Content Based Document Image Retrieval: A Review

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Abstract: Information and Communication Technology (ICT) has influenced the people by facilitating large storage, instantaneous transmission, efficient processing and enhanced retrieval of data. With its economic feasibility along with the extraordinary development of the technological tools, including the availability of high end image acquisition and capturing devices such as digital cameras & scanners, the possibility of maintaining large collections of digital images has realized and is growing constantly. Maintaining the large repositories of document images has however created an incredible need to access and manipulate document images using effective permissible ways. Proficient image searching and retrieval tools are demanded by users from various domains that include medicine, remote sensing, entertainment, architecture and many more in order to bring efficiency in their respective extents. In this direction, many general purpose image retrieval systems have been developed particularly in the form of text and content based frameworks. In text based systems, the document images are manually annotated by text descriptors which are then used by a conventional database management system to perform the identification and retrieval. This approach however has two significant disadvantages; first a reasonable level of human labor & skill is required for manual annotation; second is the annotation inaccuracy due to the subjectivity of human perception. In content based image retrieval systems, images are indexed by their visual content and the fundamental idea requires the user to provide a description of some of the prominent visual features of the image such as color, texture and shape. The designed system can search the archive subsequently and return the images that best match the description. Many researchers focused on content based image indexing and retrieval using only color as visual feature. There are several projects in this field such as Query By Image Content (QBIC), Visual Information Retrieval (VIR), Multimedia Analysis & Retrieval System (MARS) and many alike. The fundamental consideration in the design & development of a content based image retrieval system is to extract the image features that best represent the image contents in a database.

Index Terms **– Content Based Image Retrieval, Document Image, Image Indexing.**

I. INTRODUCTION

The wealth of information available on conventional paper documents or in any other media, scattered across various repositories has always been of great importance to historians, researchers, designers, students and other users. The easy access to this information however has been always cumbersome & time consuming especially when the collection is very large. The improvements in processing & communication technologies, availability of sophisticated digital scanners & reasonable cost of storage devices has provided the fresh opportunities to fully convert these documents into electronic form, thereby giving rise to the development of huge collection of digital repositories. The data in these repositories is however, either poorly annotated or entirely not annotated and as a consequence the retrieval of required information from these digital documents is still not getting improved and continues to remain a serious challenge. Moreover, the information elements in addition to normal text or numeric, like pictures, graphs, diagrams etc. are also posing other challenges with respect to its retrieval because of its unstructured nature. As a result of this poor accessibility of documents, an effective & efficient information retrieval system is highly desirable. In this regard, one alternate reliable way to treat every electronic document as a document image has been considered for recognizing and interpreting varied type of data. The retrieval systems based on the context and content of this document image have been continuously explored and developed. These retrieval systems are indispensable part of the modern day life while using the huge sources of information available in local or remote digital repositories.

II. DOCUMENT IMAGE RETRIEVAL

For long, information retrieval has been one of the prime areas in the field of information processing and data management. In the present era, multimedia information retrieval is an emerging area of research & development that comprises of text documents, images, video and audio. The principal component in most of the present day multimedia applications is the visual information with an emphasis on images. Digital images are a convenient media for describing and storing spatial, temporal, spectral and physical components of information contained in variety of domains including architecture, drawing, medicine, museum, education etc. and has the advantage of visual representation usually adopted to express other mediums of information. With the rapid development of processing technology and communication network, the storage and transmission of large number of images has become possible, which resulted in the wide use of digital images in different realms for last couple of decades. Furthermore, the availability of variety of sophisticated data acquisition instruments along with the possibility of gigantic storage has resulted in the creation of large repositories of imagery data.

There has been lot of interest growing in late 90s with regard to image retrieval and its application areas that extended the need to improve it further as its scope was not only limited to few areas rather resulted in large scale scientific data management, land information management, geographical information maintenance, interactive design creation, picture archiving, law enforcing, criminal investigation and many more like this.

Two evolutionary, but scientific frameworks have been developed for the purpose of effective retrieval of images. These two frameworks are based on text annotations assigned to images, called as Text Based Image Retrieval (TBIR) and content understanding of the images, called as Content Based Image Retrieval (CBIR).

