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Content Based Image Retrieval: An Overview of Architecture, Challenges and Issues

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***Abstract* - The objective of this paper is to present a brief overview of existing Content-Based Image Retrieval (CBIR) technique. The CBIR method is used to retrieve relevant images from the database based on the query image submitted by the user. The retrieval of images from a database relies purely on the image features such as color, shape and object identification using texture(s) in the query image. Apart from CBIR architecture and its existing methods, the paper presents the issues and challenges of CBIR system that needs to be addressed along with the future scope.**

Keywords — CBIR, Feature Extraction, Feature Dimension, Dimensionality Reduction, Relevance Feedback, Similarity Measures..

I. INTRODUCTION

In the computing era, huge data transactions (in the form of text, image, audio and video) take place in various domains such as medical field, image and video repositories, satellite data, digital libraries, historical research, digital forensics, biometrics and much more. Among these types, the Text-Based Image Retrieval (TBIR) is the standard system where the relevant images are retrieved from the database based on the query string [1]. The major drawback of TBIR is that sometimes it results in irrelevant images even after the massive computations. To overcome the disadvantages of TBIR, CBIR is developed to retrieve the relevant images. CBIR uses visual contents present in the image such as low-level features (texture, color, shape, etc.) and spatial location of objects during the retrieval process to get more retrieval accuracy than the TBIR method. As the CBIR accepts input as an image, the need of detailed explanation about the objects in the image becomes obsolete.

Figure 1 shows the conventional CBIR architecture summarized from [2]. The visual and discriminate features (such as color, texture, shape and spatial) of database images are extracted and stored in the feature database. When the user submits the query images (input image), the feature vector(s) are determined using the visual contents. Then the similarities between the features of the query image and database images (also called as gallery images) are calculated. Based on the similarity measures, the relevant images from the database (if any) are retrieved. By incorporating the indexing approach along with the retrieval process, the efficiency of the CBIR (retrieving the relevant images) is improved. Relevance Feedback (RF) mechanics is adapted to retrieve more relevant images from the database.

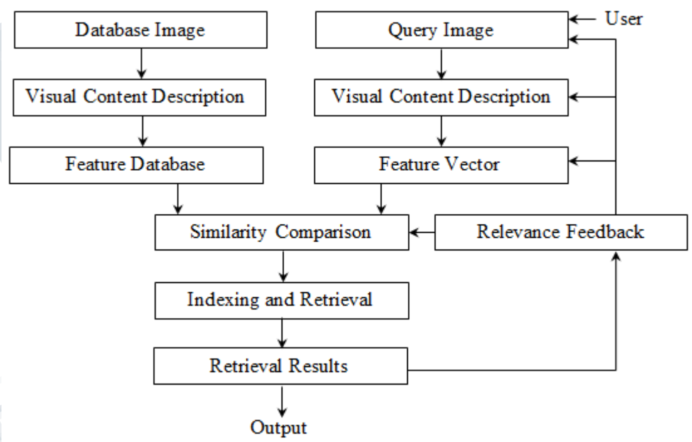

Figure 1. Architecture of the Conventional CBIR System

The RF provides feedback about the retrieval results for querying image, visual content descriptor, feature vector calculator and similarity comparison phases during every image retrieval process. Subsequently, user's decision about the retrieval images as relevant or irrelevant images regarding the query images is also provided as a feedback to RF phase. By these feedbacks, the CBIR updates the ranking criterion to retrieve the new set of relevant images from the database during the retrieval process. Thereby, CBIR is incorporated with human perception to identify the similarities between the images. Henceforth, the retrieval efficiency of CBIR is improved using RF iterations.

The paper is organized as follows: Section 2 summarizes the existing CBIR techniques and Section 3 provides the challenges and issues in implementing the CBIR system. Finally, section 4 draws the conclusion.

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2. EXISTING METHODS

The following section deals with an overview of existing and contemporary CBIR methods with its performance and retrieval accuracies.

