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An Overview of Content Based Image Retrieval Techniques

R.Sahaya Jeya Sutha
Research Scholar,
Manonmaniam Sundaranar University,
Tirunelveli, India

Dr.D.S.Mahendran,
Associate Professor,
Dept. of Computer Science,
Aditanar College of Arts & Science,
Tiruchendur, India

Dr.S.John Peter
Associate Professor
Head, Dept. of Computer Science,
St.Xavier's College, Palayamkottai,
India

***Abstract*—This paper presents an introduction about Content Based Image Retrieval (CBIR) using different techniques. The objective of CBIR is to search the relevant images from the large image collections by analyzing the content of the user required query image. It is one of the fastest growing research areas because of the availability of image databases over internet and the tremendous growth of image capturing devices. It is found that there is plenty of research being undertaken to fulfill the searching request with right visual contents in a reasonable amount of time. This paper attempts to provide an overview of the fundamental theories and emerging techniques for Image Retrieval. Further, various similarity distance measures for CBIR, performance measures and future potential research directions are discussed.**

Keywords—Content Based Image Retrieval (CBIR); Feature Extraction; Similarity distance measures; Performance measures

I. INTRODUCTION

Content based image retrieval (CBIR) is a method to search the relevant images from the large image collections by analyzing the content of the user required query image. It has become an active and fastest growing research area. With the recent explosive growth of internet and the inventions of efficient image capturing devices like mobile phones, high resolution digital cameras and scanners, the availability of digital images is increasing exponentially. This created a need of efficient image retrieval techniques for users in various field.

There are two types of image retrieval techniques available. The first one is "Text Based Image Retrieval (TBIR)" and other one is "Content Based Image Retrieval (CBIR)". In text based approach, the images are manually annotated by text descriptors. The retrieval is based on the matching of user query text to the annotation of image.

There are two drawbacks with the TBIR approach. The first is that a considerable level of human labor is required for manual annotation. The second is the annotating images manually found in an expensive task for large image databases, and is often subjective, context-sensitive and incomplete. For example, same word having more synonyms and spelling variations (US vs. UK). As a result, it is difficult for the traditional text based methods to support a variety of task dependent queries. To overcome the above drawbacks in TBIR, content based image retrieval was introduced.

To facilitate image retrieval, a variety of query methods applied in CBIR systems [10]:

- Query by example
- Query by sketch
- Query by Concept
- Random browsing
- Hierarchical Navigation by category

Query by example allows the user to specify a query by providing an example image. It is also known as content-based image retrieval, content-based visual information retrieval and query-by-image content.

Query by sketch allows the user to draw a rough sketch of the image, and the systems locate images whose shape matches with the sketch.

Query by Concept allows the user to specify a query by a conceptual description associated with the image.

Random browsing allows the user not necessarily to have specific idea about images. It provides simple, effective, iterative, interactive featured browsing interface to the user.

Hierarchical Navigation by category images are structured as hierarchical, domain specific categories.

In the query by example, the user is not required to provide an explicit description of the target, which is instead automatically computed by the system. If the target is an image of the same object or set of objects under different viewing conditions then query by example method is suitable. Most of the current systems are using this query by example method.

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II. CONTENT BASED IMAGE RETRIEVAL (CBIR)

CBIR is the computer vision application used for the image retrieval problem of searching for digital images in large databases. One of the main advantages of this approach is the possibility of an automatic retrieval process, instead of the traditional text based approach, which requires very laborious and time consuming previous annotation of database images.The basic steps used in CBIR process are shown in Fig. 1.

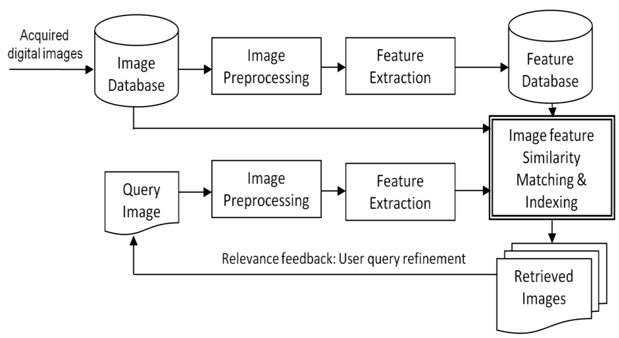

Fig. 1. Block diagram of the typical CBIR system

The typical CBIR system mainly consists of the following stages[11]:

Image acquisition: Digital images are taken from internet, image capturing devices like mobile phones, digital camera and scanners.