In the beginning of image data retrieval, the only convenient method used was inherently based on text annotations like image labeling and captioning of images included at the time of their storage for the purpose of retrieving them based on these annotations.

However, this approach of labeling images with text annotations and their subsequent retrieval was primarily based on common human subjectivity and therefore the prime limitation of such a framework is the different interpretations of an image by different users which is always likely possible and as different users may use different words while describing the same image, the dissimilar retrieval of images against any given query image is always a possibility. Moreover, the vocabulary used while describing contents of an image is usually domain specific and thus adversely affects the performance of retrieval procedures to further extent. These limitations have also shown extremely poor performance while dealing with the present day large volume image databases. As a result of this, query by image content (QBIC) got serious attentions globally from numerous research communities of information retrieval. An independent system based on content understanding of an image that allows sophisticated index structures and retrieval procedures to be used was highly appreciated and finally designed for implementation. The understanding was systematically worked out using the image descriptors mostly based on low level features like color, shape and texture. In spite of the complexities involved in the understanding of the image content, the experiments have shown consistently improved results and modern disciplines are integrated more to bring further efficacy in establishing the robust image retrieval systems.

III. Related Work

This research work commenced with the exhaustive study of related existing literature on indexed storage and retrieval of document images and helped in thorough understanding and comprehension of various features used for content understanding of document images that explored the possibility of design and development of an effective conceptual model for indexed storage and retrieval of images. Besides lot of research work carried out in last many decades, one of the foundational and significantly contributing study was proposed by Swain [1] wherein the algorithm known as histogram back-projection based on a novel technique of histogram intersection, was introduced for efficient indexing and objects identification. Successful indexing and identification of objects was possible by considering the color feature specifically as one of the features used in this histogram based back-projection algorithm. After this benchmark study, a large number of efficient image retrieval systems, considering color as their prime feature, were evolved. In this section detailed discussion of some of these content based retrieval studies with special focus on color content is presented.

Two distinct methods based on color matching for the purpose of image retrieval were developed by Mehtre, B.M., et al. in 1995 [2]. The methods known as "Reference Color Table Method" and a "Distance Method" were applied along with the already existing “Histogram Intersection” on a database of 170 color images. The results drawn from the regressive testing clearly indicated an improved performance because of these two methods. Moreover, the performance of “reference color table method” was found extraordinary.

One of its first integrated approach that successfully exploited the visual characteristics of color and shape was proposed by Jain, A. K., et al.in 1996 [3] for the purpose of building an automatic image browsing system of a large database. The method unlike the rest of the existing image browsing methods was focused to combine the color and shape visual feature representation. Experiments carried out on 400 trademark images were encouraging with a top 2 precision of 0.99 against a query image. The technique was further improved in-terms of the performance by following a match of branch & bound with clustering scheme.

A two-stage approach based on statistical "exploring and explaining" of a pictorial database was given by [4] for picture indexing and retrieval. The method extracts the image classes by taking advantage of correspondence analysis. The correspondence analysis additionally facilitate in comprehending the role of image attributes and primitives destined for image indexing. This type of unique comprehension leads to an intelligent selection of features that in turn results in minimizing the computational complexity. Moreover, this approach helps in efficient database organization, thus results in simple indexing and retrieval of images.

An indexing and retrieval algorithm with the capability of handling partial sketch image browsing in a large collection of images was presented by Wang, J. Z., et al.in 1998 [5]. This Wavelet-Based Image Indexing and Searching (WBIIS) offer image comparisons which are semantically meaningful while unfolding the variations in color over spatial extent of images. This technique involves a two-step process to speed-up the retrieval wherein a crude selection of color variances is carried out in its first step followed by the refining process of search using the comparison of feature vectors of selected and query images. This technique results in better performance in capturing object granularity, image coherence and avoidance in bias than existing color based algorithms. The technique was evaluated on an image set of 10000 general images and the result of 100 best matches was recorded in just 3.3 seconds.

A technique based on extraction process of set of features from the domain of JPEG discrete cosine transform (DCT) was proposed by Ngo in [6] for the purpose of indexing and retrieval of images. The standard image analysis methods were used to handle DCT coefficients for the purpose of examining the features of color, texture and shape of images. Experimentation study reveals that this approach offers better indexing without any forfeit on retrieval accuracy.

