toolbox to access, and information about how to find the data, such as driver, directory, server, or network names. Instructions for setting up a data source depend on the type of database driver, ODBC or JDBC. For testing purposes JDBC drivers were usually used [7].

After setting up the data source for connecting to and importing data from a database we have used several standard functions of the Matlab Database Toolbox. We can retrieve BINARY or OTHER Java SQL data types. However, the data might require additional processing once retrieved. For example, data can be retrieved from a MAT-file or from an image file. Matlab cannot process these data types directly. One needs knowledge of the content and might need to massage the data in order to work with it in Matlab, such as stripping off leading entries added by the driver during data retrieval.

The last step in the adaptation is to create Matlab applications that use the capabilities of the World Wide Web to send data to Matlab for computation and to display the results in a Web browser. In the simplest configuration, a Web browser runs on a client workstation, while Matlab, the Matlab Web Server (matlabserver), and the Web server daemon (httpd) run on another machine. In a more complex network, the Web server daemon can run on a separate machine [7].

4.2. Proposed method

The main problem in the application of multiresolution analysis for the purpose of image procession is the large number of operation per image. Bearing in mind the current procession speed it is certain that practical application of multiresolution analysis for image retrieval is almost impossible. On the hand we saw that even though CBIR method has no problems concerning the speed of retrieval, one cannot always achieve the desired goals.

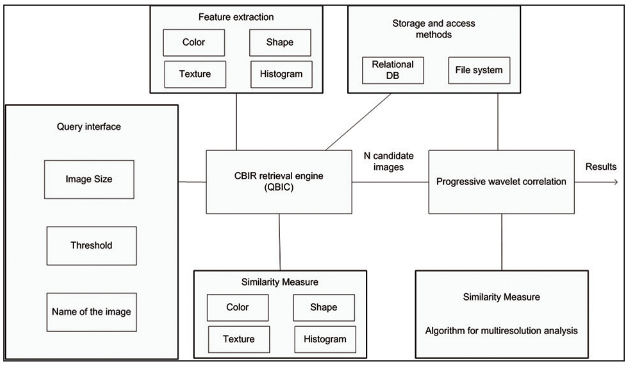

Figure 3. A modular scheme for the proposed system

Results obtained from a number of performed experiments by retrieving images from a database via application of both CBIR and progressive wavelet correlation led us to the idea of combining them in order to make the best use of their positive features [7, 9, 10]. The initial idea was extended into a developed proposal for a new algorithm intended for recognition and retrieving images from a database. The proposed algorithm is described in this section.

IBM QBIC [2] is used as a specimen of the descriptor based engine. QBIC reduces the search place and thus multiresolution can only be used for comprehensive search. This way it takes less time to locate a particular image in the given image library, compared to the time needed to locate the image solely by the use of multiresolution analysis.

Figure 3 presents a modular scheme for the proposed system.

5. Experimental results

Using QBIC, we established a database for the following characteristics of images: color, text, color histogram, and texture feature. We query the database for those images in the library with the most similar characteristics to the input image. On this set of candidates, we apply the PWC to obtain the desired image.

As an example, we show our work on recognition and retrieving the image 21.jpg (Figure 4) in a database. Using QBIC, we isolated ten candidate images based on the Color Histogram Feature. After that these images are subjected to detailed pixel-based recognition based on PWC.

For testing we used two PC on 3 GHz with 1 GB RAM. On one of them we installed Oracle Database Server version 10.1.0.2.0 and on the other we installed MATLAB version 7.0.4.365 (R14) Service Pack 2.

We tested a different number of images stored in the database for different values of threshold *thr*. The results of retrieval performance are shown in Figure 5.

