Image Information Retrieval using Wavelet and Curvelet Transform

Muzhir Shaban Al-Ani, Abdulrahman Dira Khalaf

Abstract— The rapid growth of multimedia data applications via Internet becomes a big challenge over the world. This research is concentrated on the implementation of an accurate and fast algorithm that retrieves image information based on vector space model. The big challenge of information retrieval is a semantic gap, which is the difference between the human perception of a concept and how it can be represented using a machine- level language. This paper aims to design an information retrieval system based on hybrid algorithm through two stages; first one is training and the second one is testing. This algorithm based on extracted features using Wavelet and Curvelet decomposition and the statistic parameters such as mean, standard deviation and energy of signals. The system is tested over 1000 images which are divided into 10 categories, each category has 100 images. The tested results of system are compared between system based on Wavelet and system based on Histogram. Performance measures are implemented applying two metrics called precision and recall. The results of training phase show that the elapsed time of system based on hybrid Algorithm is greater than the elapsed time based on DWT or Histogram. The Average Retrieving Time (ART) for system based on hybrid algorithm is less than ART based on Wavelet and Histogram.

Keywords— Information Retrieval, Multimedia Information Retrieval, Discrete Wavelet Transform, Curvelet Transform, Vector Space Model, Feature Extraction.

I. INTRODUCTION

The rapid developments of information technologies and Internet lead to a huge volume of different types of data (audios, videos, images, music, texts … etc), these data are transmitted over electronic and digital media in all countries over the world. Many techniques and algorithms are developed to provide the users by a simple and easy access of the existed huge amount of multimedia data. These factors lead the researchers to accelerate their works to introduce acceptable solutions for these problems. Image retrieving techniques can be classified into three categories according to query of user formulation [1]:

- Text-Based Image Retrieval (TBIR): In this category, the User can retrieve media (text, image, audio and video) based on textual description or keywords which are done by human annotators. For example, retrieving flowers images can be done by typing flower, rose, etc.
- Content-Based Image Retrieval (CBIR): In this category, the User can base on visual features (low level features) which are extracted from images such as color, shape and texture.
- Hybrid Image Retrieval: In this category a combination of the textual description and visual features will be on retrieving image.

II. IMAGE INFORMATION RETRIEVAL

The concept of information retrieval technique aims to retrieve information stored via large amount of data then access and contribute these data in a fast and accurate method in different forms. The retrieved data will be stored to be available and ready for future use. The user can retrieve the information that satisfies the mentioned query via database system. The architecture of the image retrieval can be divided into several steps: features extraction from image database using Histogram, Wavelet transform, Curvelet transform, features vector and the decision making must be taken to identify the input image as shown in figure (1).

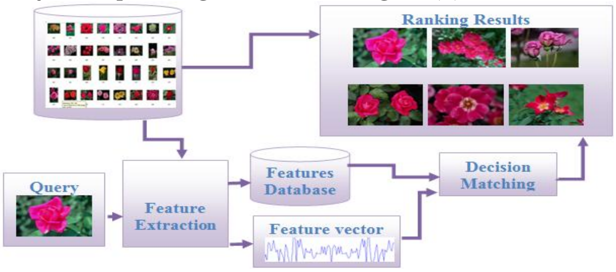

Figure (1) the architecture of the image retrieval

A. Image Retrieval

The convergence between the image processing and database communities resulted in many content-based image retrieval systems. The semantic interpretation of visual information is much more complicated than the structured text. In text every word has a finite number of meanings. Through sentence or paragraph analysis, the correct meaning can be determined. Visual objects with the same semantic notion show enormous variety of appearances, for example images of cats in children books. The search of image retrieval systems is approximate, i.e., these systems use automatically extracted image features to determine the visual similarity. The visual features are derived from a computational process executed on the image object. Simple features (color histograms, shape, and texture) are computed based on the characteristics of pixels, like color and position [2].

B. Wavelet Transform

Wavelet transform is used to convert a spatial domain image into frequency domain. It provides the time-frequency representation. The wavelet transform is created by repeatedly filtering the media (audio or image) coefficients on a row-by-row and column-by-column basis.

