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A Journey from basic Image Features to Lofty Human Intelligence in Content-based Image Retrieval: Motivation, Applications and Future Trends

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Abstract*: *Due to a remarkable increase in the complexity of the multimedia content, there is a cumulative enhancement of digital images both online and offline. For the purpose of retrieving images from a vast storehouse of images, there is an urgent requirement of an effectual image retrieval system and the most effective system in this domain is denoted as content-based image retrieval (CBIR) system. CBIR system is generally based on the extraction of basic image attributes like texture, color, shape, spatial information, etc. from an image. But, there exists a semantic gap between the basic image features and high-level human perception and to reduce this gap various techniques can be used. This paper presents a detailed study about the various basic techniques with an emphasis on different intelligent techniques like, the usage of machine learning, deep learning, relevance feedback, etc., which can be used to achieve a high level semantic information in CBIR systems. In addition, a detailed outline regarding the framework of a basic CBIR system, various benchmark datasets, similarity measures, evaluation metrics have been also discussed. Finally, solution to some research issues and future trends have also been given in this paper.

Keywords*: *Deep Learning, Feature extraction, Image retrieval, Relevance Feedback, Similarity Matching.

I. INTRODUCTION

With the tremendous advancements in technology related to image analysis and capturing, the image database has increased rapidly both online and offline. To find any image in which a user is particularly interested is a tedious task. So, in order to search for interesting and relevant images, a typical method is required for querying and searching of images and the solution is denoted by content-based image retrieval (CBIR) system. CBIR is an expert technology which is based on retrieving visual image features like color, shape, texture, etc. from a massive image database according to the interest of the user. The use of a large number of images over the internet and the continuous increase in the number of images has led to the necessity for the evolution of an efficient image retrieval systems which can be used for disposition and categorization of images [1]. The image retrieval techniques are broadly divided into two types: (1) Text based image retrieval (TBIR) (2) Content-based image retrieval (CBIR). In TBIR, images are retrieved on the basis of keywords and text. But, the performance of this method is deteriorated with certain pitfalls like images have to be manually assigned to keywords which is a cumbersome task and also this system fails to retrieve visually similar images [2]. Content-based image retrieval system vanquish the drawbacks of text based image retrieval. In a typical CBIR system, query from a user is taken in the form of a sketch or an image and based on this query image, features are extracted from images to form feature vectors. Images are also present in an image database, whose feature vectors are also extracted based on image features [3]. Then, the comparison of feature matrix of user's query image and total images in the database is done by using a distance metric technique to retrieve visually similar images. The architecture depicting the basic CBIR system is given in Fig. 1.

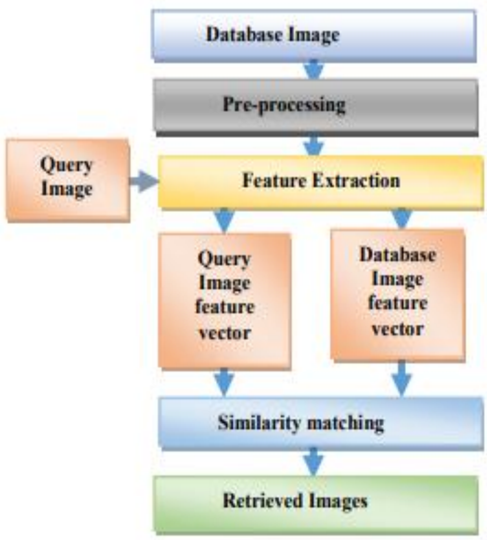

Fig. 1 An architecture of a basic CBIR system

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From Fig. 1, it can be seen that almost similar processes are adopted for both database images and a specific query image and lastly required top N images are retrieved after similarity matching stage.

There are many CBIR systems which have been analyzed and developed successfully for the retrieval of desired images. Systems like Blobworld, VisualSeek, SIMPLicity [4], etc. are among the renowned CBIR systems. Based on the successful performance of these systems, the interest of the researcher community has been more increased for the development of CBIR systems based on latest techniques and human-like intelligence. The main aim of the researchers is to develop a CBIR system based on human perception and can be utilized in various fields like artificial intelligence, medical diagnosis, machine learning, deep learning etc.

