Towards Effective Relevance Feedback Methods in Content-Based Image Retrieval Systems

Sunitha Jeyasekhar and Sihem Mostefai

***Abstract*—Information Retrieval is one of the major research areas in the recent years. There are two kinds of IR i.e., Content Based and Text Based Retrieval. Text-Based Retrieval is focused on document Retrieval and Content-Based Retrieval is focused on the visual features. It includes audio, video, images, text. Content-Based Information Retrieval includes the CBIR (content-based image retrieval), CBVR (content-based video retrieval) and so on. CBIR system has become a very active research topic during the last few years. To improve the retrieval (text, image, etc.,) performance in content-based image retrieval system, an approach was introduced, named "Relevance Feedback". It accepts the feedback from the user to retrieve the content which is closest to what he is thinking about. In this paper we discuss the current state-of-the-art in Relevance Feedback as seen from content-based image retrieval point of view and recommend a novel approach for the future.**

***Index Terms*—Content-based image retrieval, relevance Feedback, query vector weigh.**

I. Introduction

The rapid growth in the use of digital media such as images, video and audio has led to a proliferation in research in multimedia retrieval, indexing, ranking. As far as technological advances are concerned growth in content-based multimedia retrieval has been unquestionably rapid. Since there is a vast collection of multimedia information stored in databases ranging from gigabyte to terabyte to petabyte sizes, high performance algorithms will be needed in order to respond to a query in an acceptable time period [1].

It is essential for multimedia systems to allow the user to (1) search for a particular media item and (2) browse and summarize a media collection. A known challenge in multimedia retrieval is that using natural language for searching for information from a large database can lead to unexpected results because of the inability to understand user's vocabulary [1]. Recent research focused on improving image retrieval by bridging the semantic gap in an approach similar to human-centered computing. The term, semantic gap refers to the breakdown that can occur when users interpret inaccurate meaning from information that is presented visually to users in a given situation [2]. While human-centered computing aims to support users by enabling them to conduct queries in their own vocabulary, a similar approach can be adopted with image retrieval by searching based on the content of the image rather than its associated description or tags.

For that, the Relevance Feedback approach has provided an effective way to understand the intensions of users and their specific needs by exploiting information obtained during their interaction with the system. The Relevance feedback framework is similar in all the Content-Based Information Retrieval (CBIR) systems. Using this approach, a query is presented to the system, which responds by retrieving a set of images. Following that, users can provide feedback in form of comments or measures that indicate the level of relevance for images in the set. User suggestions and feedback is then used by the system to refine the retrieval scheme with the aim of achieving optimal retrieval performance. CBIR systems often vary in this refinement and selection process.

Content-Based Retrieval has been used by different communities for various applications like Personal photo albums such as Picasa and Flickr [2], Medical Diagnosis [3], Intellectual Property [3], Broadcasting Archives [3], and Information Searching on Internet [16], Biomedicine [9], and in Crime Prevention [4].

This paper is organized as follows: Section II sheds some light about the basic structure of Content-Based Image Retrieval systems; Section III presents an overview of state-of-the art approaches of Relevance Feedback (RF). In Section IV, we present a comparative analysis of the various RF approaches; Section V describes a novel approach to Relevance Feedback that we propose to improve the efficiency of CBIR. We conclude the paper by conclusions and future work in Section VI.

II. Basic CBIR System Structure

A number of images are stored in image databases. The retrieval process involves four basic steps as depicted in Fig. 1:

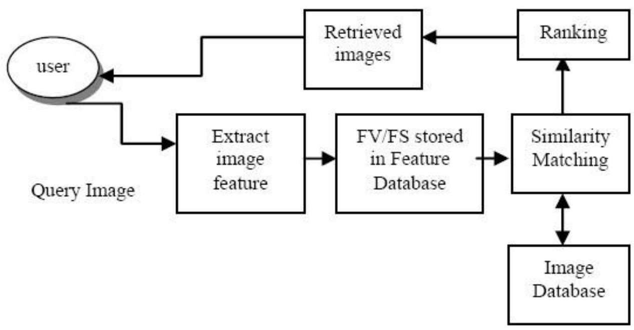

Fig. 1. Basic CBIR system.

1) Extract features as Feature space/vector.
2) Store feature vector in feature database.

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Sunitha Jeyasekhar and Sihem Mostefai are with Information Technology Department, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia (e-mail: sjeyasekhar@ksu.edu.sa, smostefai@ksu.edu.sa).

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3) When a query comes in either the form of query-by-example or query-by-keywords, its feature space will be compared with those in the feature database one-by-one.
4) And the similar images with the smallest feature distance will be retrieved.

In the following, each step is explained in more details.

A. Feature Extraction

Feature extraction is the process of extracting information from images and representing it in a suitable way, then storing it in an index and using it during query processing. Features are used in the content-based indexing and retrieval [5]. Features are classified into either Low-Level and High-Level Features. Low-Level Features can be extracted directly from the original images and High-Level Features can be extracted based on Low-Level features [6]. It is a method of capturing visual content of images for indexing and retrieval.

