Image database management systems design considerations algorithms and architecture
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Chapter 8

Summary

The objective of this thesis was to design an architecture for image database systems. In this quest we explored many techniques effective in both image retrieval and image analyses systems. The exploration lead to several refined objectives.

The first refined objective is how to incorporate images and image operations in an extensible DBMS? The extensible DBMS was Monet. In chapter 3 we showed a mapping of images to BATs, i.e. binary tables. We indicated how a default implementation of the image algebra operations could be readily achieved. This also proved the completeness of our approach. Using this representation we showed many possible optimizations to be used by the query optimizer to find better query plans.

It convinced us that pixel-set based image processing in a DBMS context is a viable alternative against the image (C++) data structure approach, the dominate approach taken in image analyses domain. It permits one to focus on effectiveness and lets the query optimizer take care of the efficient evaluation.

The second refinement of the global objective dealt with queries, i.e. how should an image database system support image retrieval queries?

In chapter 4 we introduced an algebraic framework to express queries on images, pixels, regions, segments and objects. We showed the expressive power of the Acoi algebra using a representative set of queries in the image retrieval domain. The algebra allows for user-defined metric functions and similarity functions, which can be used to join, select and sort regions. The algebra is extensible with new region properties to accommodate end user driven image analysis in a database context.

In Section 4.2.1 we showed our prototype image retrieval system and explained the Multi-level signature image description. The multi-level signature approach shows that an image algebra should accommodate multiple image descriptions and requires multiple index-structures.

In Section 4.3 we have introduced the necessary data structures and op-
operators to build an image database system aimed at supporting embedded image querying. We have experimentally demonstrated that a bottom-up index construction outperforms a top-down approach terms of storage requirements and performance.

We have implemented the algebra within an extensible DBMS and developed a functional benchmark to assess its performance. In the near future we expect further improvement using extensibility in search methods and index structures to improve the performance of the algebra.

The third refinement dealt with image analysis, could an image database system be used for image analyses tasks?

In chapter 5 we showed that an image database could be used profitably to support image analyses researchers. In a case study it has been shown that an extensible DBMS can be efficiently used to tackle the line-clustering problem. The overhead of the conversion between database structures and application structures is not a dominant factor. Moreover, there exists a small algebraic extension to the DB core functionality, which enables us to tackle the line clustering problem. The performance is promising compared to the original solution written in C++.

Although we proved the effectiveness of using a database system for image analyses, the image community is far from taking up this route. The main reason for this is a mentality issue. It is hard to change a researchers approach which has been used for over a decade. In due time we expect that the object-at-a-time approach, as dictated by the imperative languages like C++, is replaced with a set-based approach.

The next refinement to the global objective dealt with similarity queries, how to support similarity queries?

In chapter 6 we have presented and analyzed the class of fitness joins, which appear regularly as building blocks in advanced database applications. They differ from the traditional equi-, theta- and set-joins by a mathematical complex formula in the join condition combined with a selection from a group.

We have shown that this class can be handled efficiently for relatively simple fitness functions using moderate extensions to the algebra. In particular, the bounded theta-join appears a valuable addition to the standard repertoire and can be implemented using traditional optimization techniques. It extends early work on theta-joins [34] by uncovering the real handle to tackle the problem efficiently. Namely, judicious use of the monotonicity properties of compound mathematical functions combined with a variation of the theta-join.

Further optimization, along the line of exploring the mathematical properties of the fitness expressions have been indicated. Its scope has been barely scratched upon and we foresee much better support of advanced applications when their mathematical properties are properly accessed by an optimizer. The optimizer framework of Monet is extended to cope with the
8.1. **GENERAL RESEARCH DIRECTIONS**

information presented and we plan to isolate and include the primitives for further experimentation in its algebra.

Derived from the objective to deal with similarity queries was the objective to improve the performance of similarity queries. In chapter 8 we presented a cheap index structure to improve the query performance of joins involving a distance metric. This index structure works on any distance metric, as long as it obeys the triangular inequality. There is no need for a full metric. We showed that the index structure is profitable in higher dimensions for small selectivities.

**8.1 General Research Directions**

This thesis opens new research directions. The first direction, there is a need for more investigation in *Region-based Querying*. We defined regions as the basic building blocks for image descriptions. The regions describe small parts of the image by associating region features. The query implications of such regions needs more investigation.

The multiple-features associated with regions will form a single high dimensional space. All problems associated with the *high dimensionality curse* are valid. Therefore, all regions will be evenly distributed over this space.

The predicate query model as available in current database management systems proved inadequate for image retrieval queries. More advanced query models such as *Proximity-based Querying* and *Relevance feedback* are considered good alternatives and need more research.

Opposed to this we could question such a fuzzy query evaluation model. Is the current accepted query model, i.e. image retrieval based on similarity, the proper solution. Is such a Fuzzy model really needed? Maybe we could guide the user to better understand the image descriptions used to describe the image content. A better understanding of the image descriptions could lead to precise image queries which could be handled using the predicate query model.

The main problem of image retrieval systems is that the results obtained through an index using similarity measures are often only understood by the the image analyses experts. For naive users, it is often difficult to understand why the answer to a query image showing e.g. a sunset should return nice images about the African savanne. This is typically an artifact of non-precise query formulation and weak indexing structure.

A way out of this problem is to give the user more insight in the features used to solve the query against the image database. This insight is given by specifying the query and showing the results in terms of the indexed image features directly.

The usage of image databases by image analyzing researchers will give
the database researchers more input on there query behavior and requirements. This input could be used to improve the performance of image analyzing applications. Once the image analyzing community has accepted set based processing they can again focus on the image analyzing problems and let the database take care of the performance issues.