Yogital and Ingole presented a detailed study on the classification of CBIR system [3]. The main components of CBIR are image database, feature extraction and match phases. The subdivisions of feature extraction process include color features (Histogram based and statistical features), texture based (spectral and statistical based approaches) and shape-based descriptors (model boundary and region-based methods). The author discussed some of the other color-based CBIR methods such as cumulative Color Histograms, Histograms of Oriented Gradient (HOG), Object-based Spatial Color Features, Adaptive Hierarchical Density Histogram and Color Histogram based Local Feature Regions (CH LFR). The alternative approaches for texture-based CBIR systems are Grey Level Co-occurrence Matrix (GLCM), Wavelet Transform, Curvelet Generalized Gaussian Density (CGGD), Modified Curvelet Transform (MCT), Atrous Wavelet Transform (ACT), Color Co-occurrence Matrix (CCM) and Enhanced Gabor Wavelet Correlogram (EGWC). Further, the shape based CBIR has two broad categories, namely, (i) Boundary based (such as chain code signatures and Fourier descriptor) and (11) Region based methods (such as Grid based and Invariant moments). Authors concluded that the hybrid feature extraction phase (such as integrating the color, shape and texture features) resulted in the improved retrieval rate of the CBIR Systems.

Ritika presented the overview of methods/techniques involved in CBIR system [4]. Author categorized the CBIR methods into three levels namely (i) The first approach by using color and or shape features, (ii) Logical features such as object identity and (iii) Finally, the abstract features (using significant retrieval scenes). The color based CBIR approach has distinguished retrieval features such as improved efficiency with reduced storage requirements and invariant to image rotations. The second method, Shape based retrieval method has two divisions namely boundary and region based object identification and concern image retrieval methods. When compared to region based approach methods, boundary based method resulted in better feature description and better retrieval accuracy. The next approach spatial analysis method deals with partitioning the image into smaller regions and then applying the shape and color feature based processing individually on each region. In this retrieval accuracy, i.e., more partitions lead to high accuracy and excessive processing time. Experimental results revealed that partitioning image into nine rectangular regions has better results. Authors concluded their study, with the strong implication that the retrieval efficiency of the CBIR system can be substantially improved by incorporating the Relevance Feedback mechanism.

Kranti and Venu illustrated the general framework for CBIR with its applications [5]. The authors discussed the various categories of CBIR systems namely (a) Color features based retrieval (b) Texture feature based retrieval (c) Shape based retrieval. The color feature based retrieval has sub categories namely local and global color histograms. The sub categories of texture based retrieval include statistical approach, structural approach, and spectral approach methods. The shape based Retrieval's sub categories were region based and shape based representation. Authors concluded that, based on the application and images to be retrieved, the CBIR categories (color/shape/texture) might be employed to maximize the retrieval rate of relevant images.

Tohid proposed a robust, flexible and efficient image retrieval system using a weighted combination of image retrieval features [6]. The texture, shape and spatial information were considered as primary and secondary features of the proposed study. As texture features were derived from six grids using Gabor filters, the feature weights are flexible and customized based on the needs of image retrieval. The similarity between the query image and database image was measured by features such as texture, shape and space through Euclidean distance. The weights of the average recall precision curve using those three features were 0.7, 015, 0.15 respectively. The study used a database of Pennsylvania State University consisting of 800 images. Authors concluded that the advantage of using Gabor filters with various grid sizes enables to retrieve the maximum relevant images according to the query image.

Yadav and Sengar [7] presented a review on various methods of CBIR method into three phases namely (i) Representation of low-level image features (ii) Similarity measurement with indexing and (iii) User interaction. The first phase dealt with image identification using color features (such as color histogram, color moments, dominant color), texture features (such as Gabor filters, wavelet filters, Grey Level Co-occurrence Matrix (GLCM), Tamura features) and shape features using Histogram directions for edge detections (such as Zernike Moments, invariant moments, legendre moments). In the second phase, the author discussed various similarity measures used to identify the exact similarity between the test image and gallery images. The distance measures used to determine the similarity index are (i) Quadratic form distance, (ii) Euclidean distance, (iii) Minkowski Form Distance, (iv) Mahalanobis distance and (v) Kullback-Leibler Divergence and Jeffrey Divergence method. To improve the retrieval efficiency, indexing of database image(s) was carried out using R-Tree, Linear-quad-tree, K-d-B tree and grid file methods. The final phase, user interaction phase, deals with image retrieval and accuracy. Some of the image retrieval techniques are Query By Sketch (QBS), Query By Example (QBE), Category browsing and Query By Concept (QBC). Authors concluded that employing the Relevance Feedback Mechanism in the retrieval phase considerably improved the image retrieval efficiency of CBIR system.