Image Database: It contains the collection of images depending on the user range and choice.

Query Image: It is the input image given by the user to search in the image database whether the query image is present or not or how much similar type of images are present.

Image preprocessing: The image is first preprocessed in order to extract the features, which describe its contents. It involves filtering, segmentation, normalization and object identification. The output of the preprocessing stage is a set of significant regions and objects.

Feature Extraction: The features shape, texture, color, pattern or any combinations of them are used to describe the content of the image. These features further can be categorized as low-level and high-level features. In this step, visual information is extracted from the image and saves them as feature vector in a features database.

Similarity Matching & Indexing: The information about each image is stored in a form of feature vectors for computation process and these feature vectors are matched with the feature vectors of query image which helps in measuring the similarity. This step involves yielding a result that is visually similar with the use of similarity measure method called as Distance method. Here different distances method are available such as Euclidean distance, City Block distance. Most similar images are found and indexed among the selected.

*Retrieved images:*The resultant images will be the similar images having same or very closest features as that of the query image. Normally, the selected images with least metric value is displayed first followed by images with increasing metric values.

*Relevancefeedback:*Recent retrieval systems have integratedwith users relevance feedback to modify the retrieval process in order to generate perceptually and semantically more meaningful retrieval results. User feedback marks some results as relevant or non-relevant. The system computes a better representation of the information need based on feedback. Relevance feedback can go through one or more iterations.

The two main task performed by CBIR are *feature extraction and similarity measurement.*The first task is extracting feature of the image which accurately represents the content of each image in the database. These are very smaller in size than original vectors. The retrieval is done by using image features such as color, texture, shape, pattern or any combinations of them. The second task measures the distance between the query image and each image in the database using the computed feature vectors and hence retrieves the closest matches.

Today's CBIR systems suffer from main problems like unsatisfactory results and the long response time, because of the inaccurate existing methods and large memory required for storing a large scale image dataset.

III. APPLICATIONS OF CBIR

Some of the applications of CBIR are [12]:

Copyright detection: Copyright owners to be able to seek out and identify unauthorized copies of images, particularly if they have been altered in some way.

Web searching: A large number of digital images are accessed by the Internet users. CBIR systems can help the users to effectively find out what they are looking for.

Medical diagnosis: In hospitals, a large number of medical images have been stored. Thus, CBIR systems can be used to find various stages of the disease progression and aid diagnosis by identifying similar past cases.

*Geographical information and remote sensing:*Using satellite images, so many predictions done like forest fire, climate variability, sea surface temperatures, storms watch, monitoring land cover, identifying floods, deforestation.

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Journalism and advertising: Articles, photographs, videos of the news papers, journals or televisions are queried by using CBIR systems.

Military: Enemy soldiers or vehicles monitoring, detection and identification of targets, guidance of aircraft and missiles from radar screens, satellite photographs, etc.

Intellectual property: When companies developing their own trademark image, that image must be registered and compared with existing trademark images to eliminate duplications.

Crime prevention: After a serious crime, law enforcement agencies maintain archives of visual evidence for identifying criminals. Such archives include face photographs, fingerprints, shoeprints, etc. of the past occasions.

*Robotics:*Motion control through visual feedback, recognition of objects in a scene.

IV. FEATURE EXTRACTION FOR CBIR

The most common features are based on color, texture, and shape also known as low level features. It can be accurately and automatically extracted from the image. Single feature based retrieval systems were not giving satisfactory results because image contains several visual features. So that different combinations of the visual features are used to retrieve the required image.

In CBIR, the images are automatically indexed by summarizing their visual contents from the extracted low-level features. However, extracting all visual features of an image is a difficult task and there is a problem called semantic gap. Image grouping into semantically meaningful categories based on low-level visual features are very hard. In order to alleviate these limitations, some researchers use both low level and high level techniques together using different features. Some feature extraction techniques referred from [1]-[9] are discussed below.

