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An integrated approach to region based image retrieval using firefly algorithm and support vector machine

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ABSTRACT

Intelligent image retrieval is a challenging technology in multimedia applications where bridging the gap between user's expectation and low level features is typically hard for computing systems. In the proposed approach, a unique method is projected which integrates support vector machine based learning with an evolutionary stochastic algorithm, called firefly algorithm as a relevance feedback approach into a region based image retrieval system. This system overcomes the semantic gap through optimized iterative learning and also provides a better exploration of solution space. Support vector machine learning automatically updates the weights of preferences for relevant images based on the both relevant and irrelevant feedback images. The firefly optimizer guides the swarm agents to move towards the cluster of relevant images in the exploration of the search space based on user's feedback. This research study has a focused approach to increase the performance by optimizing region feature with the firefly algorithm. The efficiency of the proposed approach is experimented on the standard subset of Corel, Caltech and Pascal database images. The performance of the proposed approach is compared with other existing retrieval methods like particle swarm optimization, genetic algorithm, support vector machine and query point movement to identify the excellence with regard to the model in terms of precision and recall.

1. Introduction

With the huge requirements of multimedia information processing to process the real-time information, information retrieval becomes essential, among which image retrieval is becoming widely recognized. To browse and search the images recorded on the internet effectively and efficiently it is essential to develop image retrieval tools. The traditional keyword based approach for retrieval of images suffers from the limitations as follows: (i) Requires an enormous amount of manual work [1,2]. (ii) Subjectivity of human perception leads to inappropriate results. To overcome these limitations, content-based image retrieval (CBIR) [3] has been applied. CBIR is a set of techniques and algorithms which specifically focuses on low level image content such as color, texture and shape for retrieving the images from an image database based on the query image provided by a user. The performance of CBIR is far from satisfaction on user's expectation of high level concepts as it primarily focuses on low level visual features of the images. With CBIR, only low-level visual features can be automatically extracted from images, to reflect the color, texture and shape information of the image. Yet none of them capture high level concepts in the user's mind, as a result the retrieval performance is far from satisfactory. To address this issue [4], two widely used approaches are: (1) Region based image retrieval (RBIR) that corresponds to the representation of the user's perception of image substance into segmented region features and (2) Relevance feedback (RF) is especially to ascertain a user's inclination.

Region-based visual signatures [5,6] have been introduced based on image segmentation to boost the performance of an image retrieval system. The understanding of the mechanism of the human visual system reveals that in order to estimate the human perception, the image similarity must be able to distinguish the region features properties. The region based methods attempt to compute features of the segmented region at the object level and the similarity comparisons are performed at the granularity of the region whereas earlier traditional approaches represent and retrieve images primarily based on global features.

Several recent works [7,8] have been proposed to carry out image segmentation for integrating local information into the representation of the image. In [4], an outsized false-image is constructed by assembling the entire regions of relevant images and this image is used for further iterations of RF. To increase the speed of image retrieval, the false-image's regions are incrementally clustered into

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compact representation. In [9], low level features of input regions are modified to generate a set of synthetic images from which feature weights are derived within each input query region. Then the feature weights are adjusted by the retrieval system based on the heuristically manipulated images. In [10], an adjacency matrix is used for representing the connectivity of regions in an image and a graph based approach is suggested for updating the ideal queries according to adjacency matrices. In [11], the regions of feedback images are clustered to obtain the ideal query. Then, from the ideal query, representative regions are learnt and feature and region weights are updated based on the clustered results by proposing an optimization method. The main intention to use region based approaches is to improve the capturing ability as well as to interpret the user's perception. But distinguishing the features within images through reliable segmentation is crucial.

Relevance feedback has been established as a useful tool that retrieves relevant data according to a user's view by iterating within the loop [12–14]. The feedback collected from the user allows reformulating the input query or helps in better separation of the relevant image cluster. In the earlier case, also referred as query shifting, several inputs of the user in different iterations are allowed to obtain user's expectations in the feature space by moving the initial query towards the core of the relevant image cluster [15]. In the latter case, the solution space metrics are altered using an adaptation [16] algorithms or feature re-weighting [17] by giving importance to only certain features. Su et al. [18] proposed novel, efficient and effective image retrieval by using discovered navigation pattern from user query log for reducing the problem of long iteration. In the last decades, as the technology in machine learning developed, a number of machine learning techniques have been pertained to the problem of relevance feedback in image retrieval. Some of them are Bayesian learning [19], boosting techniques [20], discriminant analysis [21], dimension reduction [22], ensemble learning [23], decision tree [24], etc. Recently, Support Vector Machines (SVMs) have been tremendously investigated in machine learning as its performance in real-world applications is comparatively higher in pattern classification.