The comprehensive study in this paper highlights the following main contributions which are as follows:

- The usage of a single feature extraction technique vs the results of a hybrid descriptor for extracting features.
- The analysis of machine learning techniques vs deep learning techniques and a comparative assessment of latest CBIR systems.
- Analysis of various similarity matching techniques to determine the most effective for calculating the similarity between a query and database images.
- Finally, based on the increasing research in the domain of CBIR system, an in-depth analysis on latest and promising research areas have been given.

The remaining organization of this paper is as follows. The motivation or importance for CBIR systems has been given in section 2. An overview of different feature extraction techniques like color, texture, shape and spatial information based on global and local image features with their fusion techniques are discussed in section 3. Overview about relevance feedback is given in section 4. Various machine learning and deep learning techniques have been given in section 5. Varied benchmark CBIR datasets and evaluation metrics are given in section 6. Distance metrics and various applications of CBIR system are given in section 7. Solution to some typical CBIR issues is given in section 8. Finally, Conclusion and future trends have been given in section 9.

II. MOTIVATION

The importance of CBIR system has increased rapidly in present time due to the vast number of ever increasing images on the internet and different techniques are being utilized in CBIR systems to retrieve these images like fusion based, similarity based etc. [5]. Therefore, there must be an appropriate technique or system to manage these images effectively. Therefore the significance of CBIR systems has increased apparently [6]. Also, the complexity of data is another factor because data can be implemented in different ways and different methods can be used for the representation of its image content, which also contributes in enhancing the importance of CBIR systems. Time of retrieval is another factor which is also considered as an important factor because it takes large amount of time in this process. So, to reduce the time of retrieval is an important factor. All these issues motivated the growth of CBIR systems.

III. FEATURE EXTRACTION TECHNIQUES

The feature extraction stage deals with the extraction of different features of an image to an acceptable level. The most widely used basic features of an image are color, texture, spatial information and shape. These extraction techniques are either based on global features of an image or on local image features.

A. Based on global image features

Global image features are those which are extracted from the whole image. On the basis of global features, the main extracted attributes of an image are categorized as under:

Color: Color is the most important feature of an image which makes humans to identify objects. It is the most basic and important method of image retrieval. Various techniques which are commonly used for color feature extraction are color histogram [3], which defines the intensities in terms of probability, related to three color channels, color correlogram [7], which defines the information related to color feature with the change in distance. This method has many advantages too. Dominant color descriptor (DCD) [8] describes the typical colors in an image region, color co-occurrence matrix, color moment [9] which describes color features of an image based on three moments like mean, skewness and standard deviation. Color information can be found in various color spaces like YCbCr, denoted by luminance and two chrominance components [10], RGB color space which is the most basic representation of color and many more.

Texture: Texture signifies the tectonic features of an image such as smoothness, roughness, etc. of an object and its neighbors. These features are classified into four different types which are statistical, model-based, signal processing and structural. Discrete cosine transform (DCT) [11], gabor filter [12] denotes a set of wavelets which apprehend power at a particular scale, frequency and orientation [13], wavelet transform, curvelet transform are various signal processing methods. Gray-level co-occurrence matrix (GLCM) [14], local binary pattern (LBP), edge histogram descriptor (EHD), steerable feature extraction [4] are also used for texture extraction.

Shape: Shape is symbolized as one of the most important features of an image. They are broadly classified into contour based and region based. When the features are extracted based on external region of an image, it is called contour based while in region based extraction is from complete region. Various methods for its extraction are based on radial chebyshev moments [15], invariant moments, b-splines, aspect ratio, circularity [3], canny edge detector, etc.

Spatial Information: Some of the customary low level extraction methods suffers from the lack of spatial information like histograms and shape points. Therefore some of the spatial information techniques are RoI's (Region of Interests), geometric based, graph based, topology based [16] have also been used in CBIR systems.