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The wavelet transform clearly separates high-frequency and low-frequency information on a pixel-by-pixel basis [3]. A continuous type of wavelet transform (CWT) that applied to the signal x(t) can be defined as :

$$w(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t) \psi\left(\frac{t-b}{a}\right) dt \qquad (1)$$

where: a is the dilation factor, b is the translation factor, $\psi(t)$ is the mother wavelet and $1/\sqrt{a}$ is an energy normalization term that makes wavelets of different scale has the same amount of energy.

The Discrete wavelet transform has become a useful computational tool for image processing applications. The computation of the wavelet transforms of a 2D signal involves recursive filtering and sub-sampling, the signal is decomposed into four frequency sub-bands, Low Low (LL), Low High(LH), High Low (HL), and High High (HH) [4].

C. Curvelet Transform

Curvelet transform is a multi-scale representation of data which is the most suitable method for objects with curves, this transform is developed by Donoho and Duncan in 1999 [5]. There are no losses of information in Curvelet transform. In this transform the image could be decomposed into a set of wavelet bands, and each band could be analyzed by a Ridgelet transform [6]. The block size of image can be changed at each scale level. These formal properties are very similar to the results expected from an orthonormal basis, and reflect an underlying stability of representation.

D. Discrete Curvelet Transform Via Wrapping

Discrete curvelet transform is implemented using the wrapping based fast discrete curvelet transform. Coefficients Wedge wrapping is done for all the wedges at each scale in the frequency domain, then a set of sub-bands or wedges at each curvelet decomposition level is obtained. These sub-bands are represented via the collection of discrete curvelet coefficients. The curvelet coefficients are grouped according to the orientation and scale, starting with the lowest scale (low band) of the center. Sub-bands of the same scale are ordered within these coronae so that the orientation suggested by their position matched the spatial frequencies that represented [6]. Discrete Curvelet transform is applied to an image to obtain its coefficients. Then these coefficients are used to form the texture descriptor of that image. Curvelet coefficients of a 2D Cartesian grid f [m,n], $0 \le m < M$, $0 \le n < N$ is expressed as [7]:

$$C^D(j,l,k_1,k_2) = \sum_{\substack{0 \le m < M \\ 0 \le n < N}} f[m,n] \varphi^D_{j,l,k_1 k_2}[m,n] \qquad (2)$$

where: $\varphi^D_{j,l,k_1k_2}[m,n]$ is a digital Curvelet waveform.

This transform generates an array of Curvelet coefficients indexed by their scale j, orientation l and location parameters k_1, k_2.

E. Vector Space Model

Vector Space Model (VSM) is a standard technique of Information Retrieval in which the documents are represented through the words that contain. VSM was developed by Gerard Salton in the early 1960's [8]. In the vector space model, each image is represented by many corresponding vectors. If the collected document have M documents, then the collected data is represented as a matrix A of dimension M*N. Then during retrieval process, the query is also represented in an N-dimensional term weighted vector.

F. The similarity

The similarity between the query and each of the stored documents are calculated as either dot product or the cosine coefficients between the query vector and the document vector. In this paper the Canbbera Distance is used to represent the similarity [9]:

$$CanbDist(x,y) = \sum_{i=1}^{n} \frac{|x_i - y_i|}{|x_i| + |y_i|} \qquad (3)$$

where x and y are the feature vectors of database and query image respectively, and n represents the number of images in the database.

III. LITERATURE REVIEWS

Many lectures were examined the challenges and opportunities of Multimedia Information Retrieval and we will try to explore some of them.

Ibrahiem M. and Atwan J. [10] proposed Automatic Information Retrieval system using a traditional model technique of Vector Space Model (VSM) in which cosine measure is used to perform the similarity. The output results indicate and show that the root indexing improved the retrieval performance more than the full-ward indexing on the Arabic documents; furthermore it reduces the size of the stored data and minimizes the processing time.

Magalhães J., Overell S. and Rüger S. [11] explained an algorithm of semantic vector space for query by image example; the user submits an example that is compared to the images in the database by their low-level characteristics such as color, texture and shape. While visual similarity is essential for a vast number of applications, there are cases where a user needs to search for semantically similar images.

Chung Y.Y. et al [12] demonstrated a Content-Based Multimedia Retrieval System (CBMRS). The proposed CBMRS includes both video and audio retrieval systems. The Content-Based Video Retrieval System (CBVRS) based on DCT and clustering algorithms. The audio retrieval system based on Mel-Frequency Cepstral Coefficients (MFCCs), the Dynamic Time Warping (DTW) algorithm and the Nearest Neighbor (NN) rule.