A technique capturing high-level concepts generated from low-level features of images using binary Bayesian classifiers was given by Vailaya, A. in 2001 [7]. This technique based on a constriction that a test image always belongs to one of the classes of images. In this method a compact but optimal vector quantizer was used to build the requisite feature densities (class-conditional) for the Bayesian methodology. This system has been experimented and finally evaluated on a collection of 6931 vacation images. Classification accuracy for indexing of images was achieved ranging from 90.5% in-case of indoor/outdoor images to 96.6% of sunset & mountain images. Once extra data becomes available, a learning component was also incorporated into the system for the purpose of classifier training.

For the effective and speedy retrieval of database images, Nascimento in 2002 [8] presented a variable-bin allocation (VBA) retrieval technique based on image abstraction that involves signature bitstrings along with the corresponding similarity metric. The signature using its color content represents an image in a very compact manner and has retrieval efficiency better than the classical global color histograms (GCHs) and provides far better results when compared with color-coherence vectors (CCVs). Moreover, the technique has resulted in an improved model with regard to access structure and storage overhead.

A distance measure based on the computation of dissimilarities between two histograms has been proposed by [9]. Taking into consideration both overlapping as well as non-overlapping parts, this distance measure is found to be significantly efficient as compared to other existing distance measures in-terms of the distribution overlaps.

In order to avoid monotonous jobs of image understanding and object processing, Ahmad, I., et al. in 2003 [10] proposed a novel symbolic image representation model. This model carries out hierarchical decomposition of image space into spatial arrangements of features without compromising the spatial relationship among the objects. The hierarchical decomposition process involved is

based on QuadTree, which in-turn contributes in the similarity measure. This scheme, in addition to geometric variance independence is also incremental in nature and reduces the search space continuously at each new level of hierarchical decomposition, thereby allowing further comparisons to be carried out on possible matching database images

A QuadTree based organization supplemented by a centroid algorithm has been presented by El-Qawasmeh [11] wherein database was virtually divided into multiple subsets before any image is forwarded for storage and few additional fields were associated to route the query image to its relevant subset. The algorithm uses the circular moment to select some random pixels from the query image and compares the same for image match. The search process is restricted to the relevant subset(s) only instead of the whole collection. The unique organization however maintains the respectable recall and precision values of retrieval.

A model based on spatial-relationship known as 2D Be-string ('two dimension begin-end boundary string) was proposed by Wang, Y. H in 2003 [12] that represents an icon and without any spatial operator instinctively can represent image information after applying dummy objects. A modified method of "Longest common subsequence" is used to measure and evaluate the image similarities. The proposed method retrieves the images having similarities based on icon and spatial relationship with respect to a query image, to an improved acceptable level rather than complete matching. Moreover the rotation and reflection challenges of linear transformation with regard to similarity evaluation also have been improved.

The representation of color distributions using fixed-binning histograms was found to be less efficient than adaptive image histogram as was analyzed by [13]. Adaptive histograms were found to be more accurate in using less number of bins, non-empty bins and precise computation while comparing with non-adaptive methods of image classification and clustering for retrieval.

A method providing 10 bin histogram based on fuzzy linking of color histograms using L*a*b color space was proposed by Konstantinidis, K., et al. in 2005 [14]. This method is entirely different from the conventional method of color histogram wherein a limited bin creation is achieved instead of large histograms having significant variations in their neighboring bins and mostly possesses a serious complexity of three components for each color space that leads to 3-dimensional histograms. Diverse image collection was used to evaluate its performance and significantly it was observed that the proposed method is reasonably less sensitive to lighting variation and occlusion against the existing methods and had additionally better retrieval results.

A statistical image indexing system which is based on stochastic model was proposed by Al-Omari in 2005 [15] and was found very much robust among the color content understanding retrieval systems. In this system a very systematic vector of 12 dimensions was used to label images in a collection. This feature vector possesses the mean, variance, skewness of the color histogram of images in addition to the correlation factors of components of color. The knowledge of the histogram was clearly found in this complex vector as analyzed by statistical analysis models. The evaluation in comparison to the several existing techniques was carried out and it was observed that the developed model outperformed all the other especially in feature size and reliability and robustness values were very much ahead of all of them.