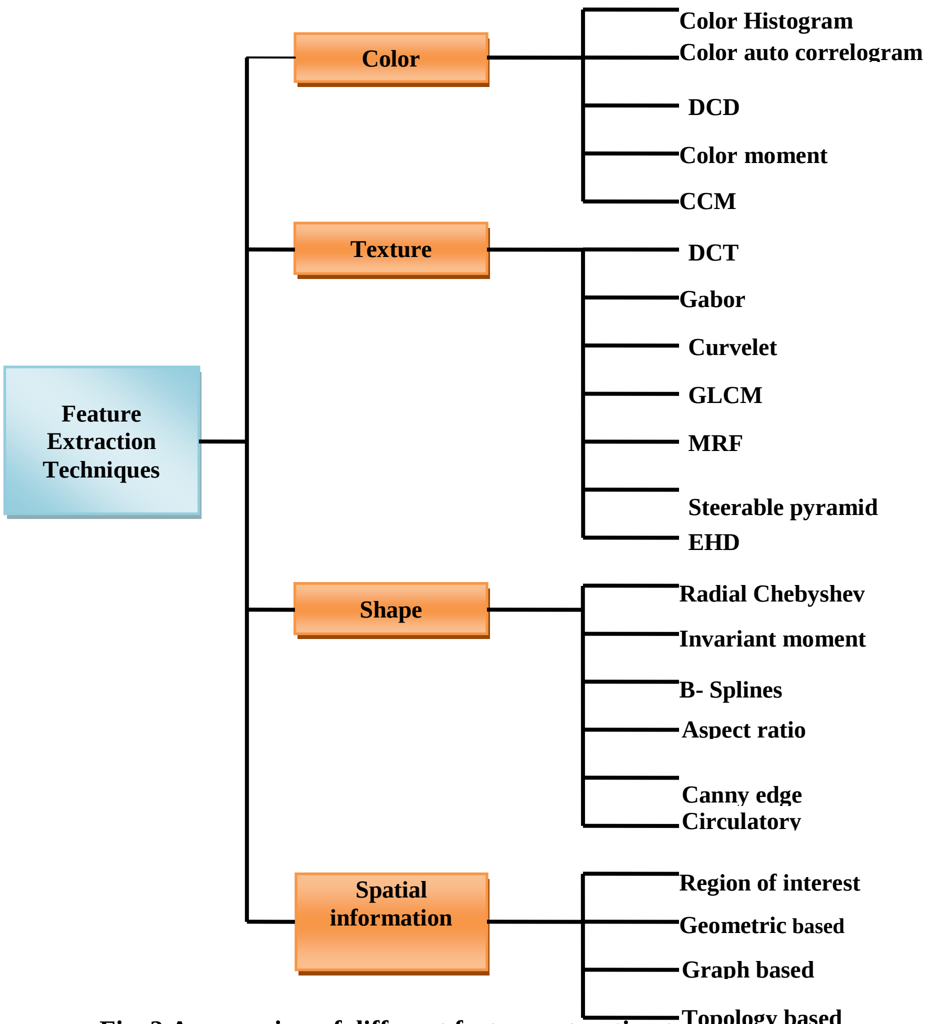

Fig. 2 An overview of different feature extraction techniques

B. Based on local image features

Local image features describes the specific parts of an image in which interest of a user is present like region of interest (RoI), object, local corners, edges etc. These local image features have gained more importance as compared to global image features because of many added advantages like reduced time and memory requirement of a system. Also, these features do not depend upon rotation and scale change of an image and are very near to human intelligence and both 3D view and illumination changes. Based on the above given description about all the techniques, an overview of various feature extraction techniques is given in the form of a diagram and is given in Fig. 2.From Fig. 2, it can be concluded that there are primarily four types of basic features of an image and the user can use any of the above mentioned techniques to extract these features. Many techniques are used for the extraction of local features like scale invariant Feature Transform (SIFT). Another local feature extraction method is speeded up robust features (SURF) which is dependent upon the addition of 2D haar wavelet transform. Next is local binary pattern (LBP) [17], histogram of oriented gradient (HOG) [18] and much more.