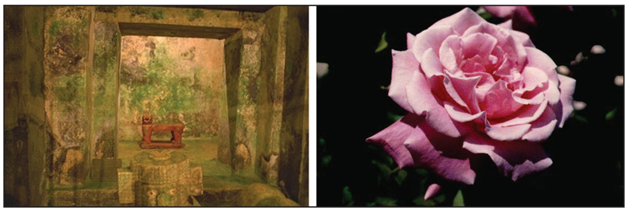

Figure 4. 21.jpg and flower10.jpg

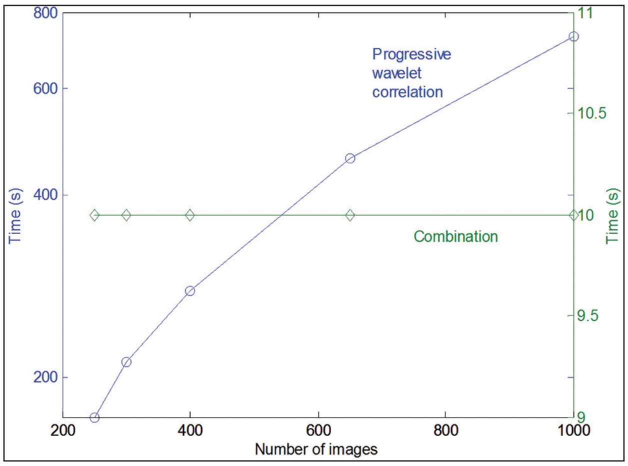

Figure 5. Retrieval performance for different number of images for the image 21.jpg and thr ≥ 0,7

We can conclude from Figure 5 that the time required recognition and retrieving increases approximately linearly with the rise in the number of images stored in the database. On the other hand when the proposed algorithm is used for image retrieval, the retrieval performance is practically independent of the database capacity.

Investigating how the number of selected images depends on the number of images into database we obtain practically the same shape (Figure 6). Based on our experience we propose the following minimum threshold values when the combination of two methods is used:

- 0.5 for images not having visually similar images in the database (image *21.jpg*);
- 0.7 for images having visually similar images in the database (image *flower10.jpg*).

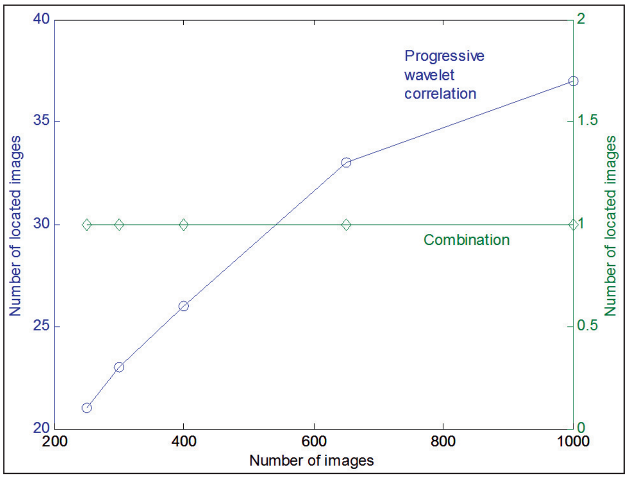

Figure 6. Number of located images versus number of images into database for the image 21.jpg and thr =0,5

Using the PWC, the value of the threshold should be equal or higher than 0.7. Figure 6 presents number of located images for constant value of threshold *thr*=0.5. When PWC are used, increasing the number of images into the database will result with an increased number of located images.

5.1. Results obtained by applying the proposed system to large databases

Considering the results obtained from a number of image retrieval examples, we become aware that the use of the proposed algorithm for recognition and retrieval of images from a database can be very useful.

The results demonstrated in the previous examples referred to a database of 1000 images. The following charts present results concerning the time needed to retrieve image from a database of 10 000 images.

The database used in these experiments is taken from http://wang.ist.psu.edu/docs/related.shtml.

In this section the adopted value of the image size is *N*=80, while the correlation threshold value is *thr* = 0.7.

Table 1. flower01.jpg

Number of images	2000	4000	7000	10000
Time (sec) (proposed system)	11.07	11.09	11.42	11.88

Table 2. flower10.jpg

Number of images	2000	4000	7000	10000
Time (sec) (proposed system)	9.07	9.15	9.23	9.26

Table 3. 21.jpg

Number of images	2000	4000	7000	10000
Time (sec) (proposed system)	4.5	4.67	4.72	4.91

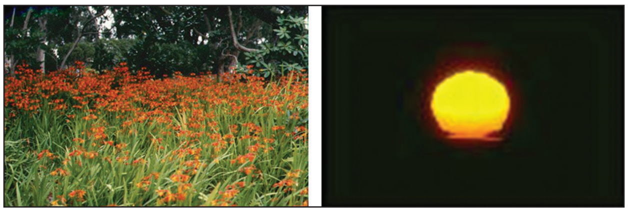

Figure 7. flower01.jpg and 1795.jpg

Table 4. 1795.jpg

Number of images	2000	4000	7000	10000
Time (sec) (proposed system)	7.18	7.26	7.36	7.64