A. *Color:*

The color feature is one of the most commonly used visual features in image retrieval. Frequently used color descriptors are color space, color moments, color histogram, color coherence vector and color correlogram. Color space must be determined first before selecting an appropriate color description.

*1) Color spaces*each pixel of the color image can be defined as a point in a 3D color space. Commonly used color spaces for image retrieval are: RGB (red, green, and blue), CMYK (cyan, magenta, yellow, and black), HSV (hue, saturation, and value, Lab color space(CIE L*a*b*)- is one of the uniform color spaces defined by the CIE abbreviation for the L*a*b* (lightness, a and b are two Chromaticity coordinates), CIELUV color space (CIE L*u*v*)- is one of the uniform color spaces defined by the CIE abbreviation for the L*u*v*(lightness, u and v are two Chromaticity coordinates), and HIS (hue, saturation, and intensity).

*2) Color moments*have been successfully used in many retrieval systems especially when the image contains just the object. The first order, second order and third order (mean, variance and skewness) color moments have been proved to be efficient and effective in representing color distributions of images. Normally the color moment performs better if it is defined by both the L*u*v* and L*a*b* color spaces. The third order moment can be used additionally to improve the overall retrieval performance rather than using only the first and second order moments. But, this third order moment sometimes makes the feature representation more sensitive to scene changes.

3) Color histogram serves as an effective representation of the color content of an image if the color pattern is unique compared with the rest of the data set. The image in which color bins of frequency distribution are represented by color histogram and it counts the pixels which are similar and store it. The color histogram is effectively used for characterizing both the global and local distribution of colors in an image. In addition, it is easy to compute, robust to translation and rotation about the view axis and changes only slowly with the scale, occlusion and viewing angle. It focuses on individual parts of an image. Two most important methods used frequently in image retrieval are: color histogram using GLCM, and color histogram using KMeans. Similarity between queried image and the target images are calculated using Euclidean distance. Color histogram with K-Means method is better than GLCM method because of its high accuracy and precise. For the color histogram representation, the HSV color space provides better results than CIE L*u*v* and CIE L*a*b* space.

*4) Color Coherence Vector (CCV),*each histogram bin is partitioned into two types coherent or incoherent. If it belongs to a large uniformly colored region then it is coherent else incoherent. Due to its additional spatial information, the CCV provides better retrieval results than the color histogram, particularly for those images which have either mostly uniform color or mostly texture regions. For CCV, the HSV color space provides better results than CIE L*u*v* and CIE L*a*b* space.

*5) ColorCorrelogram,*expresses how the spatial correlation of pairs of colors changes with distance. The first and second dimension of the three-dimensional histogram is representing the color of each pixel pair and their spatial distance described by the third dimension. An autocorrelogram captures only the

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spatial correlation between identical colors and its information is a subset of the correlogram. The color autocorrelogram provides the best retrieval results than color histogram and CCV, but it is the most computational expensive due to its high dimensionality.

B. Texture:

Texture is an important property of images and it is a powerful regional descriptor that helps in the retrieval process. Texture images appears everywhere in nature like natural images, remote sensing images and medical images. Human vision perceives scenes with variations of intensity and color which form certain repeated patterns called texture. Texture can be recognized by everyone but it is not easy to define. Texture occurs over a region rather than occur over a point. It can be measured by quantitative and qualitative method. The deviation of the surface intensity and quantifying properties such as directionality, coarseness, uniformity, density, roughness, regularity, linearity, frequency, phase, randomness, fineness, smoothness, granulation, etc. are some measures. Basically, texture representation methods can be classified into structural, statistical and spectral.

*1) Statistical techniques*characterize texture using statistical properties such as smooth, coarse, grainy of the gray levels of the pixels comprising an image. Normally, in images, there is periodic occurrence of certain gray levels. The spatial distribution of gray levels is calculated.

2) Structural techniques characterize texture as being composed of texels (texture elements). These texels are arranged regularly (repeatedly) on a surface according to some specific arrangement rules. For example, regularly spaced parallel lines.

*3) Spectral techniques*are based on properties of the Fourier spectrum and describe global periodicity of the grey levels of a surface by identifying high-energy, narrow peaks in the spectrum.

