The MedGIFT project: Global perspectives of a medical doctor

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Abstract

Medical image retrieval covers an important and wide application area in medical imaging, with one major goal being in providing assistance in medical diagnosis. With the availability of image data in the electronic patient records and thus to all medical doctors, the need to search and retrieve images efficiently and accurately from large image databases such as picture archiving and communication systems (PACS) has drastically increased. To address this demand, content-based image retrieval (CBIR) has been proposed for a long time with many systems being built to meet several application demands. However, in most systems there is still a gap between the end user's expectations and the system's retrieval capabilities. Relatively little attention has so far been paid to the process of evaluating the effectiveness of CBIR methods and its real impact among the health care professionals through optimized user interaction.

This paper addresses the actual problem of content-based medical image retrieval, which aims more particularly at highlighting the perspectives of a medical doctor on content-based image retrieval.

Keywords: medical image retrieval, visual information retrieval, multimodal information access.

1. Introduction

Medical environments offer new opportunities and challenges for many applications in the filed of multimedia systems [1,2]. When we discuss about medical multimedia systems, we include multimodal data analysis and data retrieval technologies specific to the medical domain [3]. The digital creation and storage of medical data makes many applications possible that could not be imagined with a paper-based record and make the entire patient data available to all clinicians in the hospital (including imaging data, lab results, etc.) [4]. The coherent presentation of data of a single patient from all available sources allows a physician to plan, deliver, and evaluate the most appropriate treatment for that person [5]. Helping a physician to treat a single patient or assisting research needs to include multimedia more than this is currently the case [6]. Medical multimedia tools have to keep pace with the technological changes in data acquisition. Problems that currently need to be solved concern mainly the reuse of patient data in an anonymized form to help for the diagnosis or treatment of other patients.

Computer science institutions performing research in this domain need to focus as much as possible on the user needs to create useful tools and explain the possibilities and shortcomings of current tools to clinicians. For a real impact, the multimedia information retrieval (MIR) community has to keep a close contact with the practitioners in order to find out more about their needs and perspectives towards the use of such systems.

2. Motivation

The amount of digital image information available for a single patient has increased massively in just a few years [7]. Over 60’000 images are currently produced per day in the radiology department of the University hospitals of Geneva.

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This rapid development in the amount of image information produced has stimulated the research on retrieval systems to facilitate medical images search [7,8]. For the practitioner, access to medical image databases is vital in order to cope with the growing amount of information available. Comparing a new case with visually similar past cases can help in the decision making [9]. Several solutions for visual information retrieval were developed, some using mainly the visual information but often completely neglecting the context in which the images were taken in. An even more frequent approach is to only use the contextual information of the release letter or radiology report but neglecting the important visual information. Combining text and visual information for retrieval from specific databases for particular diseases is needed [9,10] to be able to include as much domain knowledge as possible into the retrieval process. There are several challenges in developing computer-based information systems [10,11]. Although many image retrieval systems are still in their infancy, it remains important to focus research on the most important aspects and to include feedback from the end-users to optimize the development process. Some systems do not achieve their potential, often rather due to political reasons or negligence than to technical reasons [12,13,14]. This highlights the need for more prototypes in clinical practice in order to help clinicians to understand possibilities and limits of these technologies.

3. The MedGIFT project

MedGIFT [15] is a project covering various aspects of medical information management from its creation and access to the availability of computational power, and towards real applications in contact with clinicians to aid diagnosis and treatment planning. The evaluation of the practical impact of the applications is regarded as a goal although it is hard to measure and depends on many factors. This section will give an overview of the various sub-projects of medGIFT.

3.1 @neurist

Aneurist is a large research project financed by the European Union to help with the diagnosis and treatment of cerebral aneurisms [16]. The objective of the medGIFT part in the project is to design a decentralized, scalable, and reusable database architecture with low maintenance costs for managing and integrating heterogeneous data required as basis for such a large-scale project. Technical and legal aspects from several countries are taken into account in the design based on various use cases. The architecture contains several layers: data storage and access are decentralized at their production source, a connector as a proxy between the CIS and the external world, an information mediator at a central level as a data access point and the client side. This design will be implemented inside six clinical centers from four countries participating in the @neurIST project as part of a larger system on data integration and reuse for aneurism treatment with the goal to make research data available in an easier way.