C. Fusion of low level features

Various low level image features can be combined in an efficient manner to develop a hybrid or fusion based CBIR system. Fadaei et al. [8] developed a system which uses DCD, curevelet and wavelet features. DCD has been used for color feature extraction while for the extraction of texture attributes, curvelet and wavelet technique has been used. Chandan Singh et al. [19] proposed a system based on a combination of color and texture. Here, in this paper, block difference of inverse probabilities (BDIP) and block variation of local correlation coefficients (BVLC) has been used for texture extortion and color histogram for the extraction of color attributes, and precision has increased to an appreciable level with the retrieval of more similar images. Anandh, et al. [20] described the CBIR system based on three techniques namely color auto co-orrelogram for color, gabor wavelet for texture and wavelet for shape feature. The results of the paper showed that average accuracy rate of 88% has been retained for Li dataset, 83% for corel database and 70% for caltech dataset. Color moment has also been used as a technique to filter the initial set of images. Then, the features of the remaining images have been extracted by using LBP and Canny edge detector for texture and shape respectively, in a technique proposed by Pavithra et al. [9]. Both, the techniques depict a great level of enhancement in the obtained results with the usage of multiple attributes for feature extraction. Naveena et al. [1] described about different basic features of an image like color, shape and texture which can be extracted using different techniques like color moment for color extraction, wavelet for texture and canny edge descriptor for shape extraction. Also, support vector machine (SVM) classifier is being used to classify images in the database. With the emergence of machine learning, different machine learning techniques like SVM, random forest, bayesian network, decision trees, K-NN, etc. have been used with basic CBIR systems to enhance their performance [21]. Now, in this current era in spite of machine learning, its counterpart called as deep learning [22] has been used in CBIR systems for the extraction as well as classification of various image features. Thus, it can be concluded that a fusion based CBIR system is more efficient in retrieving the semantic features of an image as compared to a system based on single feature.

IV. RELEVANCE FEEDBACK

Concerning about various hitches in the existing CBIR system, focusing mainly on obtained results, still there exists a major disparity between the results processed by machines and human understanding and is symbolized as Semantic Gap. So, to cover up this gap, many intelligent techniques specifically relevance feedback (RF), response based on user's feedback could be used. This process works iteratively until the desired results are obtained or the user gets satisfied. This technique can be used at different levels of the system like, based on support vector machine (SVM), query expansion with weighted technique, with optimization techniques and much more [23]. The three basic ways of a query refinement in relevance feedback are as follows [14]:

(1) Extension of Query: In this technique, the neighboring images of an actual query image are also included in it, based on the feedback obtained by the user. Thus, in a way, an expansion of an original query image is done.

(2) Query Re-Weighting: This method enhances the weights of some prominent attributes of an image and simultaneously reduces the weights of some un-important attributes. In this way, a query becomes more refined.

(3) Movement of Query: A query is moved close to the required images by the adjustment in the attributes of a utilized distance function.

For the users to easily understand, the concept of relevance feedback, the basic process of this technique can be shown with the help of Fig 3.

From Fig. 3, it can be seen that a query image of penguin is given and based on this query image, only two relevant images are retrieved. Then, the user gives the feedback about

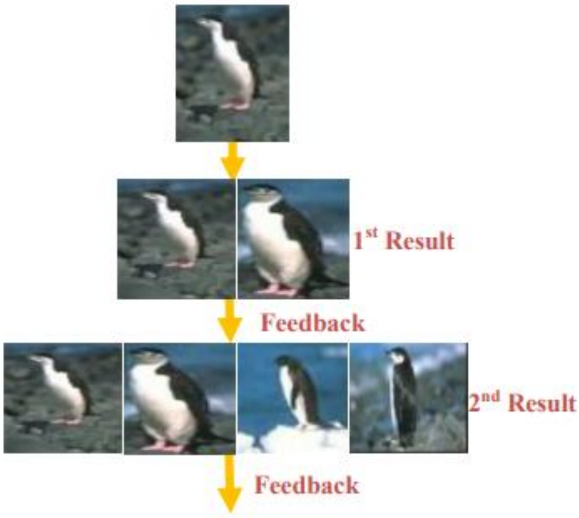

Fig. 3 Basic process of Relevance Feedback

retrieved images and based on the user feedback, non-relevant images are discarded and only relevant images have been chosen which increase the retrieved results to four, in 2nd time results. Thus, it is an efficient technique which utilizes more semantic information.