Fazul and Baharum studied the various issues in efficient extraction of features and efficient matching of images from the image database [8]. The input RGB color image was converted to grayscale and then DCT (Discrete Cosine Transformation) was applied. The statistical texture features such as mean, standard deviation, skewness, Kurtosis energy, entropy and smoothness were computed from the quantized DC Histogram. The similarity measurement of the queried image was compared with other database images by calculating the distance metrics such as Sum of Absolute Difference (SAD), the Sum of Squared Absolute Differences (SSAD), Euclidean Distance, City Block Distance, Canberra Distance, Maximum Value Distance and Minkowski Distance. The retrieval performance of CBIR is evaluated based on Precision, Recall and F-score. The authors tested the method on Corel Database. The results revealed that the Euclidean Distance, City Block Distance and SAD metrics gave good performance regarding precision using quantized Histogram texture features in the DCT domain for compressed images. The authors compared the proposed method with [9] (average precision of 70%), [10] (average precision of 65%), [11] (average precision of 53%), [12] (average precision of 55%), whereas the average precision of the proposed method was 82% using quantized texture features and the Euclidean Distance for similarity measurement in DCT domain. Thus the proposed method outperformed other methods regarding Precision and F-Score when evaluated with Corel Database.

Reshma and Patil suggested a CBIR system using Color Coherence Vector (CCV) method [13]. In CCV approach, both the coherent and incoherent vectors were considered for adequate representation of image features, so that the clear distinction between the objects in the images was accomplished. To refine the image retrieval accuracy, this method integrated color and shape features of the objects present in the images. The similarity measures between the query image and gallery images were determined by the Euclidean distance and ranking relevant images was done based on the similarity index values. Authors evaluated this method with six categories of images each consisting of 10 images to form 60 images regarding precision and recall parameters. When compared with existing, histogram based CBIR approach; this method resulted in an improved average precision value of 72% from 44% retrieval accuracy.

Nitisha and Latika presented the summary of recent CBIR techniques with their applications [14]. Some of the color feature extraction methods discussed include (i) Color moments, (ii) Color Histogram, (iii) Color Correlogram and (iv) Color Coherence vector. The other feature extraction methods were texture based (such as Gabor filters, Wavelet Transform and Tamura Features) and Shape descriptors (such as Invariant moments and Fourier Transform). Further, authors added the summary of existing findings in CBIR. They were (i) Feature extraction using Gabor filters has better retrieval accuracy than color based and texture based feature extraction methods, (ii) Multilevel sequential searching technique resulted in the substantial increase in the retrieval efficiency of images, (iii) Integrating the Relevance Feedback method improved the retrieval accuracy, (iv) Color texture moments resulted in good precision rate with low feature dimension, (v) Texture based CBIR systems resulted in better performance than the traditional methods and (vi) Based on the importance and applications of CBIR (where it is employed) the feature extraction and matching processes were chosen to provide the appropriate recall and precision rates. Even though the authors summarized various CBIR methods with their advantages and drawbacks, they failed to specify the databases used for evaluation.

Haldurai and Vinodhini [15] presented an overview of existing CBIR processing into four stages namely (i) Preprocessing (denoising, segmentation and object identification), (ii) Feature extraction (predominant features were extracted from the Region of Interest (RoI), (iii) Feature selection (Reduction of extracted features to improve the retrieval accuracy) and (iv) Classification (with training and testing phases). Some of the feature extraction methods discussed include shape-based, color-based, texture-based and integrated methods (such as Wavelet-based Color Histogram Image Retrieval, Discrete Wavelet Transform with Principal Component Analysis, Block Truncation Coding (BTC) and Fuzzy Rule). The study concluded that the processing time and memory management were directly proportional to the database size, i.e., higher the number of images stored in the database leads to crucial task, storage and memory management issues. Even though the authors discussed many feature extraction processes, failed to specify the datasets used for evaluation purposes.