3.2 KnowARC

KnowARC is a project trying to enable Grid networks for the biomedical research community [17]. The objective is to make the computing power available to support better information retrieval and data analysis. Many medical institutions do not possess a specific research computing infrastructure or the required budget for such an infrastructure to enable processing of large amounts of data. Still, most institutions have many desktop PCs that can serve for biomedical research during the time they are little used without the need for expensive investments. The ARC (Advanced Resource Connector) middleware is applied in this project.

3.3 TALISMAN

The Talisman project brings together various specialists to create a diagnostic aid tool on interstitial lung diseases [18]. This section will give a short state of the art and describe the project.

3.3.1 State of the art

The development of new imaging techniques has widely influenced the diagnostic accuracy of professionals. In clinical practice each technique requires specific skills to be optimally used. Many radiology residents can not be experts in all available techniques, which can result in interpretation errors. To assist the radiologists in improving the accuracy of their diagnosis, many computer-aided diagnosis systems (CAD) have been developed, applied to various imaging modalities and body parts. CAD was applied in breast cancer detection and to assist the differential diagnosis of various lung diseases in thoracic computer tomography (CT) [19].

The potential of CAD to improve the accuracy of the radiologist's performance was underlined in several studies [20,21,22]. In [23], a CAD developed to detect lung abnormalities on chest radiographs underlines that the output obtained from computerized analysis can be used by radiologists as second opinion. To advance computer aided diagnosis for lung anomalies in thoracic CT scans, many researchers focus on the development of tools for classifying, indexing, and retrieving images in order to depict similar. The content-based image retrieval (CBIR) system ASSERT [24] requires a physician to delineate the region of interest (ROI) and proposes a web-based approach for diagnosing lung CT images. In [25], a CBIR system is proposed to provide similar images of lung diseases by using spatial information along with texture features. In another project [26], the researchers developed a visual query-by-example Image Management Environment (IME) for managing image databases with a large number of lung CT images to assists radiologists in interpreting chest CT images and saving interpretation time. The usefulness of providing similar images was also demonstrated in an observer performance study [27,28]. Indeed, the knowledge obtained from the visual impression of inter- and intra-disease variability constitutes the foundation for the medical imaging professional's diagnosis.

3.3.2 Computer aided diagnosis for lung diseases integrating clinical data

Interstitial lung diseases are considered as a heterogeneous group of illnesses with often little specific clinical symptoms [29]. When the first investigations on past medical history, physical exam, routine lab examinations, and chest x-ray do not give enough clues for a diagnosis, a high-resolution computed tomography (HRCT) of the chest can deliver more information [30]. In daily clinical practice, even if the HRCT plays a crucial role in the investigation of lung diseases, the diagnosis is still often difficult. Various kinds of radiographic patterns and many symptoms are encountered with often subtle changes. Parameters such as demographic and environmental factors, past medical history have to be taken into account to establish the diagnosis and need to be collected for every case [31]. Our current emphasize is on the creation of CAD with a database of clinical cases containing images and other metadata necessary. It will allow the emergency radiologist to use an electronic system to find similar cases by submitting images from the case under observation. The selection of the relevant clinical parameters according to the most frequent interstitial lung diseases was done in collaboration with lung specialists and radiologists based on their experience in clinical practice [32]. This selection was also supported by knowledge bases of computer-based

diagnostic decision support systems [33] and all selected clinical parameters were mapped to the UMLS (Unified Medical Language System) terminology wherever possible. For the missing items, the SNOMED (Systemised NOmenclature in MEDicine) terminology was chosen. A database structure and web-based user interface developed for data acquisition were based on MySQL and PHP. Cases are annotated according to the criteria described in [18]. The clinical parameters of each selected cases were extracted from the electronic medical record (EMR) with the elimination of all data permitting to identify the patient. Regions of interest were annotated by radiologists in the 3D volumes (see Figure 1).