V. CBIR USING MACHINE LEARNING VS DEEP LEARNING TECHNIQUES

In order to increase the performance of CBIR systems, many machine learning algorithms have been developed. A combination of neural network (NN), K nearest neighbors (KNN) and support vector machine (SVM) have been used to develop an image retrieval system [24]. Many more machine learning classifiers have been developed which can be used for an effective image retrieval. Random forest is also a machine learning based technique which has been used for classification purpose. The retrieval results can be enhanced by grouping them into relevant and non-relevant categories and then these relevant images are again used to retrieve more precise results by the technique of relevance feedback. A combination of relevance feedback and random forest has been proposed by Bhosle et al. [25]. These machine learning models can be categorized under supervised, unsupervised and reinforcement learning. The performance of many classifiers like naïve bayes, decision tree, random forest, logistic regression, SVM have been compared for an analysis based on text reviews [21]. Now, in this era, the focus of the researcher section has been shifted from machine learning to deep learning. Although, this deep learning is itself a subset of machine learning but it is based on the conception of human neurological nervous system. Therefore, more human perception and intelligence can be added to a system. Hybrid deep learning architecture (HDLA) [26], is a technique based on deep learning which can be used for an effective image retrieval. This model uses boltzmann machines in the upper layers and softmax model in the lower levels.

Another technique based on deep convolutional neural network (DCNN) [27] has been developed which extracts the features of an image using convolution layers which subsequently employs max pooling layers for its execution. Also, once a model is trained using CNN, again retraining is being employed, based on three different techniques.

Deep learning techniques can also be successfully applied to biomedical images. Content-based medical image retrieval (CBMIR) based on unsupervised learning is proposed by Shamna et al. [28] where to reduce the semantic gap, Bag of visual words (BoVW) is being used. This technique is used here for feature extraction by using a distance measure called as skip similarity index. Different types of deep learning techniques like deep neural networks, restricted boltzmann machines, deep belief networks (DBN), auto encoders etc. can be used for the formation of a CBIR system [29]. Based on the discussion of these machine learning and deep learning techniques, prominent techniques related to machine learning category is given in Table I and techniques related to deep learning category is given in Table II.

Table I. An overview of prominent machine learning techniques

Technique used	Brief description
Decision Trees	Uses a tree-like graph for various decisions and based on varied consequences
Linear regression	To plot a relationship between a dependent and an independent variable
Support vector machine (SVM)	Find the optimal hyper-plane which divides the given points into two parts with maximal distance
Naïve Bayes	The presence of any specific attribute is unrelated to any other feature is assumed.
K-Nearest neighbor (KNN)	It works by taking the majority opinion of its K neighbors.
Ensemble methods	Works by the formation of many classifiers and then classify the data according to the obtained predictions.
K-means	Data is partitioned into different clusters with homogenous data in an individual cluster
Random forest	Each tree is classified and then each tree votes for a specific class in the classification procedure.
Principal component analysis (PCA)	Uses orthogonal transformation to convert observations into linearly uncorrelated variables.
Singular value decomposition (SVD)	It is a factorization of real complex matrix
Independent component analysis (ICA)	It is a generative model for the given multivariate data

VI. CBIR BENCHMARK DATASETS AND EVALUATION METRICS

A large variety of databases have been utilized for the purpose of evaluation in CBIR systems. These benchmark datasets can be a collection of few hundred images or more. Each dataset contains some categories of images and among a particular category, images with similar semantics are present like images related to humans, butterflies, monuments, beaches, etc. Some of the sample images from the prominent CBIR datasets are given in Fig. 4.

The most prominent benchmark datasets utilized in CBIR systems are Corel-1K, Corel-5K, Corel-10K [9], Caltech-101, Caltech-256 [30], GHIM-10 [26], Oxford flower dataset [31], Brodatz dataset [32], COIL-100, Holidays [22], UKbench, etc. An overview of some of the important datasets is given in Table 3.