An integrated method of color correlation histogram and multiresolution image decomposition was presented by Moghaddam, H. A in 2005 [16] for image retrieval. This method based on computation of image wavelet coefficients by means of a directional wavelet transform (Gabor wavelets) is followed by application of quantization step just before the final computation of one-directional auto-correlogram of wavelet coefficients. The system is completed by the construction of index vectors form these early attained one-directional wavelet correlograms. The system has been experimented and finally evaluated on a collection of 1000 images and results in a substantial improvement both in indexing and retrieval of images when compared to other existing indexing and retrieval methods of image wavelet transform or color correlogram.

A method proposed by Ozden, in 2007 [17] employed texture descriptors for better segmentation of images in addition to color and spatial features wherein both color and spatial information were poorly contributing in the effective segmentation process of images for their retrieval. The method offers texture analysis which is translation invariant by making use of wavelet frames

A fuzzy color histogram for color retrieval and Lie descriptors for the retrieval of shapes was proposed by Rallabandi, V. S. in 2007 [18]. This approach exploited the characteristics of Kohonen's self-organizing maps (SOM), an unsupervised algorithm for the purpose of training the images along with the R-tree SOM for indexing scheme. The presented model was evaluated on subset of Corel photo gallery and found to be an efficient image retrieval system.

A technique based on the global features of an image, represented by color distribution, mean value and standard deviation was proposed by Lu, T. C in 2007 [19]. This technique additionally is using bitmap image of local characteristics for enhancing precision of a retrieval system. In-addition to low memory space requirement for the purpose of storing the image features, this technique was found to perform better when compared to other schemes.

An image retrieval system exclusively designed for the medical images was presented by Hliaoutakis in 2009 [20] that automatically performs indexing in large medical image collections including MEDLINE, a standard medical database of US. The available resource of terminological lexicon of National Library of Medicine (NLM), US, was used to integrate with the developed technique to extract the terminology vector. The developed system was compared with the state of art medical repository indexing and retrieval system called as MetaMap Transfer (MMTx) using two premier data sets of medical images and was found performing better in indexing with a minimum improvement of 20%.

A method based on the integration of color and texture features was presented by Yue, J., Li, Z., et al. in 2011 [21]. In this method an improved technique was initially used to extract the color (color histogram) and texture feature to create the corresponding feature vectors, using the co-occurrence matrix. The method subsequently proposes the consideration of texture features and color histogram (global & local) for analysis, thereby constructing the weights of feature vectors, after rationally quantifying the color space. The experimentation proved that the retrieval results after the integration of features were highly encouraging and marginally improved compared to the results independently achieved from the same set of features when considered.

A well advanced method conceived from the general process of natural image retrieval, using latent semantic analysis (LSA) and duly augmented by Support vector machine (SVM) with exclusive emphasis on multi-instance learning (MIL) was proposed by [22]. In this method an image is treated to correspond to bag and visual low level features of a partitioned image corresponds to an instance. A k-means algorithm is used to generate the collection of words in order to translate every bag into a single sample, only to construct a projection space. A mapping is defined to obtain the projection feature of every bag, by treating each bag as a point in the projection space. These projection features with training bags in the form of matrix is conditioned for extraction of latent semantic feature of every bag using LSA method, which subsequently becomes ready for SVM as it stands already converted to a standard learning problem. COREL data sets were used for experimentation and results show that method proposed was robust and superior in performance than key existing MIL retrieval methods.

A local tetra pattern based image indexing and retrieval algorithm was proposed by Murala in 2012 [23] for efficient image retrieval. The proposed technique uses the directions computed from first order derivatives in vertical and horizontal directions to encrypt the referenced pixel and its neighboring pixel relationships. The experimentation process of the proposed model was carried out on specific benchmark image databases like Brodatz texture database (DB2) & Corel 1000 database (DB1) and it was found that the retrieval results obtained were significantly improved.

A Nearest Neighbor (NN) based improved relevance feedback algorithm was proposed by Arevalillo-Herráez, M., et al. in 2013 [24] to improve retrieval results. In this model, improved retrievals were only possible because of the use of efficient method for computing the relevance scores. Estimated densities of samples (relevant or non-relevant) in a particular feature space are used for calculation of relevant scores. In comparison to other relevance feed-back approaches, this approach showed significant improvements.

