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Descriptive Abstract
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Abstract Title:
Query Analysis to Improve Medical Image Retrieval

Topic:
Imaging Informatics for the Enterprise

Preferred Presentation:
Demonstration (computer display)

Background:
Advances in digital imaging technologies and the increasing prevalence of Picture Archival and Communication Systems (PACS) have led to a substantial growth in the number of digital images stored in hospitals and medical systems in recent years. In addition, on-line atlases of images have been created for many medical domains including dermatology, radiology and gastroenterology.

Medical image retrieval systems can be important aids to diagnosis and treatment. They can also be highly effective in health care education, for students, instructors and patients alike.
Image retrieval systems generally do not perform as well as their text counterparts. Historically, image retrieval systems (medical and otherwise) have relied on indexes built from annotations and captions associated with their source images. Generating and maintaining these metadata is traditionally done by hand, and is both labor-intensive and prone to errors. The last few decades have seen numerous advancements in the area of content-based image retrieval (CBIR). CBIR systems have been successful in fairly constrained medical domains including pathology, dermatology, chest radiology, and mammography, though they have demonstrated poor performance when applied to databases with a wide spectrum of imaging modalities, anatomies and pathologies. In this work, we focus on image retrieval strategies that are primarily applicable to general image retrieval in databases contanining images acquired using a variety of imaging modalities, resolutions and with varying quality of annotations.

Demonstrable retrieval performance improvements have been produced by fusing the results of textual and visual techniques. The most dramatic improvements can be seen in a system's “early precision” performance.

This project consisted of two parts, the first being an analysis of the performance characteristics of many existing medical image retrieval systems and the second being the construction of a wholly new system.

The first part took place in the context of ImageCLEF, which is an annual cross-language image retrieval event in which teams from dozens of countries participate. The medical image retrieval task within ImageCLEF's 2006 campaign (“ImageCLEFmed”) provided a forum and set of test collections for the medical image retrieval community to use to benchmark their algorithms. The test collection provided a set of thirty “queries” to be run against a collection of 50,000 annotated images. The query topics were generated by analysis of log files and are believed to be representative of those of a casual internet user.

The medical track's organizers grouped the thirty queries into three search strategy categories according to which of three search strategies they felt would be most appropriate: semantic (or textual), visual or “mixed methods”. The categorization was based on a set of heuristics derived from previous analytical experience on the part of the organizers. The participants had similarly classified their systems along those lines (purely textual, purely visual or mixed).

The medical image retrieval query can be evaluated along different axes including imaging modality (e.g. CT, MRI, x-ray, gross pathology, and microscopy), anatomic region (e.g. hand, brain, and heart), orientation (e.g. axial, coronal, and sagittal) and findings (e.g. malformation, diseases). Heuristically, queries with modality and/or anatomic region lend themselves to the use of visual techniques. However, images of findings such as specific diseases, malformation, or other pathologies are still quite difficult for purely content based retrieval systems to process effectively.

The second half of this project consisted of the construction of an adaptive medical image retrieval system which uses both contextual and visual data, as well several innovative query parsing techniques.

Evaluation:
We investigated both the queries and the results of the participating systems across the 2006 ImageCLEFmed tasks. We examined the performance of the systems along the query axes of modality, anatomy, view and pathology, and calculated the average precision and Mean Average Precision (MAP) by system type as well as the precision and MAP of the best textual and visual systems. The image itself has important visual characteristics such as color and texture that can help in the retrieval process, and we evaluated the use of visual characteristics of the image to improve the precision of the retrieval process.

We built an adaptive retrieval system uses a hybrid approach to image retrieval. We wrote a query parser which uses both a Bayesian Classifier as well as a part of speech tagger to attempt to identify the desired imaging modality, anatomy and finding within the user's query. With this knowledge, we were able to send different parts of the query to the appropriate search subsystems. In addition, synonyms of the finding, derived from the UMLS metathesaurus, were used to increase the recall of the search. We evaluated the different options for the textual and visual searches using the ImageCLEF 2006 test collection.

Discussion:
In 2006, there were significant differences between the queries themselves, as well between as the systems. A few queries were uniformly easy, others were uniformly difficult, and others were easier for either the visual or the textual systems
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Textual systems performed well on textual queries and visual systems performed well on visual queries based on the results of ImageCLEF2006. However, visual systems performed extremely poorly on textual queries. The degradation of the performance of the textual systems on visual queries was not nearly as profound.

Queries that include specific disease or pathology such as of “Budd-Chiari malformation” or “parvovirus” were uniformly difficult for purely content based retrieval systems. In recent years, image processing algorithms have occasionally allowed for computer aided diagnosis of disease or malformations; however, these algorithms are usually extremely narrow in scope and not suitable for use in the more general domain of medical image retrieval.

The user of our custom query parser significantly improved the retrieval performance. Figure 1 shows that the use of the automated query parser results in performance on one of the topics from ImageCLEF 2006 similar to that of manually modifying the query by a expert user.

Conclusion:
Analysis of historical ImageCLEF data provided a set of heuristics about the nature of a medical image retrieval query and the methods that can best be used to improve performance. Based on the heuristics and historical data, we created a query classifier that can be used to appropriately weight results from the textual and visual components of a fusion image retrieval system. Adaptive combining of the results of visual and textual search engines can improve the precision of the retrieval system.

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Keywords:

Information retrieval

Image retrieval

Recall

Precision

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