Figure 8. 1890.jpg and 1993.jpg

Table 5. 1890.jpg

Number of images	2000	4000	7000	10000
Time (sec) (proposed system)	4.58	4.84	5.09	5.27

Table 6. 1993.jpg

Number of images	2000	4000	7000	10000
Time (sec) (proposed system)	4.53	4.69	5.96	5.17

The time required for retrieving of image *flower01.jpg* with proposed system for image recognition from the database is takes approximately 11 seconds because the image appears eight times in the database. Image *flower10.jpg* appears six times in the database and the time needed for recognition and retrieve is 9 seconds. For image *1795.jpg* time for recognition and retrieve is 7 seconds, the image appears four times in the database. The time require to locate the images *21.jpg*, *1890.jpg*, and *1993.jpg*, is approximately the same as the usage of the proposed system for image retrieval because the three images too, appear once in the database.

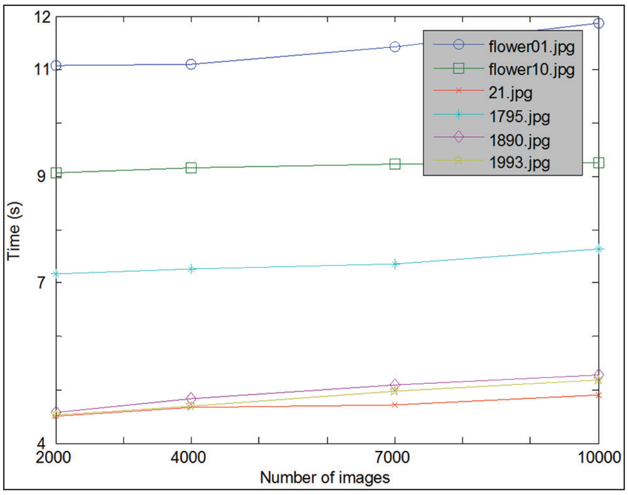

Figure 9. Retrieval performance for different number of images

From Figure 9 we can conclude that with using of proposed system for recognition and retrieving of images the time required to locate an image doesn't depend on the number of images stored in the database.

5.2. Precision

Different experiments were set up as follows:

- The required image is included several times in the database with different names;
- The image is included only once in the database;
- Aside from the required image, the database also contains an image very similar to the required one (smudged in some parts or an image generally slightly different);
- The required image is not present in the database.

Evaluation of the quality of the system concerning its precision p is estimated using the following the definition:

$$p = \frac{|A(q) \cap R(q)|}{|A(q)|} \quad (12)$$

where q stands for query, $R(q)$ signifies a set of relevant images for the query in the database, while $A(q)$ stands for the set of images returned as a response to the set query q.

5.2.1. The required image is present several times in the database

Two images, called flower01.jpg and flower10.jpg, served as search targets. Image flower01.jpg appears eight times under different names in the database, while the image flower10.jpg appears six times. The database contains images that are more visually similar to the image flower10.jpg.

Table 7. flower01.jpg

Threshold	Retrieved images	Precision
0.2	9	0.89
0.3	8	1
0.4	8	1
0.5 – 1	8	1

Table 8. flower10.jpg

Threshold	Retrieved images	Precision
0.2	10	0.6
0.3	10	0.6
0.4	10	0.6
0.5	10	0.6
0.6	10	0.6
0.7 – 1	6	1

The Table 8 shows that the image flower10.jpg, when in the database is more visually similar to her, is extracted with a threshold equal to or greater than 0.7.

5.2.2. The required image is present only once in the database

The results presented in this part refer to two different images 21.jpg and 40.jpg. Each of these images is included only once in the searched database.