Table II. An overview of prominent deep learning techniques

Technique used	Brief description
Convolutional neural network (CNN)	Consists of convolution, pooling and various other layers for performing tasks
Recurrent neural network (RNN)	Uses the information from previous layers to predict its current outcome
Deep Reinforcement learning	It is based on the concept of an agent communicating with an environment
Fully connected neural networks	Here, every neuron is connected to the other neuron of the preceding and succeeding layer
Boltzmann machine	These structures are based on the working procedure of RNN
Deep belief networks (DBN)	These have connections among layers but not between different units present in those layers
Auto encoders	These are specifically designed to learn the encoding of given data with the main aim of reduction in dimension of data
Bag of visual words (BoVW)	It is vector of occurrence counts of words and can be used for different applications

Fig. 4 Sample images from some benchmark CBIR datasets

There are various types of evaluation metrics which can be used to judge the performance of an image retrieval system but the most prominent are:

$$Precision = \frac{\text{No. of relevant images retrieved}}{\text{Total no.of retrieved images}} \quad (1)$$

$Recall =$

$$\frac{Number\ of\ relevant\ images\ retrieved}{Total\ number\ of\ relevant\ images\ in\ the\ database} \quad (2)$$

$$F - score = 2\frac{Precision*Recall}{Precision+Recall} \quad (3)$$

$$\text{Total average precision } = \frac{1}{|DB|}\sum_{k=1}^{|DB|} Precision(P) \quad (4)$$

$$\text{Total average Recall} = \frac{1}{|DB|}\sum_{k=1}^{|DB|} Recall(R) \quad (5)$$

Images in Fig. 4 are some of the sample images from standard benchmark datasets available online. In Table III, different standard CBIR datasets are present, showing the total number of images in the dataset with the number of images present in each category of dataset is also given. For example, Corel-1K dataset has a total of 1000 images and there are 10 categories in this dataset.

Table III. An overview of CBIR benchmark datasets

Datasets	**No. of Images**	**Categories present**
Corel-1K Corel-5K Corel-10K	1000 5000 10,000	10 50 100
Caltech-101 Caltech-256	9000 30,600	102 257
GHIM-10	10,000	20
COIL-100	7200	100
ZUBUD	1005	201
Oxford flower	1360	17
Holidays	1491	500-Queries 991-relevant images
UKbench	10,200	2550
Brodatz	1456	13
MIT-Vistex	640	80

A detailed analysis related to latest techniques used in the domain of CBIR with their comparative assessment is given in Table IV.

Here, I_i denotes the input query image and D_i depicts all database images related to euclidean, manhattan and minkowski distances whereas X_i and Y_i denote i_{th} values of sequences X and Y related to spearman and cosine distances.

VII. DISTANCE METRICS AND APPLICATIONS OF CBIR SYSTEM

The similarity measure techniques determine the similarity in terms of calculated feature vectors (distances) between a query image and database images. Various distance metric techniques which are mostly used for similarity measurement are euclidean distance, minkowski distance, hamming distance, cosine distance, manhattan distance, chebyshev distance, L1, L2, etc. and many more [5]. Some of the prominent distance metric techniques are given in equation (6)-(10).

$$Distance_{Euclidean} = \sqrt{\sum_{i=1}^{n}(|I_i - D_i)^2|} \quad (6)$$

$$Distance_{Cosine} = 1 - cos\theta = \frac{X.Y}{\|X\|\|Y\|} \quad (7)$$

$$Distance_{Manhattan} = \sum_{i=1}^{n}|I_i - D_i| \quad (8)$$

$$Distance_{Minkowski} = \left[\sum_{i=1}^{n}(|I_i - D_i)^{1/P}|\right] \quad (9)$$

$$Distance_{Spearman} = 1 - \frac{6\sum_{i=1}^{n}((rank(X_i) - rank(Y_i))^2}{n(n^2-1)} \quad (10)$$