Magalhães J. [13] improved multimedia information retrieval by exploring semantic-multimedia analysis. Two search paradigms used; search by keyword, in this approach, for each possible query keyword statistical model is based on multimedia features that were pre-processed and estimated. Other paradigm, the semantic multimedia information retrieval system searches the multimedia database by evaluating the semantic similarity between the query and the previously indexed multimedia.

Siewt T. C. [14] proposed a title feature selection in content-based image retrieval using statistical discriminate analysis; the proposed method intends to improve the feature of selection method to solve the gap between the high level concept and low the level visual feature. Besides, it reduced the high dimensionality of feature vector. Also, fuzzy classification has been used to implement vagueness judgment of human when searching for image.

Prasannakumari V. [15] introduced a study that dealt with the contextual information retrieval from multimedia databases which have feature descriptors and metadata for the data items in it. This study uses vector space method for IR and uses a stemming process to throttle feature descriptors to root words which in turn increases efficiency. Learning by feedback enables the database to accommodate more feature descriptors related to the data and builds it as a better described database.

Murthy, Vamsidhar, Kumar and Rao [5] presented an approach for Content Based Image Retrieval using Hierarchical and K-Means clustering techniques where images were initially clustered into groups having similar color content and then the preferred group was clustered using K-Means to group the images into clusters based on the color content. These clustering algorithms have been frequently used in the pattern recognition literature. Most of the images filtered in the hierarchical clustering and applied the clustered images to K-Means.

IV. PROPOSED ALGORITHM

The features of images data are extracted from images. These features are used to compare with database features through matching the similarity using Canberra Distance. The results are ranking according to the degree of similarity. The Sample of images for test stage selected from Image Database as shown in figure (2).

Figure (2): Samples of images for test stage

The main algorithm is designed via two operations; first one is Off-line operation deal with images datasets as shown in figure (3), this operation takes a long time depending on the size of datasets and types of it, in addition to the specifications of the hardware and software for these operations.

This approach deals with steps of components of image database. These steps are resize images in database, read each image, decomposition each image using Discrete Wavelet Transform (DWT), decomposition each image with Curvelet Transform via Wrapping, all these are input to the system which can recognize the type file through the extension, such as (.jpg, .bmp for Image …etc).

The second one is called On-line operations as shown in figure (4) these deal with user query, the same procedure is applied here.