Avinash and Veena proposed a CBIR system to retrieve the similar images from US patent database based on the keywords submitted by the user [16]. This method has two sub stages namely, feature vector creation and retrieve similar images. In the first stage, horizontal scanning was carried out to ensure the presence of one black pixel. If such one black pixel was identified, then the complete connected component was identified through horizontal scanning in the entire page, else (in the absence of one black pixel) there was no image in the current page. Upon identifying the horizontal block, vertical scanning was carried out to segment vertically based on the vertical threshold value. The block with less than 5cm2 was considered as noise and discarded. Subsequently, such image's page and patent numbers were retrieved and stored in the database. Feature extraction process for those images was accomplished through Edge Orientation Auto Correlogram (EOAC) due to its low computation cost and invariant to scaling and translation nature. The 200 images were randomly selected from Patent Full-Text Database, United States Patent Office (USPO) to evaluate the method. The Euclidean distance was used to determine the similarity measures between the images. Experimental results concluded that the proposed method resulted in 66% of average recall rate, whereas the precision value ranges from 10% to 35% and depends on the database size. There was a considerable improvement in the retrieval efficiency when the rotation angle was set to 180◦. Even though the algorithm has higher retrieval rate, suffers from computation time of 90 seconds (time elapsed between the submission of query image and retrieval of the relevant image(s)).

Malini and Vasanthanayaki proposed an enhanced CBIR system based on averaging color technique [17]. Authors compared the two techniques, mean based and central tendency regarding recall and precision values. In the first method, the average mean based technique, the extracted feature vectors got reduced by 50 % and hence the processing time and storage space also reduced to half the original values. In the second method of feature extraction, central tendency method, descriptive measures such mode, median, min and max values of images were calculated and considered as image features. The similarity measure between the two images is determined using Euclidean distance. Two databases namely Wang Image database and Intensity database from Tineye Labs were used for evaluating this method against the recall and precision values. The Experimental results revealed that even though the mean based feature extraction technique resulted in 50% reduction in storage space and processing time, central tendency based approach outperformed mean based approach regarding the recall and precision values. Authors suggested that CBIR retrieval efficiency may be improved by integrating the texture based and shape based feature extraction methods with the color based retrieval methods.

3. CBIR: CHALLENGES, ISSUES AND LIMITATIONS

The following problems and limitations of CBIR are summarized from [18].

a) Mapping the low-level image features is easy when compared to higher-level of abstraction about the images by CBIR, i.e., managing the semantic gap becomes overhead.
b) Careful examination and scrutiny are required during the similarity matching process.
c) Choosing the threshold level in the matching phase provides the optimum correct and incorrect matches in the retrieved images.
d) Considering the well-known context as one of the parameters to retrieve the images from the database improves the performance considerably.
e) Implementing the CBIR for biomedical images becomes very challenging task due to the following factors and is summarized from [19].
    1. Reliability of retrieval rate.
    2. Complexity in implementing the automated segmentation and feature extraction phases.
    3. Input image's size and resolution.
    4. Dimensions of the resultant image from feature extraction phase.
    5. Bridging the semantic gap.
f) The following challenging issues related to CBIR are summarized from [20].
    1. Recall and precision values of CBIR is mainly affected by a semantic gap.
    2. Human's subjectivity about content's description and analysis.

3. The techniques/methods used in the feature extraction phase greatly influences the efficiency of CBIR system.
4. Categories and varieties of images also have the impact on retrieval rate, i.e., higher the image categories leads to complexity in the development of robust feature extraction phase. Few factors to be considered are Image resolution and size, Image with different illuminations, homogeneity and non-homogeneity textures of objects in the images.
5. The threshold value(s) selected for feature extraction
6. When the size of the database grows, then optimizing the time elapsed between the submission of query image and retrieval of the relevant image(s) becomes tedious.
7. Choosing the algorithm/mechanism for a CBIR system is a domain specific and will not be applicable for other CBIR systems. For example, the segmentation algorithm adopted for natural images is not suitable for medical images and hence needs domain specific techniques/algorithms for concern CBIR systems.

CONCLUSION

In this paper, authors had presented a brief overview of recent CBIR methods with its performance. As a concluding remark, authors would like to provide the summary of findings in this paper. It includes, (1) Proper feature extraction phase to extract and represent homogeneous and heterogeneous images, (2) Semantic Gap, (3) Image properties (such as size, resolution, color, texture and shape) plays a significant role in retrieval of relevant images, (4) the size of the features used to represent an image is directly proportional to the computation time of the CBIR system, i.e., higher the feature vector size results in higher computation time.
By considering the issues and challenges depicted by various authors in the existing methods, authors would like to implement an effective CBIR method with the impact of dimensionality reduction in feature vector representation and relevance feedback mechanism.

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