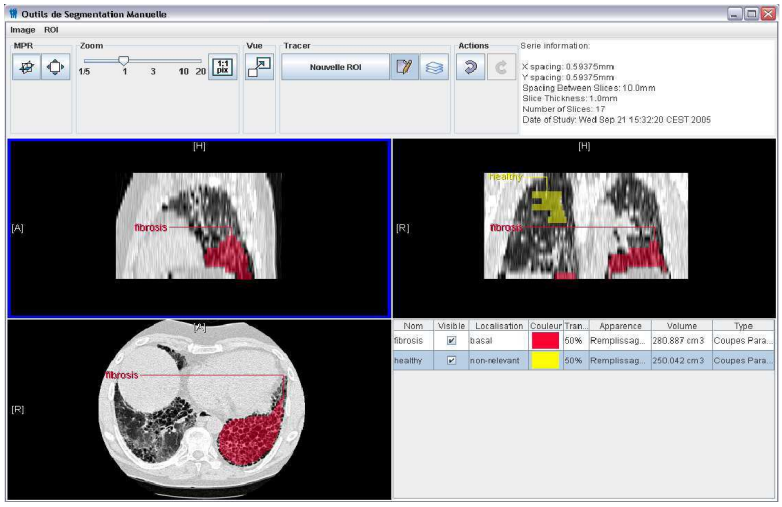

Fig 1. A screen shot of the graphical tool for the annotation of image regions.

3.4 ImageCLEF med

ImageCLEF is the cross-language image retrieval track which is run as part of the Cross Language Evaluation Forum (CLEF) campaign [34]. The ImageCLEF retrieval benchmark was established in 2003 with the aim of evaluating image retrieval from multilingual document collections. ImageCLEF provides tasks for both system-centered and user-centered retrieval evaluation within two main areas: retrieval of images from photographic collections and retrieval of images from medical collections. The medical retrieval task has topics divided into visual, mixed and semantic. ImageCLEF has already seen participation from both academic and commercial research groups worldwide from communities including: Cross-Language Information Retrieval (CLIR), CBIR, and user interaction.

4. Perspectives of a medical doctor towards image retrieval

4.1 Why is IR useful for healthcare professionals?

Medical institutions are producers of enormous amounts of data on patients including multimedia data produced in digital form. These data in their clinical context contain much information that is currently not being used up to its full potential. The variety of images produced increases the complexity of interpretation even for trained specialists, which can result in information overload. For healthcare professionals it becomes obvious that the use of information systems helps to better manage the data produced and to extract the useful information. Performance of current systems is limited due to an incomplete and weak modeling of the user's needs/goals/perception/cognition [12,35,36]. The potential application of MIR is wide and diverse.

4.2 The healthcare professional's search behavior

The focus of information retrieval research should be as much as possible on the user who wants to explore and retrieve data. The system designers need to understand the medical domain and its workflow. Studies on user needs are required to optimize tools. New interactive devices have largely been overlooked and need to be tested to provide possibilities such as the detection of the emotional state [37].

To explore image retrieval needs, a qualitative survey was conducted in collaboration between the University hospitals of Geneva and the Oregon Health and Science University (OHSU) in Portland, Oregon, USA [38]. This is currently difficult as almost no systems running in clinical routine exist and user can thus only discuss there ideas on possible systems. More such studies are needed and particularly a feedback loop that starts when implementing a system. User comments need to be taken into account at all stages of the development process.

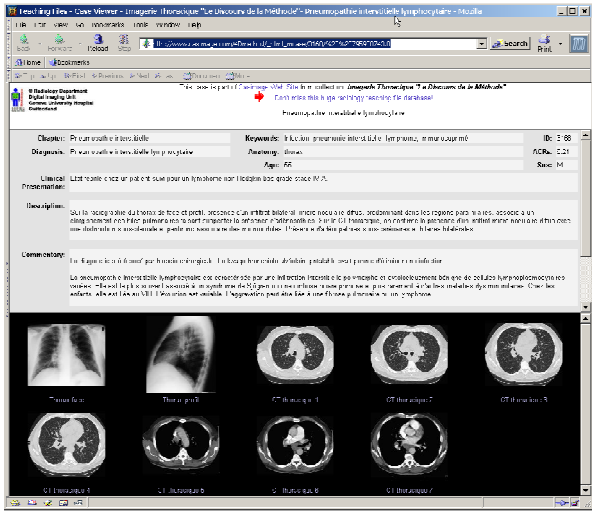

Fig 2. A screen shot describing the use of the medical case database of Casimage, via the website[2].

