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Content-based image retrieval based on multiple extended fuzzy-rough framework

Sk Mazharul Islam [a,*], Minakshi Banerjee [a], Siddhartha Bhattacharyya [a], Susanta Chakraborty [b]

[a] RCC Institute of Information Technology, Canal South Road, Beliaghata, Kolkata 700015, West Bengal, India
[b] Indian Institute of Engineering Science and Technology, Shibpur, Howrah, West Bengal, India

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ABSTRACT

This paper presents a content-based image retrieval (CBIR) system with applications in one general purpose and two face image databases using two MPEG-7 image descriptors. The proposed method uses several sophisticated fuzzy-rough feature selection methods and combines the results of these methods to obtain a prominent feature subset for image representation for a particular query. Next, fuzzy-rough upper approximation of the target set (relevant list of images) with respect to the entire database that is represented by the prominent feature subset, is computed for retrieval and ranking. The information table on which every feature selection method works is small in size. Main reasons of performance boost of the proposed method are twofold. One is efficient feature subsets selection. The other reason is the fuzzy-indiscernibility relation based fuzzy-rough framework for computing upper-approximation which supports the approximate equality or similarity sense of CBIR. Fuzzy-rough upper approximation possibly adds more similar images in the relevant list from boundary region to expand the relevant list. The effectiveness of the proposed method is supported by the comparative results obtained from several single dimensionality reduction method, several clustering based retrieval techniques and also tested for face image retrieval.

1. Introduction

Digitized visual information is growing constantly due to the progress in multimedia and internet technologies. This significant dissemination of visual contents in various fields such as [1–4] clinical medicine and biomedical research, crime prevention, geographical information systems, journalism, art, law enforcement, etc. are producing gigabytes amount of contents daily, which require finding similar contents on demand. During last two decades the researchers from different areas, for example, image processing, pattern recognition, computer vision have proposed many effective methods for one particular problem called *image retrieval problem* (IR) for retrieving similar images from the repositories. Initially, image retrieval methods used keyword-based models, then visual content-based image retrieval (CBIR) methods were proposed, and now automatic image annotation (AIA) [5] models are being used to facilitate the image retrieval [1–4]. The content-based approaches for IR may be the better way than keywords based IR because the keywords based IR uses metadata which requires enormous human intervention and is improper because only metadata cannot capture the diversity and ambiguity present in an image. On other hand, the CBIR systems [1,2] represent images by low-level features vectors which are derived from color, shape, texture properties of images. Then retrieve similar images by measuring similarities between the features vector of the submitted query image and those present in the database. In this regard in consonance with the impact and increasing demand of visual contents retrieval, ISO/IEC has proposed MPEG-7 benchmark [6], which proposes some specific descriptors to evaluate new image retrieval schemes. The feature-vector representation as per these MPEG-7 standards is compact, distinctive which may help in efficient retrieval.

The image understanding by human vision system is not same with the image representation by the low-level feature vectors and this fact leads to a challenging problem in CBIR is called visual *semantic gap* [2]. This *semantic gap* problem and its interdisciplinary researches have raised several interesting problems and challenges which are mentioned in [1,2,7,8]. At present, the researches are

* Corresponding author.
E-mail addresses: mislam2911@gmail.com (S.M. Islam), mbanerjee23@gmail.com (M. Banerjee), dr.siddhartha.bhattacharyya@gmail.com (S. Bhattacharyya), susanta.chak@gmail.com (S. Chakraborty).

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going on the following areas: (1) automatic image annotation and tagging for integrating semantic meaning of the visual contents as much as possible; (2) constructing efficient indexing method for image repositories; (3) tackling higher dimensional feature vectors; (4) effective use of relevance feedback methods for properly learning user's preferences and needs; (5) defining standard format for metadata representation; (6) proposing more compact, distinctive and informative feature extraction and representation; (7) resolving semantic gap problem. Till now, there is no universally acceptable algorithm from the CBIR community which will commensurate fully the human vision system. Therefore, the development of a sophisticated and robust model is yearning for organizing, indexing, retrieving similar images in better and effective way to tackle the semantic gap issue.

The semantic gap issue can be progressively minimized using the suitable low-level visual features [9] jointly with relevance feedback mechanism or machine learning algorithms. The better precision-recall performance of a low-level features based CBIR can be further utilized for automatic image tagging by considering retrieval results of a CBIR system as training set. So starting with an efficient low-level features based CBIR, there are the scopes of bridging semantic gap.