Statistical techniques are most important for texture classification because it is these techniques that result in computing texture properties. Some of the existing texture features are gray level co-occurrence matrices, Tamura texture feature, Markov random field model, Gabor filtering, and local binary patterns. Tamura texture feature found to be important in psychological studies using six visual texture properties namely, Coarseness (Size of the texture elements), Contrast (More or less picture quality), Directionality (Same angle but different orientation is considered as same directionality), Line-Likeness (average coincidence of the edge directions), Regularity (regular or irregular pattern), Roughness (contrast + coarseness).

C. Shape:

Shape descriptors can be divided into two main categories: region based (interior) and contour based (outer boundary) methods. For shape description, the region based methods use the whole area of an object but the contour based methods use the outer boundary of an object information only. When compared with color and texture features, the shape features are usually described after images have been segmented into regions or objects. Since the precise image segmentation is complex to achieve, the use of shape features for CBIR has been limited to special applications where objects or regions are readily available.

1) Region based include area, Euler number, eccentricity (i.e., ratio of the maximum length of line or chord that spans the region to the minimum length chord), elongatedness (i.e., ratio between the length and width of the minimum bounding rectangle of the region), and compactness.

*2) Contour based*include chain codes, Fourier descriptors, simple geometric border representations (curvature, bending energy, boundary length, signature), and compactness.

The most successful representation for these two categories are Fourier descriptors and moment variants. The main idea of Fourier Descriptor is to use the Fourier transformed boundary as the shape feature whereas moment invariants is to use region-based moments, which are invariant to transformations as the shape feature.

D. Compressed domain features:

The features discussed above are typically extracted from pixel data. Nowadays, images are almost stored in compressed form to reduce storage and bandwidth requirements. CBIR techniques based on the compressed data stream have become an important issue to rectify these problems. Some compressed domain based CBIR, first the images are decompressed and then features calculated in the pixel domain.

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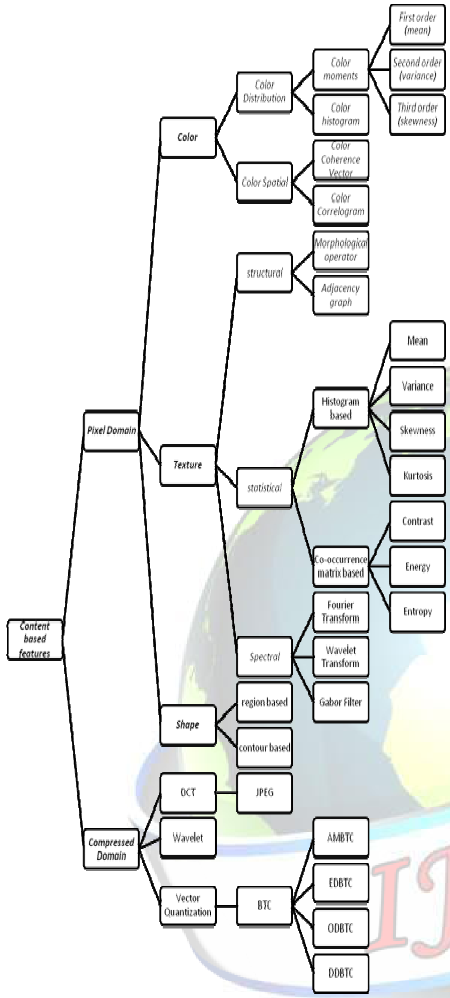

Fig. 2. Hierarchical Diagram of Content Based Features

In later techniques the feature extraction can be done directly in the compressed domain without performing the decompression process. Compressed domain CBIR is classified into DCT, Wavelet, and Vector Quantization (VQ) based. JPEG and BTC are some of the famous compressed domain methods of DCT and VQ based methods.

V. Similarity Measurement For CBIR

The similarity between two images of a query image and the set of images in the database as target image can be measured using the distance measures. The distance plays the most important role in the CBIR system since the retrieval result is very sensitive with the chosen distance metric. A set of similar images to the query image is returned and ordered based on their similarity distance score. The lowest score indicates the most similar image to the query image.

The similarity distances between the query and target images can be formally defined under various distance metrics. Let, Q is the query feature vector and D is the database feature vector. Table I shows various distance measures[14].