Table IV. Comparative assessment and detailed analysis of latest CBIR systems

Authors	**Technique**				
	Color	**Texture**	**Shape**	**Edge**	**Other**
Fadaei et al. [8]	DCD	DWT and Curvelet	-	-	PSO
Bhardwaj et al. [14]	-	GLCM and DWT	-	-	ELM and RF
Pavithra et al. [9]	CM	LBP	-	Canny edge	-
Naghashi et al. [17]	-	LBP, LTP and GLCM	-	-	-
Govindan et al. [26]	-	-	-	-	Deep learning (HDLA)
Shamna et al. [28]	-	-	-	-	BoVW
Tzelpi et al. [22]	-	-	-	-	Deep CNN

From Table 4, a detailed assessment of a comparative analysis based on latest CBIR systems can be seen. From this table, it can be concluded that different types of techniques can be used for the development of an effective CBIR system. In equation (4) and (5) total images in the database are represented by *DB*. Although, there are many more evaluation metrics which can be used to evaluate the performance of any CBIR system, but, the metrics given in above equations are the most important and useful.

In an image retrieval system, the retrieval of images can be done based on various concepts like image, text, sketch, etc. and this can be seen with the help of Fig. 5.

From Fig. 5, it can be seen that the retrieval of desired images can be done by using a user query in the form of an image, by using typed text or in the form of sketch of an image.

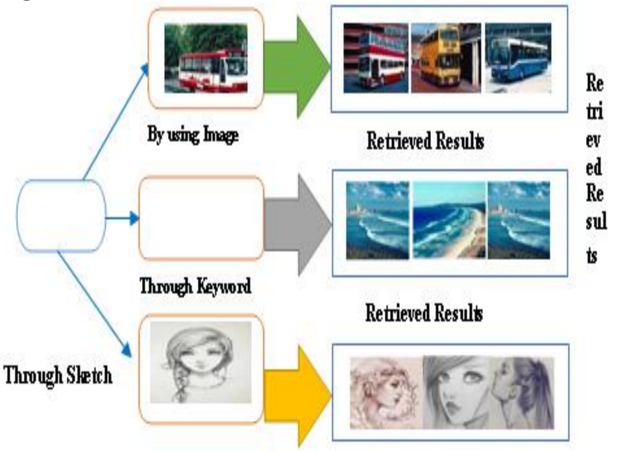

Fig. 5 Different forms of retrieval using various forms of query

In order to show the retrieved results, different types of graphical user interface (GUI) have been designed by the users. Here, the top 5 to top 10 images based on Oxford flower dataset by using a GUI is given in Fig. 6(a) and 6(b).

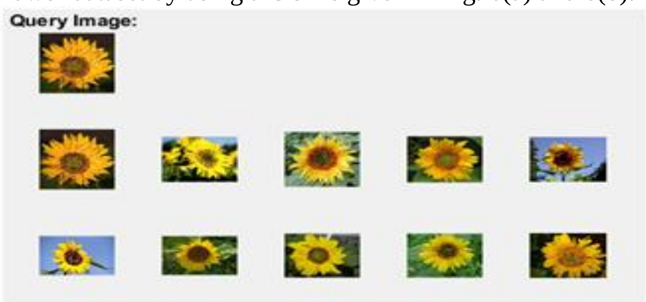

Fig. 6(a) Retrieval results based on top 5 images

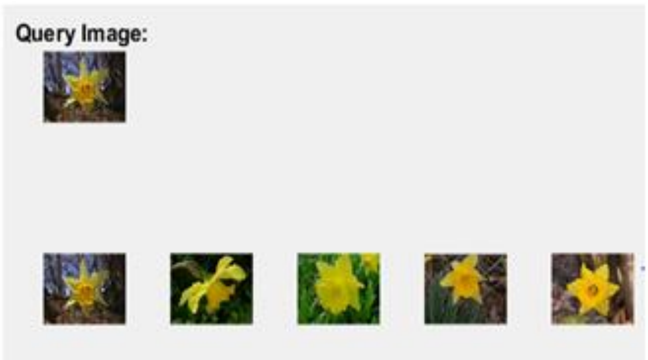

Fig. 6(b) Retrieval results based on top 10 images

From Fig. 6(a-b), it can be seen that based on the top 5 retrieval, images related to the same category as of the given query image are retrieved and similar is the case with top 10 retrieval. Thus, from the GUI of the developed system, the user can visualize that the CBIR system is efficient in retrieving the required and relevant images.

