Hybrid Query Refinement: A Strategy for a Distance Based Index Structure to Refine Multimedia Queries

Kasturi Chatterjee, Florida International University, USA
Shu-Ching Chen, Florida International University, USA

ABSTRACT

This paper proposes a hybrid query refinement model for distance-based index structures supporting content-based image retrievals. The framework refines a query by considering both the low-level feature space as well as the high-level semantic interpretations separately. Thus, it successfully handles queries where the gap between the feature components and the semantics is large. It refines the low-level feature space, indexed by the distance based index structure, in multiple iterations by introducing the concept of multipoint query in a metric space. It refines the high-level semantic space by dynamically adjusting the constructs of a framework, called the Markov Model Mediator (MMM), utilized to introduce the semantic relationships in the index structure. A k-nearest neighbor (k-NN) algorithm is designed to handle similarity searches that refine a query in multiple iterations utilizing the proposed hybrid query refinement model. Extensive experiments are performed demonstrating an increased relevance of query results in subsequent iterations while incurring a low computational overhead. Further, an evaluation metric, called the Model_Score, is proposed to compare the performance of different retrieval frameworks in terms of both computation overhead and query result relevance. This metric enables the users to choose the retrieval framework appropriate for their requirements.

Keywords: Indexing, Multimedia Databases, Query Refinement, Retrieval Framework, Semantic Gap

1. INTRODUCTION

An index structure is one of the major components of a database management system as it assists in efficiently organizing the data and enables quick and accurate retrieval. There are multidimensional index structures such as Berchtold and Keim (1996), Chatterjee and Chen (2006), Ciaccia, Patella, and Zezula (1997), and Guttman (1984), which can accommodate the atypical multidimensional representation of multimedia data. But enabling them to efficiently support the popular retrieval strategies, such as content-based image and video retrievals, is still a challenge due to the semantic information carried by them. The semantic interpretation of a multimedia data is subjective and varies from user to user or even from iteration to iteration for an individual user. This makes the similarity queries issued for multimedia data imprecise in nature. A single iteration or a fixed query representation is not enough to capture the user requirements during the retrieval process. Thus, attempts to
capture the users’ interest pattern are made with
a strategy called query refinement having two
major components namely query modification
and query re-weighting (Porkaew, Chakrabarti,
& Mehrotra, 1999). In query modification, the
query representation is modified in each itera-
tion to reach the region in the feature space
which best describes the feature components of
the users’ requirement. In query re-weighting,
the semantic component of a query is modified
in subsequent iterations to better capture the
users’ perception. As a query is refined, the
similarity search and the distance functions
utilized to determine the similarity need to be
modified as well. Automatically, it becomes
necessary that the index structures, supporting
the similarity searches, also accommodate the
modified distance functions developed for the
refined queries.

Multidimensional index structures can
be broadly divided into two categories viz.
feature-based and distance-based. A feature
based indexing technique projects an image
as a feature vector into a multidimensional
space and index it. Some feature based index
structures are KDB-tree (Robinson, 1981), R-
tree (Guttman, 1984), etc. On the other hand
distance based indexing structures are built
based on the distances or similarities between
two data objects. Some famous distance based
index structures are M-Tree (Ciaccia, Patella,
& Zezula, 1997) and vp-tree (Yianilos, 1993).
Both categories are useful depending on the
dataset in hand and the application that need to
be supported. Though query refinement strate-
gies have been designed for feature-based index
structures as in Porkaew, Ortega, and Mehrotra
(1999), Chakrabarti and Mehrotra (1999), and
Chakrabarti, Porkaew, Ortega, and Mehrotra
(2004) but to the best of our knowledge there
has been no such attempt for distance-based
index structures. Another major drawback is
that if the semantic information of a multimedia
object cannot be interpreted completely in terms
of the inter and intra feature weights (when the
semantic gap is large), refinement strategies
(Porkaew, Chakrabarti, & Mehrotra, 1999) fail
to produce satisfactory results. The semantic
gap is a very common problem for multimedia
data and is illustrated in Figure 1 for an image
database where the feature-level similarity
failed to capture users’ high-level semantic
perception. Figure 1(a) represents the inverse
of the Euclidean Distance (similarity) between
the feature vectors of an image with other im-
ages of a database. Figure 1(b) represents the
high-level semantic relationship between the
same image with other images in the database.
It’s seen that the image, with which the image
under consideration shares a low similarity in
terms of feature space, has a very high semantic
relationship with it.

In this paper, we propose a hybrid query
refinement model for distance based index
structures, which organizes and manages
mainly images. However, the refinement
model used here can be utilized for indexing
other multimedia objects such as videos as long
as the distance based index structure can orga-
nize the particular data type. The proposed
query refinement strategy is called hybrid be-
cause it refines and adjusts both the low-level
feature space as well as high-level semantic
interpretations individually during refining the
queries in each iteration. It adopts a query ex-
pansion approach to refine the feature space.
To refine the semantic interpretation of a
query, it dynamically adjusts the parameter of
a stochastic construct called Markov Model
Mediator (MMM) (Shyu, Chen, Chen, Zhang,
& Shu, 2003). We introduce the hybrid query
refinement ensemble in a distance-based index
structure and enable the similarity search algo-
rithms to implement it to improve query results
progressively in subsequent iterations. We also
propose a new evaluation score called the
Model Score that can compare the overall
performance of the different multimedia re-
trieval frameworks in terms of both computa-
tion time and F1 Score (relevance). Both the response
time and the relevance of a query result is
important in case of similarity queries for
multimedia data. Thus, while evaluating and
comparing the performance of index structures
for multimedia data, one should be able to view
the combined effect of both these criteria on
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