Most of the systems use Feature Extraction as preprocessing step. Features can be extracted both globally and locally. The advantage of global extraction is its high speed for both extracting features and computing similarity [7]. In local extraction set of features are computed for every pixel using its neighborhood. The most commonly used features include: Color, Texture, Shape, Salient points in an image, spatial location of image elements [2]. Among these, color is a visual property most widely used in image retrieval. Color information is represented as point in three-dimensional color spaces such as RGB-hardware oriented, HSV, YIQ, L*U*V and L*a*b [6]. Several color description techniques have been proposed, and the color histogram is the most used descriptor in the image retrieval [8]. Extracting shape features involves different approaches such as the Fourier descriptors, Gobor Filter, Hough transform have been proposed for shape feature [9].

Several approaches using Low-Level Features have been explored in the literature in various CBIR systems. For example, system like QBIC, Virage, Pichunter, VisualSEEK, Chabot, Excalibur, Photobook, Jacob,Digital Library, CIRES, TILTOMO, and Netra. Most of these system use color features or the combinations of other features were used. Nowadays retrieving images through semantic features is complicated.

To reduce the semantic gap, high-level features derive low-level features and low-level features change into higher level ones. Semantic features are fuzziness, complicacy and abstractness. These involve color, shape, texture, other low-level features, pattern recognition, logic reasoning, and other related techniques like scene semantic, emotion semantic and behavior semantic. The present problem is how to obtain image semantics automatically from low-level features. Approaches to overcome this challenge have involved Image Semantic mining techniques [8].

B. Feature Database

Feature database is a place where the extracted feature vector will be stored. Each feature in the database has given a weight. The stored vector is indexed for the purpose of similarity matching.

C. Similarity Measurement

Similarity measure is a method to measure the distance between the feature vector of query image and the feature vector of image in the database. Images are said to be similar when the value of similarity measure is less for the feature vector. There are several functions for measuring the similarity. There are several similarity measures which are used in CBIR systems: Euclidean Function, which reorganizes image databases by constructing an indexing structure to further improve retrieval efficiency without compromising retrieval effectiveness [9]**.** Hausdorff Distance, Earth Mover's Distance, Weighted Correlation Distance, Signature Quadratic Form Distance. In the above, measurement Signature Quadratic Form Distance achieves the highest retrieval performance [10].

D. Indexing

Indexing is used to retrieve similar image from and image database for a given query image and it is used to accelerate the query performance in the search process and plays a main role in supporting effective retrieval of sequences of images. When working with the large database, efficient indexing methods are required. Most of the methods used for visual indexing are taken from text indexing [11]. There are various techniques used for indexing the images in the content-based image retrieval system. They are R-tree, R*-trees, KDB tree. Content-Based Image Retrieval with Relevance Feedback has been popular method for image retrieval [11] so, efficient index methodology is needed.

The difficult task of an advanced indexing method is to handle high-level image retrieval in efficient way. In recent years, several new approaches have been developed to handle high – level image relationship. Various approaches are AH-Tree structure [7], Hierarchical Grid-Based Indexing [19], Tertiary Hash-Tree indexing [13] etc.

III. Relevance Feedback: State-of-the-Art

Relevance Feedback (RF) is a powerful method to enhance efficient search in Information Retrieval (IR) system. There are three different learning techniques in Image Retrieval. They are Clustering, Classification and Relevance Feedback [8]. Compared to other techniques, Relevance feedback is more active with the user. It provides an interaction with the user by asking a set of questions after each round of the result. With the positive result from the user, the iteration will start to produce a best result which matches as exactly as possible with the user's actual need. It was first developed for document retrieval [12]. Later the same method was adopted for use in image or multimedia retrieval. Most of the Content-Based Information Systems use this technique for effective and efficient result.

Information Retrieval using Relevance Feedback consist of four components: [12]

1) User Interface—Initial form of Query (Typing keywords, Sketching, Example images).
2) Offline learning—Image descriptors are extracted from all images in Database.

3) Data storage—Act as a virtual file. Storing and loading necessary data and use multi- dimensional indexing techniques.
4) Online Learning—Interaction with the user.

There are various directions of research in CBIR. Bridging the gap between Low-Level Features and Semantic/High-Level Feature is the major challenge in this current trend. Semantic gap is defined as the loss of information from an image to a representation by features. [14]. Many algorithms were proposed to solve these issues. In the following sections, we describe three different algorithms which have applied the RF methods and discuss their approach in addressing the semantic gap.