Regarding applications of CBIR system, it is a very renowned field and is being used in a variety of applications related to real life. The most popular applications of CBIR system are [4] as follows:

- Medical Diagnosis: It is the most useful application of CBIR systems where the medical practitioner can search the images of X-ray, CT-scan, ultrasound etc. from large storehouse of images.
- Crime prevention: It can be used to identify finger prints and other facial records of the criminal.
- Military: For the purpose of safeguarding the country, the CBIR system can be used by military personals for various security issues.
- Art Gallery collection: Similar images can be retrieved for the purpose of displaying the images in art gallery, belonging to the same theme or category like flowers, horses, etc.

There are many more applications of CBIR system like remote sensing, face classification, pattern recognition, etc. Thus, in short CBIR system is the desire and requirement of this current era.

VIII. SOLUTION TO SOME BASIC CBIR ISSUES

There is no denying to the fact that tremendous progress is being made in various fields related to CBIR systems. But, in spite of these advancements, still there exists some major issues and challenges which should be bridged for the growth of an efficient and intelligent CBIR system. The prominent issues which produces difficulties in this field are:

- Curse of Dimensionality: Although, many dimensionality reduction techniques and index creation techniques like principal component analysis (PCA), latent semantic analysis (LSA), cluster-based indexing, etc. are available for the creation of indexes and reducing the storage requirements of the system but, still there exists a gap, as more time is utilized for the retrieval of desired and relevant images from the dataset. Therefore, there exists an urge to solve this issue by using some more sophisticated and intelligent dimensionality reduction and indexing techniques, in order to use less storage space and less retrieval time.
- Real time query image: In any CBIR system, the user can retrieve the desired set of images based on the query input given by the user. Generally, the query is given in the form of an image, from the stored set of images. But, the real issue is to provide a query image in real-time.

Based on these challenges in the field of CBIR system, the remedial solution to these issues can be addressed as follows: Different query refinement techniques like query re-weighting, query-expansion, query movement [33] can be used, so as to refine the given query image in order to obtain higher level semantic information from an image.

In order to form a hybrid CBIR system, the parameter selection can be based on effective optimization techniques like particle swarm optimization (PSO), ant colony optimization (ACO), whale optimization, etc., so as to improve the efficiency of the developed CBIR system. These systems will be more efficient in recovering the similar and desired images from the dataset.

Some more multimedia attributes like speech, video, etc. can be used in combination with image features to form a muti-modal and more developed CBIR system.

Last but not the least, in order to provide real-time query images, some more sophisticated and intelligent techniques based on Internet of things (IoT) and cloud computing can be used.

IX. CONCLUSION WITH FUTURE TRENDS

The thrust of this paper is to dispense the practicality of the basic content-based image retrieval systems. The basic aim of this study is to present an overview of different feature extraction techniques which were utilized in this field. It can be concluded that the basic low level feature extraction techniques can be classified on the basis of color, texture, shape, edge, spatial information, etc. But, these techniques when utilized in fusion-mode produces more fruitful results as compared to results based on single technique. The usage of various machine learning techniques in CBIR system have also emerged as an advantage. But, due to the advancements in technology, the trend has been shifted from machine learning to deep learning. The incorporation of deep learning has further enhanced the results of CBIR system by producing more relevant and desired results with the disposal of higher semantic information from an image. To manage large-scale datasets in a CBIR system is a challenging task, especially with deep learning model. Therefore, to assess the performance of very deep learning model with large-scale datasets will be one of the future trend in this field. Also, in future, the concept of internet of things (IoT) can also be utilized in the domain of image retrieval for the online transfer and reception of query image and retrieved results respectively. From this review, it can be concluded all the techniques, parameters, datasets, issues of the CBIR system have been effectively stated in this paper and the future researchers can utilized this information for the development of an intelligent and multimodal CBIR system.

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