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A Review on Content-Based Image Retrieval System as an Image Search Engine: From Techniques to Applications

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A B S T R A C T

There has been a tremendous increase in the number of images which are being available over the web. As there is an enhancement in the quantity of images, tremendous methods and techniques are being utilized for the retrieval of images from a large database by the user. Due to lack of adequate knowledge about the correct and the latest retrieval techniques, users are forced to employ text-based retrieval techniques. But, content-based image retrieval (CBIR) offers many advantages and unique features to the user for the retrieval of relevant images. This system also reduces the semantic gap between the human understanding of images and high level features of an image. Thus, this paper presents a detailed description of the CBIR system with latest techniques, extracted features, applications, future trends with shortcomings of the same.

Keywords: Content-based Image Retrieval, Feature Extraction, Machine Learning, Deep Learning, Classification Techniques, Search engine.

Introduction

With the increase in the sophistication and development of new technology in mobile phones and cameras, the number of images on the web has outgrown too much. Internet can be considered as a storehouse or hub of data where many people explore the data of their choice. There are a variety of search engines available to retrieve desired images from the web. A search engine is like a device used by users for searching the required pages or images from a large database (e.g. website, a searchable image, or video). One of the type of search engine is web spider. A web spider also called as spiderbot is a type of internet bot which surf the web systematically. A centralized location is chosen where all the copied results are stored and analyzed [1]. With the advancement in digital devices and expansion of internet billions of people post and view digital images. But, there are numerous applications available which are still not known to the users.

Many algorithms are available which can search for visual documents in a database in terms of text or an image, which is the query submitted by the user. But, query based on text has many drawbacks like misspellings, synonyms, homonyms, etc. So, based on the text, the retrieval is found not fit by the user [2]. All these drawbacks can be easily removed and minimized in a technique known as Content-based Image Retrieval (CBIR) system. In this system, the images are searched on the internet on the criterion of their features like color, texture, shape and many more attributes. These attributes have high level of information regarding the image and the retrieval results are mostly accurate. The basic working of a CBIR system can be well understood by the means of a figure 1.

Here, features of the particular query image which is being given by the user are extracted. The process is being applied to the database image. In this way, two feature vectors are formed. Then, these two feature vectors are being compared in a similarity matching block by using a specific distance metric. Finally, after the similarity matching block, final retrieved and required images are obtained [3].

The main highlights of this paper are:

- A detailed discussion on CBIR system with the single as well as hybrid feature extraction techniques.
- Discussion about latest machine learning as well as deep learning techniques.
- Study of different datasets available for CBIR system.
- Review of various distance metric techniques
- Last, but not the least various application areas and future applications will be discussed.

The remaining organization of the paper is as follows: The remaining organization of this paper is as follows. Section II highlights the various feature extraction techniques. Different machine learning and deep learning algorithms are highlighted in section III. Section IV depicts various datasets, utilized distance metrics and evaluation measures. In section V, various applications are present. The paper ends with a firm conclusion and future trends which are depicted in section VI.

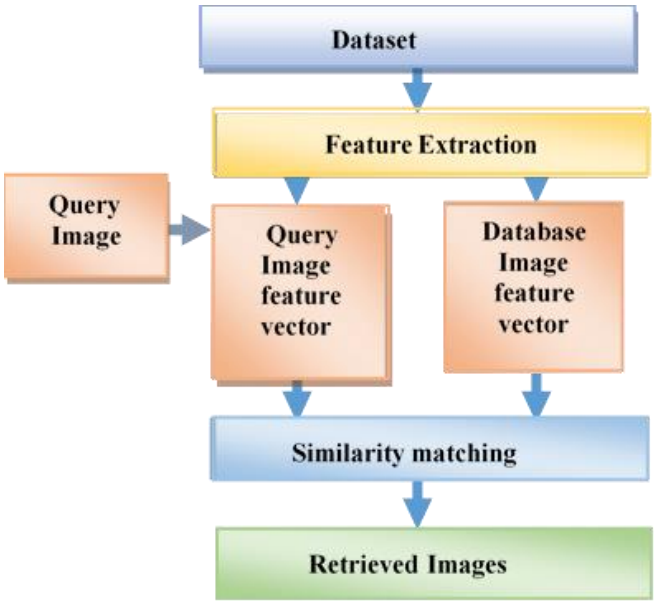

Fig.1 A Basic CBIR System

Feature Extraction Techniques

Different types of image features can be extracted based on the requirement of the user and the application for which the system has been designed. The prevalent features which can be extracted from an image are color, texture, shape, spatial information, etc. These features can be extracted individually or a hybrid system can be constructed by combining two or more features. The detailed description is as follows:

A. Color: To visualize an object, the most peculiar feature of an image is color. It is considered as one of the primary methods of image retrieval. Different color spaces can be used to extract colors like RGB, LUV, YCbCr, YIQ, HSV etc [4]. Among these color spaces RGB is the most commonly used but HSV preserves more features of an image and is more frequently used. A large variety of methods are used for color feature retrieval like change in distance with the change in color intensity is utilized in color correlogram, intensities defined in terms of three color channels is given by color histogram. Different statistical moments like 1st moment mean, 2nd moment standard deviation, 3rd moment skewness and 4th moment kurtosis [5] can be calculated by color moment technique. Many other color descriptors like color co-occurrence matrix, dominant color descriptor (DCD) have been also used.