Despite the fact that SVM generally furnish reasonable accuracies, the training data is frequently not linearly separable, SVM introduces the concept of "kernel influenced feature space" which maps the data into a higher-dimensional space where the data is separable into two classes. Usually, such a mapping space would create problems computationally. However, the results of SVM can be made more robust by tuning the internal parameters, such that they reduce the error, that is, the misclassification effect. So as to do thus, it could be fruitful to merge the benefits of SVM with well-organized, stochastic problem solving algorithms, like the Metaheuristic algorithms [25], which exploit a tradeoff between local search and randomization. As a consequence, in this paper, the support vector machine learning process is embedded into a metaheuristics firefly algorithm as a relevance feedback approach in region based image retrieval. Thus, the degrading performance of the SVM classifier is enhanced by the assistance of one of the recently developed metaheuristic algorithms, the firefly algorithm (FA). The firefly optimizer [25] not only serves as an efficient optimization engine, but also explores the search space effectively and avoids converging to local minima. Additionally, for the improvement of retrieval accuracy, random walk concepts based on Gaussian distribution is applied at the end of each iteration in standard firefly algorithm so that all the fireflies have moved into global best position and its movements are stabilized.

We adopted, the Earth Mover's Distance (EMD) [26] as an image similarity measure, which has a thorough probabilistic translation and has been effectively utilized as a part of region matching. The time needed to find the EMD distance value between the query image and an image is relative to the number of regions in the query. In order to reduce the computational complexity of EMD in a real CBIR system, many efforts have been made such as indexing scheme based on a modified inverted files strategy [27], adaptive clustering [28], modified subtractive clustering algorithm [29], and region filtering scheme [30]. The optimization of SVM classifier using FA in RBIR has faster convergence speed than the SVM and FA and also since the firefly algorithm is used in relevance feedback, only the top fireflies are used for comparison with database images which reduces its computational complexity.

The remainder of this paper is organized as follows: Section 2 briefly reviews the state of the art regarding RBIR, RF and firefly algorithm. Section 3 describes about firefly algorithm in nature. Section 4 introduces the proposed approach. Section 5 reports the experimental setup, adopted feature sets, parameter setting and experimental results. Finally, conclusion is presented in Section 6.

2. Related works

2.1. RBIR and relevance feedback

The state of art methods and the extensive literature about content-based image retrieval are presented in [31,32]. In order to have wide acceptance, recent approaches include human-computer interaction perspectives in CBIR. A detailed study is presented in [33] for existing relevance feedback techniques for image retrieval. Broilo et al. [34] investigated the possibility of embedding relevance feedback with particle swarm optimization (PSO) into the image retrieval process in which the problem of image stagnation in local optima is avoided and also the improved exploration of image space is provided. Zhang et al. [35] discussed about the image retrieval optimization based on PSO with r-selection and k-selection of Ecology in relevance feedback. He improved the precision and recall rate by better exploring the search space. Lai et al. [36,37] employed the genetic algorithm as an interactive process in the relevance feedback of content based image retrieval system and reduced the gap between the image retrieval results and the user's preferences. In [38], the author proposed an automatic image region annotation approach based on particle swarm optimization in which the evolutionary algorithm is applied as a searching strategy to reach the optimal region features.

CBIR systems that use global representations of images have incorporated SVM as an efficient tool for its fair and good performance [39]. Recently, Wang et al. [40] employed Interactive Genetic Algorithm (IGA) and SVM to track the user perception. IGA works on the assessment of individual accomplished by humans. SVM is useful in learning a classifier from the user feedback. The unlabeled images labeled or named as most relevant by the SVM classifier are included in the IGA training set. By the use of this unlabeled data, it is anticipated to speed up system convergence, decreasing the user tiresome owing to the IGA learning process. Pighetti et al. [41] suggested a new framework which integrates a multi-objective interactive genetic algorithm, permitting a trade-off between image features and user evaluations and an SVM to trace the user feedback. These are the works conducted in image level.

Relevance feedback technique has also been extended from image level to region level for improving the retrieval performance. Jing et al. [42] introduced a new SVM kernel in order to solve the algorithms which are applicable to region-based representations. In [43], the author carried out the work on RF learning algorithm based on generalized SVM that could be used in region based CBIR systems which use arbitrary similarity measures. In [44], Kim et al. proposed not only a relevance feedback approach based on multi-class support vector machine (SVM) learning but also cluster-merging in order to promote the retrieval performance greatly in region-based image retrieval.