The contribution of this paper is related with dimensionality issues of features vector representing an image. The study is important for the following reasons: (1) proposed method is establishing how a simple fusion of the results of several sophisticated feature selection algorithms from various fuzzy-rough set models can be effective for image retrieval task; (2) all these algorithms select only few important features from the high dimensional low-level feature vectors of the images database. All these fuzzy-rough features selection algorithms can extract knowledge from a small training set of images of the original image database to ensure the low computational burden of proposed method; (3) fuzzy-rough upper approximation based retrieval method is proposed which shows the significant boost in retrieval performance and is demonstrated with the comparative results. The efficacy of the proposed method has been presented using one general purpose and two face image databases.

The organization of the paper is as follows. Section 2 gives the review of the literature. Section 3 is describing the motivation of the proposed method. Section 4 gives the essential theoretical background related to the proposed work. Section 5 describes the proposed method. Experimental results and comparisons have been discussed and analyzed in Section 6 using one general purpose database and two face databases and Section 7 draws the conclusion.

2. Review of literature

2.1. Research background

Several CBIR systems have been developed in the past decades as commercial products and experimental prototype systems [1,2,7,8]. Few such CBIR systems are QBIC [10], Blobworld [11], CIRES [12], Photobook [13], Netra [14], MARS [15], PicToSeek [16], VisualSEEk, PicHunter [17], and SIMPLIcity [1,2,18]. Image representation in CBIR is very crucial and it can be represented by the global features using color/edge/texture information, GIST [19], CENsus TRansform hISTogram (CENTRIST) [20], etc. The patch sampling (identifying the salient points and regions), patch description and patch recognition [21,22] based image retrieval/recognition using SIFT [23], SURF [24] feature descriptors are mentioned in the literature. The locally considered features from the patches may be huge in number. The computation of these local descriptors, searching nearest neighbors of these descriptors may take long time. A remedial step is the Bag-of-Visual-Words model which is based on the construction of the codebook from local descriptors is claimed to be very effective method for image classification/retrieval [25,26]. Besides the image representation, the suitable similarity function jointly with machine learning algorithms can build robust CBIR system. The low-level image descriptors and high-level concepts (i.e., building, car, animal and so forth) can be robustly connected by three models, viz. supervised learning, unsupervised learning, and relevance feedback to facilitate image retrieval [3,4].

The unsupervised clustering in machine learning has been used by few CBIR systems, for example, Blobworld, MARS, and QBIC to identify regions in an image which facilitates the retrieval. Few use clustering for grouping images before the actual retrieval. In [27], the CBIR system uses MPEG-7 descriptors and clustering algorithms for efficient retrieval. SemQuery [28] uses hierarchical clustering method for merging heterogeneous features to perform semantic based clustering and indexing. CLUE (cluster-based retrieval of images by unsupervised learning) uses a graph-theoretic clustering method for retrieval and can be treated as a general procedure to be integrated in any CBIR system for performance boost. Also the Probability concept based semi-supervised clustering methods [29] have been tried to group the similar images as per the user demand. Recently, deep learning techniques [30] are gaining huge research attentions for high-level image representation/image retrieval.

2.2. Feature selection and dimensionality reduction issues in CBIR

The dimensionality reduction or feature selection process is prevalent in the literature of CBIR [31–33] to optimize the performance of the classification/retrieval process. It is very effective to get rid of the noisy and redundant features. In feature selection, a subset of the original features set is extracted by eliminating features with little or no predictive information by minimizing redundancy and maximizing relevance to the target. Features selection can be benefited in CBIR for the following reasons: (1) ease of data visualization; (2) storage need can be controlled; (3) training and utilization times can be reduced; (4) prediction performance can improve.

The dimensionality reduction techniques using Principal Component Analysis (PCA), Kernel PCA [34], Multidimensional scaling (MDS) and Locally linear embedding (LLE) are efficient but these methods transform the domain of the datasets. The goodness of dimensionality reduction for image classification with Bag-of-Words model by Principal Component Analysis (PCA) is also reported in [35].

On other hand, the semantic-preserving features selection [36], as desirable for the CBIR systems, can be achieved by the rough set and fuzzy-rough set feature selection techniques based on data dependencies computation. The traditional rough set theories have been used for image retrieval and classification is mentioned in [37–39]. Using fuzzy rough feature selection method, the image retrieval system are also reported in [40]. However, it uses only one feature selection method from fuzzy-rough domain which uses fuzzy-rough dependency function. This dependency function uses the definition of fuzzy-rough lower approximation which is based on fuzzy-equivalence class.

3. Motivation

The past decades witnessed the exclusive uses of soft computing tools viz. fuzzy set [41] and rough set [42] to handle the issues of noise, outliers, vagueness, uncertainty [43], misclassification and perturbation [44] efficiently. The image retrieval problem can also be tackled using the soft computing techniques due to the inherent