TABLE I. Distance Measures For CBIR

Distance Measure	Formula
Euclidian (L2)	$\sqrt{\sum_{i=1}^{n}(\lvert Q_i - D_i\rvert)^2}$
City Block (L1)	$\sum_{i=1}^{n}\lvert Q_i - D_i\rvert$
Minkowski-form (L_p)	$\left(\sum_{i=1}^{n}(\lvert Q_i - D_i\rvert)^p\right)^{\frac{1}{p}}$
Sum of absolute difference (SAD)	$\sum_{i=1}^{n}\lvert Q_i\rvert - \lvert D_i\rvert$
Sum of squared absolute Difference(SSAD)	$\sum_{i=1}^{n}(\lvert Q_i\rvert - \lvert D_i\rvert)^2$
Chebyshev	$\max_{i=1}^{n}\lvert Q_i - D_i\rvert$
Canberra	$\sum_{i=1}^{n}\frac{\lvert Q_i - D_i\rvert}{\lvert Q_i\rvert + \lvert D_i\rvert}$

VI. Performance Evaluation For CBIR

In CBIR, precisionand recall, and F-Score [13]-[14]are the most important measure of evaluation system to find the accuracy of the images retrieved. Precision is used to measure the accuracy whereas recall is used to measure the completeness. Both precision and recall measurements are combined into one to give a single value that describes the accuracy of the image retrieval is called F-Score. The precision and recall, F-Score for a query image is defined as follow.

A. Precision

Precision is defined as the ratio of the number of retrieved relevant images to the total number of retrieved images.

$$\text{Precision} = \frac{Number\ of\ relevant\ images\ retrieved}{Total\ number\ of\ images\ retrieved}$$

B. Recall

Recall is defined as the ratio of the number of retrieved relevant images to the total number of relevant images in the whole database.

$$\text{Recall} = \frac{Number\ of\ relevant\ images\ retrieved}{Total\ number\ of\ relevant\ images\ in\ the\ database}$$

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C. F-Score

The F-score is a single value that gives the overall effectiveness of the image retrieval.

$$F = 2 \times \frac{Precision \times Recall}{Precision + Recall}$$

VII. Conclusion

In this paper, the content based image retrieval techniques using various techniques exist in the past and current are reviewed. This paper starts with a brief introduction about the basic steps of CBIR process and applications of CBIR. Various feature extraction techniques have been explored. We have presented several distance measures to find the similarity between images and performance evaluation measures to find the accuracy of the images retrieved. Much progress has been made in the field of content based image retrieval but still need new approaches for getting more accurate results in lesser time. Compressed domain image retrieval is a latest alternative to common image retrieval to reduce the retrieval time. Feature Extraction techniques can be improved to achieve robust and precise visual features. The user relevance feedback scheme can be added to bridge the gap among the low-level feature and high-level semantic of images in database.

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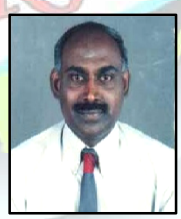
R.Sahaya Jeya Sutha received the B.Sc. (Computer Science), M.C.A. (Computer Applications) and M.Phil.(Computer Science) degrees in 1995, 2000 and 2006, respectively from the Manonmaniam Sundaranar University, Tirunelveli. She has qualified theTamilnadu State Eligibility Test (SET) Lectureshipin 2016. She is currently pursuing Ph.D. degree in Computer Applications at theManonmaniam Sundaranar University, Tirunelveli. She is a life member of ISTE. Her research interests include image retrieval, video retrieval, data hiding and image compression.



D.S.Mahendranis working as Associate Professor in Computer Science, Aditanar College, Tiruchendur. He received the M.Sc. Physics and PGDCA degrees from Madurai Kamaraj University and M.Phil and Ph.D degrees in Computer Science from Alagappa University, Karaikudi. His research interest includes Computer algorithms, Ad-Hoc Networks, Network Security and Green Network.

S.John Peter is working as Associate professor in Computer Science at St.Xavier's College, Palayamkottai, Tirunelveli. He received his M.Sc. and M.Phil. degrees in Computer Science from Bharadhidasan University, Tiruchirappalli. He also earned his Ph.D degree from Manonmaniam Sundaranar University, Tirunelveli. He has published many research papers on clustering algorithms in various conferences, national and international journals.