4.3 Incorporating image retrieval into a PACS

The availability of digital imaging in the entire hospital has the advantage that all data are available anytime and anywhere, where they are needed. The progress in computerized image analysis techniques has been steady but slow over the last decades [40]. At present no PACS is not introduced for its abilities to provide advanced image processing but rather to avoid storing film-based image copies. Not many search techniques exist in current PACS as the data access is often only possible by patient name or identification. Sometime teaching files such as Casimage (see Figure 2) offer more advanced search options such as free text search in the accompanying textual data.

In a survey [38] the following needs were mentioned for images search as being particularly important:

• search by pathology,

• search by anatomic region,

• search by several modalities combined to find similar cases,

•indexation of the entire PACS by keywords regarding the pathology, and search of rather cases instead of very abnormal cases that are often stored in teaching files.

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[2] http://casimage.hcuge.ch/

These proposed methods can really help in clinical practice and, albeit simple, can help much more to get acceptance of clinicians than developing complex search algorithms that do not correspond to the user needs.

4.4 Combining visual and textual features

To improve the effectiveness of CBIR text should be used wherever it is available as it can cover many aspects such as semantics that purely visual systems can not do. This also helps to see the images in the context that they were taken in, as would do every medical doctor when doing diagnosis. Text in this context can be free text such as in the radiology report or it can be structured, which is the case with many data in the electronic patient record such as age or sex.

An important role can be played by ontologies such as UMLS (Unified Medical Language System) or SNOMED (Systemised NOmenclature in MEDicine). The use of these ontologies when coding can limit the ambiguity of the free text data items and can allow an easier generalization of knowledge gained. Several problems such as the dependence on a single language can also be removed as several terminologies exist in more than one language.

4.5 Context-Oriented Image Retrieval

To address the problem of information overload, an interactive approach to the reuse of image information has to be developed. Images need to be seen in their context. Image annotations need to comply with these domain-specific goals. One important difference of the Talisman project, for example, with many other image retrieval systems is that the unit of research is always a case, so search has to include all data of a case for similarity calculation including potentially several images, structured data and also free text [18]. All these data constitute the context in which the images were taken.

4.6 User-developer differences

Fundamental differences between healthcare professionals and computer developers exist. On the surface, differences in education, experience, language, and work interests are obvious. These differences can lead to conflicts when developing a system. If the style of designers/developers is different from those of end-users the final product may not be appreciated. There is the need for greater mutual understanding. The healthcare professionals and developers need to create development teams as in the Talisman project by making work together physicians, image researchers and radiologists in order to optimize a tool for diagnostic aid and teaching. User motivation is a key point that developers have to take into account in the implementation. Motivation requires satisfaction and if the system does not meet the users' needs, they will either refuse to use it or limit the use. Users need to be involved in the IR system design as they know much more about their domain. Developers need to respect the end users comments already at an early development stage.

4.7 A user-centered evaluation framework

Over the last years several proposals have been made on how to evaluate the performance of visual information retrieval systems. Several benchmarking events such as TRECVID, ImageEval, and ImageCLEF were started [41]. The most important problem when reading the current literature on image retrieval evaluation is that the concept of user-centered evaluation has to be strengthened. For medical image retrieval evaluation this remains a key point. Surveys among clinicians can help to collect important facts for system evaluation. In order to prepare multimedia

tools for real-world use, they need to be tested and evaluated based on real-world tasks created by the real users.

5. Conclusion

This paper presents the view of a medical doctor involved in the medGIFT project towards image retrieval with the goal to propose research directions for content-based multimedia information retrieval. These ideas can improve the acceptance of retrieval techniques in the medical domain. One important result is that more collaboration between medical practitioners and computer science researchers is required to improve current applications and their usefulness to the end-users. Much work is still be needed to make visual information retrieval an everyday tool in medical practice but the overload of information for MDs and the potential to deliver the right information at the right time can make visual information retrieval a powerful tool. First applications will most likely be in less critical domains such as teaching and research but the most potential remains definitely in diagnosis assistance.

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