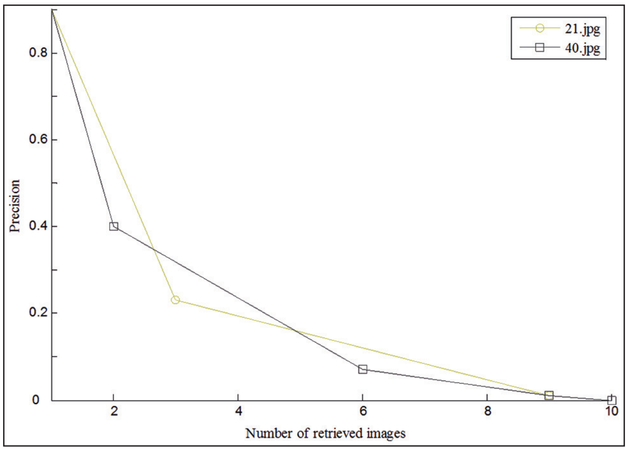

Figure 10. Relationship between precision and the number of retrieved images for the images 21.jpg and 40.jpg

Table 9. 21.jpg

Threshold	Retrieved images	Precision
0.2	9	0.11
0.3	3	0.33
0.4	3	0.33
0.5	1	1
0.6	1	1
0.7 – 1	1	1

Table 10. 40.jpg

Threshold	Retrieved images	Precision
0.2	10	0.1
0.3	9	0.11
0.4	6	0.17
0.5	2	0.5
0.6	1	1
0.7 – 1	1	1

For the purpose of locating one image, the correlation threshold value should be equal to or greater than 0,6 for images having no visually similar images in the image library such as images 21.jpg and 40.jpg

5.2.3. The database contains two very similar images

The next example refers to image 181.jpg. This example is specific because the database contains a similar image 183.jpg with its vertical sides slightly smudged. The similar images are shown in Figure 11 and Figure 12.

Figure 11. 181.jpg

Figure 12. 183.jpg

In the previous examples, the number of candidate images that QBIC gives for further processing is 10, and in part 5.2.3 and 5.2.4 that number is 20. These images are then processed by PWC.

Table 11. 181.jpg

Threshold	Retrieved images	Precision
0.3	20	0.05
0.4	20	0.05
0.5	17	0.12
0.6	2	1
0.7	2	1
0.8	2	1
0.9 – 1	1	1

It is evident from Table 11 that when correlation threshold values are 0.6, 0.7 and 0.8, both the images 181.jpg and 183.jpg are retrieved. If the correlation threshold is equal to or greater than 0.9 only image 181.jpg is retrieved.

5.2.4. The required image is not present in the database

Table 12 gives the number of retrieved images for different values of the correlation threshold for image 50.jpg, which is not present in the database. For correlation threshold values greater than or equal to 0.5 there are no images retrieved from the database.

Table 12. 50.jpg

Threshold	Retrieved images
0.2	17
0.3	16
0.4	7
0.5 – 1	0

6. Conclusion

Based on our experience and experimental evidence we conclude that the proposed system is a useful tool for image recognition and retrieval of the image from the collection of images. The main feature of PWC is its high accuracy. With the choice of an adequate correlation threshold it is possible to detect if the given image is present in the database, whether there are images similar to the required one with different names, whether there are images slightly different from the required one, and whether the required image is present in the database.

We conclude that by changing the threshold value of correlation it is possible to identify all four cases examined by the proposed system. In addition, the proposed system locates and retrieves images faster than the PWC. This is achieved by using QBIC as a first step in the proposed system for obtaining a small number of candidate images.

The efficiency of joint content and pixel-based recognition of images from a database can be improved in some applications such as satellite and medical imaging by appropriate selection of the threshold value. Content-based image recognition and retrieval is fast, but it normally gives more than one image due to the vast differences in perception capacity between humans and computers.

On the other hand, pixel-based recognition and retrieval using progressive wavelet correlation is impractical, due to the numerous operations per image it entails. However, a positive outcome should be expected if we combine the good features of content-based and pixel-based methods: speed and accuracy.

For some applications visual similarity can be more critical than semantic similarity. However, for other applications however, visual similarity can be of minor importance. What's the source of client's urge for image search and retrieval? What is to be achieved with the system? How is the system expected to help out in the process? These are only some of the issues that have to be dealt with in order to produce an efficient image recognition and retrieval system. In addition, successful implementation of this system involves various profiles, for instance: computer vision, information recognition and retrieval, man-computer interaction, database, theory of information, statistics, psychology etc.

According to the future researches, focused on the construction of image recognition and retrieval system, regardless of the technique that the system uses, only the issue concerning system quality assessment from the aspect of efficiency and applicability is to be tackled [11]. Retrieval systems should be comparable for the purpose of identifying the good techniques.

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