B. Texture: Texture is another important attribute used to identify a region or an object, which describes the level of gray scale variations in an image. Texture analysis is widely used in interpretation and differentiation of natural images, gray scale and microscopic cell images. Various transform techniques can be used to obtain these features. Prominent texture feature extraction techniques are given ahead. Signal processing, model-based, statistical and structural are the four basic categories of texture attributes. Wavelet transform, Curvelet transform are two primary transform based methods. Among the wavelet based descriptors, gabor filter and Discrete cosine transform (DCT) [6], calculates the divisions of an image at sub-levels at a peculiar angle, frequency and scale. In addition to above discussed techniques, Edge histogram descriptor (EHD), Gray-level co-occurrence matrix (GLCM) [7], local binary pattern (LBP), steerable feature extraction [8] can be also used. 0 to 90 degree of rotation of Local derivative pattern (LDP) is utilized in Local tetra pattern (LTP).

C. Shape: Invariance to rotation, scaling and translation is required in the calculation of shape features. Shape features are of two types: boundary based and region based. Extraction of features based on external portion of an image, is called contour based or boundary based and extraction from complete region is called region based. Some prominent methods for shape feature extraction are Canny edge detector, radial chebyshev moments [9], B-splines, invariant moments, aspect ratio, circularity [10], etc.

D. Spatial Information: Spatial information is also a customary attribute which is lacked by some of the low level feature extraction techniques like shape descriptors and histogram techniques. So, to enhance their performance, some of the spatial information techniques which are used in CBIR system are topology based, graph based, Region of Interest (RoI) [9], etc.

E. Multiple/Hybrid features: Sometimes, single feature extraction techniques do not provide complete information of an image. Therefore, multiple or hybrid descriptors like color and edge directivity descriptor CEDD in [11], Block Difference of Inverse Probability (BDIP), Block Variation of Local Correlation coefficients (BVLC), etc. have been used. Also, two single feature extraction techniques like color and texture, color and shape, texture and shape or trio of color, texture and shape can be combined to form a hybrid descriptor which has enhanced performance in terms of Precision, recall and Accuracy measures as compared to single feature extraction techniques.

Comparison of Machine learning and Deep learning techniques used in CBIR system

Accuracy of a CBIR system can be enhanced by using machine learning and deep learning algorithms in combination with the developed system. A system developed by combining K nearest neighbor (KNN), neural networks (NN) and support vector machine (SVM) have been developed as an intelligent and hybrid system [12]. Numerous machine learning algorithms have been developed which can be used for an effective image retrieval. One of the machine learning based classifier is Random forest. An intelligent semantic based technique called as relevance feedback has been used in combination with many classifiers to group the images into relevant and non-relevant categories and again the results can be utilized for more precise results. A hybrid system consisting of random forest and relevance feedback has been developed by Bhosle et al. [11]. Basically, machine learning algorithms can be divided into three main categories, viz. supervised, unsupervised and reinforcement learning. Many classifiers like naïve bayes, decision tree, random forest, logistic regression, SVM have been compared in [13]. Now a days, based on the latest trend, machine learning has been overshadowed by deep learning techniques and extra human perception and intelligence has been added to a system. Hybrid deep learning architecture (HDLA) [14], Deep convolutional neural network (DCNN) [15], Convolutional neural network (CNN), Autoencoders, Deep belief network (DBN) are some of the deep learning algorithms which have been used with CBIR systems. A fast overview of the prominent machine learning and deep learning algorithms is depicted in Table 1.

Table 1: Prominent machine learning and deep learning algorithms

Technique used	**Brief description**
K-Nearest neighbor (KNN)	It takes the opinion of its K neighbors.
Naïve Bayes	One feature is unrelated to any other attribute.
Support vector machine (SVM)	It divides the data into two hyperplanes.
Random forest	It is used as classifier where decision of tree is used.
K-Nearest neighbor (KNN)	Neighbors opinion is given to the desiring node.
Convolutional neural network (CNN)	Different layers like convolution, pooling and many other layers are used for calculation tasks
Deep belief networks (DBN)	These does not have relation among units but have connection between different layers
Bag of visual words (BoVW)	It is based on the vector of occurrence of counts of words.
Auto encoders	Their main scope is the reduction in dimensionality.