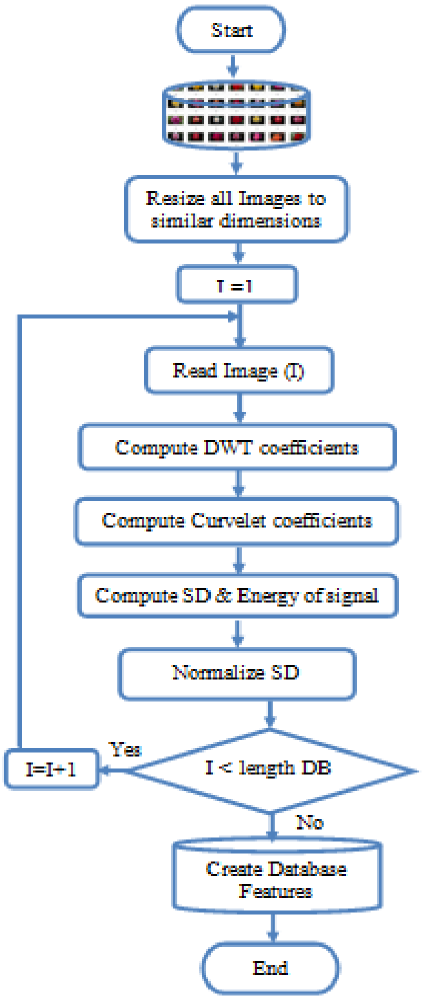


Figure (3) Off-line operations

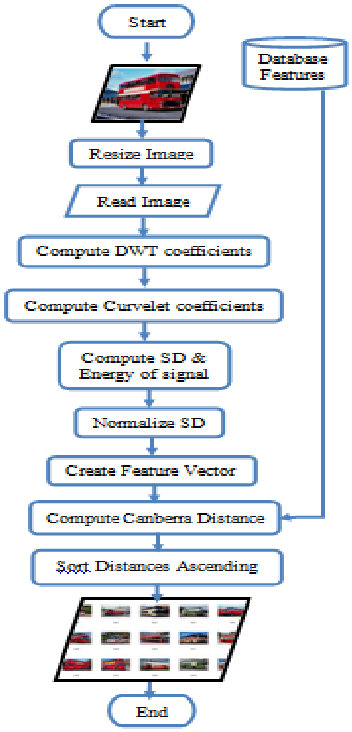
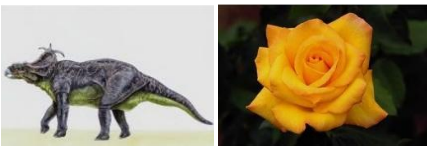


Figure (4) On-line stage operations

V. RESULTS AND ANALYSIS

In this stage ten images were selected randomly from each group in images database each image named by number between (0-999) and testing them by the Content Based Image Retrieval system based on Histogram, Wavelet and Curvelet. Two Image query was selected as shown in figure (5). The results after running these queries in CBIR system based on Curvelet can display in figure (6) for image query q1& figure (7) for image query q2.



q1 q2

Figure (5) Image queries (q1& q2)

The elapsed time for running Query example for ten images from Database using CBIR system displayed by the table (1) based on Histogram, Wavelet and Curvelet. In this table the results in Column 2 refer to the variance between values. This variance is related to overlap color for image. The average elapse time for CBIR system based on Histogram is big compared to the CBIR when based on Wavelet and Curvelet because two reasons; Wavelet and Curvelet give us efficient decomposition and reduces the noise in data and other reason the researcher used a technique to improve the results of images retrieved. This technique works with clustering Database.

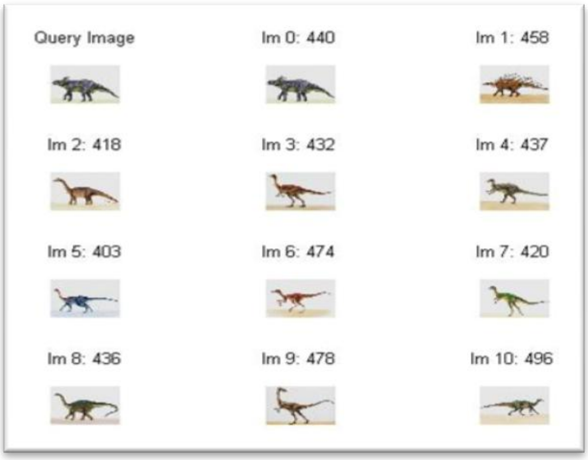


Figure (6):Retrieved images for image query q1

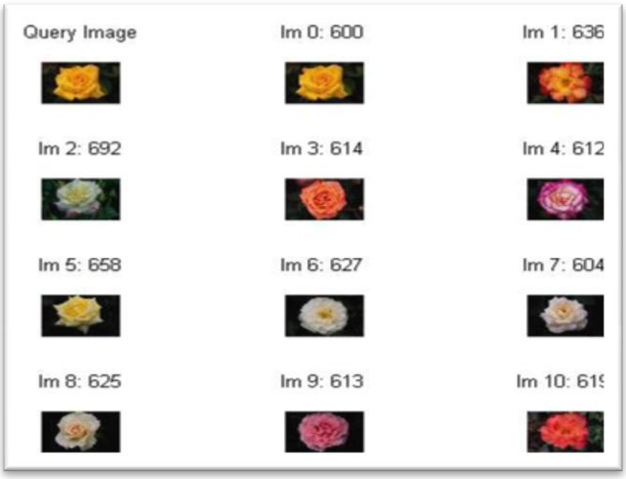


Figure (7):Retrieved images for image query q2

Recall and Precision metrics are used to evaluate Information Retrieval system. The ranking results tested by using the metrics equations; 4 & 5

$$\text{Recall} = \frac{r}{R} \quad (4)$$

$$\text{Precision} = \frac{r}{n} \quad (5)$$

where: r: number of relevant documents retrieved
n: number of documents retrieved
R: total number of relevant documents.

Average Retrieval Rate can be computed by:

$$\text{Average Retrieval Rate} = \frac{1}{M}\sum_{i=1}^{M} \text{Recall} \quad (6)$$

where: M is the number of query images.