A. Relevance Feedback Using RBF NN Feedback Algorithm Based on Gauss Function

This algorithm adopted a kind of simplification of radial basis nerve network structure [15]. It uses multi-dimensional Gauss function to be the kernel. In this approach, parameters can be modified by using user's feedback information and improve the performances. Prior research has compared this algorithm with Single-RBF which uses single-dimensional Gauss function [3]. And the result has shown that the RBF NN feedback algorithm has higher precision than Single-RBF algorithm. A drawback of this algorithm is the increased user involvement; in other words, the user needs to submit the query again and again until he gets satisfied with the result.

B. Relevance Feedback Using User Feedback Log by Coupled-SVM

The Coupled-SVM integrates both the log information of the user and the traditional Relevance feedback with the learning of Low-Level visual features of image content. This algorithm is generic so it may also be applicable for other multi-modality learning tasks. Prior research that has examined this algorithm has shown that the proposed algorithm is effective and promising [16]. iFind [17] is a web-based image retrieval system that provides the functionality of keyword-based image search, query-based image example and their combination. The key technology in this system is the integrated Relevance Feedback approach and User's feedback Log. Log mining can also help to yield more accurate retrieval system by refining the semantic features. Drawbacks of this method include the challenge in ensuring that the optimal solution applies globally, and the computation cost and convergence problems that need further evaluation.

C. Relevance Feedback Using Gustafson-Kessel Cluster Method

This approach is used to evaluate the effectiveness of the image retrieval results from the user and it is evaluated in the form of precision and recall [18]. The image retrieval results are evaluated based on prototype implementation of TCBIR (Tourism Content-Based Image Retrieval) system [18].

Gustafson-Kessel algorithm is data scale independent. It takes spherical shape into consideration. The more important part of direct search within one cluster is that the computational time at every iteration is decreased instead of searching the entire database [9].

IV. Analysis of Various RF Approaches

In this section we present a comparative analysis of the RF approaches described in Section III. All algorithms were developed for the purpose of improving retrieval relevance. Table I lists the algorithms in the first column and the systems that have been used to evaluate these algorithms in the second column. The processes involved in the evaluation are summarized in the third column.

TABLE I: Various Approaches in RF

Algorithm used	System	Process involved
NN feedback Algorithm	Digital Library	Ellipse Radial function, Euclidean Function,RBF, multi-dimentional Gaussian function
Coupled-SVM	Not Specified-	Edge direction histogram, Wavelet-Based texture technique, Euclidean distance, alternating Optimization technique,
Gustafson-Kessel	TCBIR	Median Filter, Sobel Operator, Geometric movements
New Approach	Processing	RBF NN, Hierarchical Grid-Based Indexing, Euclidean Function

In Table II the algorithms are compared with regards to key performance measures. These include convergence speed, precision, recall.

In comparing the algorithms with regards to key performance measures, we have found that they vary according to precision and Recall. The NN Feedback algorithm had better precision than the coupled-SVM and the Gustafson-Kessel algorithms as compared. In terms of recall, it seems that the Gustafson-Kessel algorithm performs better than the other algorithms. The convergence speed has been an issue with the coupled-SVM method, which motivates to us to consider an improved method of increasing the convergence speed in our proposed algorithm by changing the weight of the features and the query vector simultaneously [16] that was part of the NN feedback algorithm with HGBI techniques.

TABLE II: Performances of Relevance Feedback Using Various Approaches

Performance	**NN feedback Algorithm**	**Coupled-SVM**	**Gustafson-Kessel**	**Novel Approach**
Convergence speed	-	-	Ensured, but locally only	Accelerated
Precision	Good	Average	Average	Good
Recall	-	-	Average	-

V. Novel Approach to Content-Based Image Retrieval

To make the search efficient and effective, we need to consider the convergence speed, precision and computational cost. Once all these performances are satisfied in one system then it is said to be efficient and accurate. We propose a new approach in CBIR by using RBF NN algorithm in that by updating query vector and updating the weight simultaneously, it will increase the convergence speed and the precision call. And by using HGBI (Hierarchical Grid-Based Indexing) method for indexing will give efficient response time [19]. Moreover, the system can incorporate information obtained with human assistance and artificial intelligence to improve its efficiency and effectiveness.

VI. Conclusion

In this paper we have discussed Feature Extraction, Indexing and Retrieval methods in CBIR systems. We have shown how key approaches to applying relevance feedback compare in terms of performance measures such as convergence speed, precision, recall, and computational cost. While existing RF techniques are increasingly improving the efficiency of image retrieval, there still exist problems that need to be addressed. These include reduced retrieval speed, high computational cost, and convergence problems. Furthermore, retrieving images based high-level feature remains a topic in need of further examination. Our analysis indicates opportunities to combine schemes to improve performance. Thus, we have proposed a novel approach to addressing these problems, which we are currently working on by implementing it in the context of personal photo image databases.

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Sunitha Jeyasekhar is a researcher assistant in Department of Information Technology and is from King Saud University, Kingdom of Saudi Arabia. She holds a master degree in information technology from Madras University, India. She is actively involved in various researches like data mining & image retrieval. She has some research papers to her credit.