Prominent Datasets, Distance Metrics and Evaluation Parameters

A. Datasets: There are many types of datasets which are freely available on the web for CBIR system. These datasets has images which range from hundreds to thousands and are divided into different categories based on the type of images available in each category.

The most utilized datasets for CBIR system are Corel/Wang [16], ZUBUD, FLICKR, UW, Caltech, Oliva, Brotadz [17], GHIM-10, Holidays and many more. Some samples from some prominent databases are given in Fig.2.

B. Distance Metrics

The distance metric or similarity measure is used to find similarity between the query image submitted by the user and the complete database. Two feature vectors are formed, each for query image and the database images and based on the top N images submitted by the user, the retrieval results are obtained. There are various distance metrics which can be used to find the similarity. The most prominent distance metrics are Euclidean, City block [18], Minowski [19], Cosine, Hamming, Chebyshev [20] and many more.

$$D_{Euclidean} = \sqrt{\sum_{i=1}^{n}(|I_i - D_i)^2|} \quad (1)$$

$$D_{City\ block} = \sum_{i=1}^{n}|I_i - D_i| \quad (2)$$

$$D_{Minowski} = [\sum_{i=1}^{n}(|I_i - D_i|)]1/P \quad (3)$$

$$\text{Dcosine (X,Y)} = \frac{X.Y}{\|X\|\|Y\|} \quad (4)$$

$$D_{Chebyshev}(p,q) := \min_i(|p_i - q_i|) \quad (5)$$

Fig.2 Sample images from some prominent datasets

C. Performance Parameters

To measure the performance of a CBIR system, the three major performance metrics are:

Precision : Precision denotes the number of Predicted Positive cases that are correctly Real Positives [21].

Precision**:** P = $(Number\ of\ relevant\ images\ retrieved\ )/(Total\ number\ of\ images\ retrieved\ )$ (6)

Recall : Recall or Sensitivity is the proportion of Real Positive cases that are correctly Predicted Positive [22]

Recall**:** R = $(Number\ of\ relevant\ images\ retrieved\ )/(Total\ number\ of\ images\ in\ the\ database\ )$ (7)

F-Measure : F-measure denotes the true Positives to the Arithmetic Mean of Predicted Positives and Real Positives [22]. All these three parameters can be used to retrieve top N desired images from the utilized dataset. For example, top 10 images from oxford flower database is given in Fig. 3.

F-Measure**:** F =2× $(Recall\ \times Precision)/(Recall\ +\ Precision)$ (8)

Fig.3 Top 10 retrieved images from flower dataset

Applications of CBIR

There are numerous applications of CBIRS. Various fields where CBIRS domain has been used effectively are as under [23].

1. Prevention of Crime

Agencies of Law enforcement generally generate massive digital libraries of visual evidence, suspect's facial photo, fingerprints, etc. Whenever such a crime happens, all of the evidences can be matched to the prior formed massive dataset consisting of criminal records.

2. Military

Military applications are the best- advanced or developed application of imaging technology. By using radar screens for identification of challengers or enemy satellite photographs for recognition of targets, and for cruise missiles provision of guidance systems. To keep a keen eye on enemy, surveillance techniques can be used and this could be very effective.

3. Architectural & Engineering Design

Many 2-D and 3-D models have been utilized in architectural and engineering design [24] and there is often a lot of pressure by the clients to work within externally-imposed limitations, often financial. Hence the capability to search design repository for previous designs which are in some way similar or meet particularize suitability criteria, can be valuable.

4. Interior & Fashion Design

In the area, there can be similarities and hence the capability of the designer to find the best fabrics in terms of color and texture is highly desirable.

5. Medical Diagnosis

The increase in dependency of many diagnostic techniques such as radiology, histopathology [25], and computerized tomography on images has resulted in rapid increase in the number and value of medical images stored in repository of many hospitals.

6. Training and Education

It often becomes difficult to identify good lecture material to be presented before the students in a class. The information on some special topics like mountain safety, traffic congestion, etc. in terms of images or video clips becomes more convenient with the help of CBIR systems.

7. Searching of Web

The main and the primary application of CBIR system is to search the web regarding desired images or text from a huge repository of data. This huge repository serves as both for the purpose of information as well as entertainment.

Conclusion of CBIR with future trends

In this paper, it can be concluded that a CBIR system effectively retrieves a desired image from a large pool of images based on the choice of a user. For the extraction of feature both single level feature extraction and hybrid level feature extraction can be used. But, hybrid system offers many precise results as compared to single level feature extraction. To enhance the efficiency of the system, machine learning and deep learning algorithms can be added to the desired system. In future, real time system can be developed by using Internet of Things (IoT) through which real time processing can be done for some specialized applications like to prevent forest fires, military applications and many more

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