Table (1): Elapsed Time Search (Second)

Image Name	Elapsed Time for CBIR based Hist.	Elapsed Time for CBIR based DWT	Elapsed Time for CBIR based Hybrid (DWT & Curvelet
038.jpg	65.955846	2.781143	0.905341
138.jpg	20.585422	1.875524	0.878029
286.jpg	23.736915	1.877477	0.534334
327.jpg	68.798629	1.643920	0.904630
440.jpg	26.024927	1.984410	0.570830
505.jpg	21.874752	3.386663	0.570830
600.jpg	12.956562	1.996756	4.563500
744,jpg	7.828925	1.977065	0.544613
862.jpg	31.464219	1.779716	0.627514
999.jpg	47.569305	2.107694	0.487630
Average Elapsed Time	32.6796	2.1410	1.0587

Table (2) shows the two metrics for proposed system based on Histogram and CBIR based Wavelet while table (3) indicates CBIR based Curvelet. The results give us that the training stage consume time in CBIR system when based on Curvelet, but the searching time is low compared to CBIR when based on Wavelet and Histogram. The Recall and Precision curves can be seen in the figure (8) for CBIR when based on Histogram, Wavelet and Curvelet.

Table (2): Precision and Recall for System based on different algorithms

Image Name. Jpg	Histogram				Wavelet			
	Relevant	Non relevant	Recall	Precision	Relevant	Non relevant	Recall	Precision
038	2	9	0.02	0.18	6	5	0.05	0.54
138	2	9	0.02	0.18	8	3	0.08	0.72

286	8	3	0.08	0.72	7	4	0.07	0.63
327	1	10	0.01	0.09	5	6	0.05	0.45
440	3	8	0.03	0.27	9	2	0.09	0.81
505	6	5	0.06	0.54	7	4	0.07	0.63
600	8	3	0.08	0.72	5	6	0.05	0.45
744	7	4	0.07	0.63	8	3	0.08	0.72
862	5	6	0.05	0.45	7	4	0.07	0.72
999	1	10	0.01	0.09	4	7	0.04	0.36
Average Retrieval Rate					Average Retrieval Rate			
0.03					0.06			

Table (3): Precision and Recall for System based on proposed algorithms

Image Name	Proposed Algorithm			
	Relevant	Non relevant	Recall	Precision
038.jpg	8	3	0.08	0.72
138.jpg	9	2	0.09	0.81
286.jpg	10	1	0.10	0.90
327.jpg	9	2	0.09	0.81
440.jpg	8	3	0.08	0.72
505.jpg	8	3	0.08	0.72
600.jpg	7	4	0.07	0.63
744.jpg	8	3	0.08	0.72
862.jpg	10	1	0.10	0.90
999.jpg	9	2	0.09	0.81
Average Retrieval Rate	0.07			

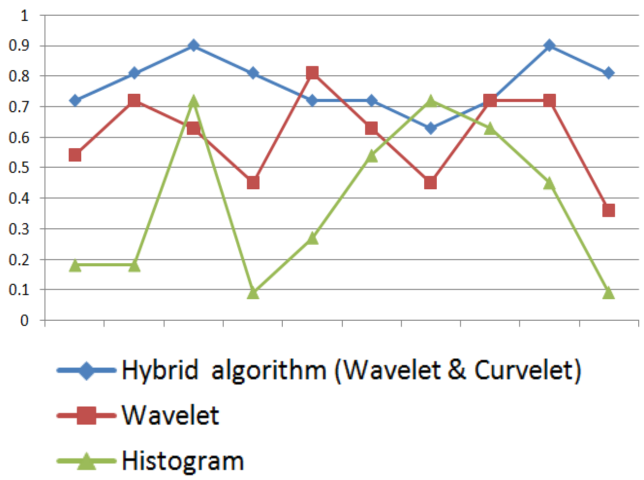


Figure (8): Precision for Image Retrieval system for ten images sample

VI. CONCLUSIONS

The goal of any information retrieval system is to retrieve documents that match the information needed by the user. But it is very difficult to specify the information needed to the IR system. Sometimes, even the users don't know their information needed precisely.

Features are classified into two types: low-level and high-level features. The low-level features, such as a color histogram, are features that can be extracted from raw multimedia data by a mathematical computation, such as image processing algorithms. On the other hand, the high-level features, such as the characteristics of a human face, cannot be readily and efficiently extracted through the use of a mathematical model.

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