The retrieval methods based on histogram usually take into account the pixel frequency count of an image and accordingly use it as metric to compare with the query image. Liu, G. H in 2013 [25] however presented color difference histogram completely different from the conventional histogram techniques. This method focuses exclusively on color and edge orientation specifically in L*a*b color space under the different backgrounds only to find out the perceptual uniform color difference between two locations. The proposed technique exploits the features used by human visual system to integrate color, edge orientation and uniform color difference for feature representation. This method in its novelty takes into account the spatial layout without using any of the process of learning, segmentation or even the implementation of clustering. This integration feature makes it a strong visual descriptor for image retrieval, which in turn is validated by the results found after the experimentation. The results having high potential discriminatory features are found much better than even MPEG-7 edge histogram descriptors, multi-text on histograms and many more alike.

An image retrieval technique based on matching of selective regions using codes commonly known as region codes was proposed by Shrivastava in 2014 [26]. In this technique, a uniform division of images present in the database collection into multiple regions is carried out with each region assigned a region code of 4-bits length. The assignment of 4-bit region codes to different regions of an image is decided by relative position of these regions to the central region. After extraction of dominant color and texture features based on local binary pattern out of the regions, these features along with the 4-bit region codes are stored in the imagery database. Same process is iterated at the time of query image retrieval to efficiently retrieve the more relevant images. The technique was experimented on Corel image database and MPEG-7 CCD databases and the results obtained were found to be highly accurate and recorded with minimum retrieval time.

Pedronette in [27] proposed a re-ranking method for efficient retrieval in CBIR systems by exploiting the contextual information. This contextual information representing the relationships among several images was solely ignored by rest of the CBIR systems. A large image dataset was consulted for the extensive experimentation process of this technique and the results obtained were found to be significantly better particularly when experimented on large collections.

A content based image retrieval system concentrating on image representation and database classification, carried out by making use of support vector machine classifier was proposed by Jenni, Kin [28]. This technique begins with a feature extraction process which is accomplished by using color string coding followed by string comparison. This retrieval system was experimented on a collection of 1800 images from Corel photo gallery and the obtained results were found to be more accurate than other existing retrieval systems.

A feature-based sparse representation technique founded on combination of iterative discrete wavelet transform and sparse representation for image retrieval was proposed by Mohamadzadeh in [29]. For evaluation & validation purpose, a comparative analysis of this technique against other techniques of same domain was made by using two quantitative metrics namely average normalized retrieval rank and precision at percent recall. The attained results showed that the proposed technique outperforms other techniques.

IV. Conclusion

This research work was initiated with the extensive study of related existing literature on indexed storage and retrieval of document images. This study helped in understanding the high demands of proficient image searching and retrieval techniques by users from numerous domains of medicine, remote sensing, entertainment, architecture and many more. And in its follow up, various general purpose image retrieval systems which have been developed earlier particularly under two domains of text and content based frameworks have been recognized in well. Besides this, in this research study, a better understanding of content based image retrieval systems has been attained which includes how images are indexed by their visual content like color, texture and shape and how user are required to efficiently retrieve images based on these prominent visual features of the image. Moreover, in this research study, text based retrieval systems have also been discussed which include the images to be manually annotated by text descriptors which are then used by a conventional database management system to perform the identification and retrieval. Besides advantageous use of content based image retrieval systems, two significant disadvantages namely a reasonable level of human labor & skill requirement and the annotation inaccuracy due to the subjectivity of human perception, have also been thoroughly concluded.

V. Future Scope

The following developments can be made in the future:

1. The integration of texture and shape with this system can be researched for the possible performance improvement.
2. The classification of images can also be performed based on the semantic consideration of images and can automatically be grouped in various semantic classes. The algorithm independently for each semantic class can be accordingly developed.
3. A system can be developed by incorporating the learning component based on the relevance feedback using machine learning algorithms.
4. The performance of existing systems can further be improved if segmentation of images can yield smart regions which can be considered for similarity matching.
5. The performance of region based retrieval system has the capacity to deliver the high performance results but is restricted because of the existing low performance segmentation algorithms. Such systems can be significantly improved if an enhancement in segmentation algorithms can be explored.

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