Mobile Medical Visual Information Retrieval

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***Abstract*—In this paper, we propose mobile access to peer–reviewed medical information based on textual search and content–based visual image retrieval. Web–based interfaces designed for limited screen space were developed to query via web services a medical information retrieval engine optimizing the amount of data to be transferred in wireless form. Visual and textual retrieval engines with state of the art performance were integrated. Results obtained show a good usability of the software. Future use in clinical environments has the potential of increasing quality of patient care through bedside access to the medical literature in context.**

***Index Terms*—Mobile information retrieval, content–based image retrieval, medical literature indexing, ubiquitous computing.**

I. INTRODUCTION

HEALTH care decisions in hospital environments are often refined during corridor discussions and while walking in the hospital [1], [2]. Communication devices and access to information outside clinicians' offices are scarce, where only pagers and wall telephones are usually available [3]. In most cases, a need for access to information occurs in a given spatiotemporal context, which has a limited shelf life. When the practitioner gets back to the office his attention is likely to switch to another task. This is particularly true for the analysis of radiological images where visual memory cannot be summarized by a small set of keywords that can be recalled when the physician regains access to the related literature [4]. Ubiquitous access to peer–reviewed medical information using mobile devices (i.e. smartphones) and simplified interfaces has the potential to improve decision quality and quickness [5], [6], [7]. Based on bedside consultations of the literature, the clinician can iteratively ask questions to the patient concerning anamnesis, physical exam or antecedents. In depth reading of the identified papers and further reasoning can then be made at the time the physician gets back to his office.

Effective search for the medical literature is challenging as many of the articles are highly specialized in a given group of diseases, treatments or organs and the results of a given study may not be directly applicable to a particular clinical problem [8]. During the past fifteen years, Internet transformed the use of the medical literature [9]. Search engines such as Google Scholar[1], PubMed[2] or HighWire[3] displaying parts of the text of the retrieved documents (e.g., title, abstract or references) may even save the user from opening full–text articles for gathering the desired information. Effective literature search on mobile devices with limited screen space is even more challenging and images may help to rapidly evaluate the relevance of returned documents in specific situations. *A picture is worth a thousand words* and images are well adapted for search on mobile devices with limited screen space. Moreover, images play an increasingly important role in clinical practice and are used in a large variety of contexts such as diagnosis, treatment planning or screening. They exist in an increasing variety of modalities and radiology protocols. Web pages of journals usually allow for text search in the articles but a particular image search is rarely possible. Whereas a few medical search engines enable textual search for medical images (e.g., Goldminer[4], Yale Image Finder[5] or BioText[6]), content–based retrieval systems are scarce [10] although several times proposed in the literature [11]. Visual search using content–based medical image retrieval has shown to well complement textual search [12], [13].

As a natural extension to text–based image retrieval, content–based image retrieval (CBIR) relies often solely on visual characteristics in the images for retrieval [14], facing other problems such as the gap between the simple visual features used and the high–level semantics a user is normally searching for. Medical visual information retrieval has been proposed several times [12], [15] but was rarely transposed to real clinical applications [16]. It has also become increasingly clear that neither visual nor textual retrieval can solve all the problems alone and a combination of the two is required to optimize performance of image retrieval systems [17], [18].

A. Mobile medical information systems

Anytime, anywhere medical information access using mobile devices has been proposed several times [19], [1], [20], [5], [6], [21], [22], [23], [24], [25]. A clear motivation from physicians was identified in [21] where 92% of 3482 physicians reported use of their personal digital assistants (PDAs) multiple times per day to manage calendars, access drug reference guides, and read medical journals. Physicians in the military experienced the use of pocket personal computers (PCs) also in a very positive way [23]. For emergency situations outside of hospitals, mobile remote access to hospitals can be used for retrieving critical information about the victims such as allergies or infectious diseases. This facilitates diagnosis and advances decision making at the accident site [22], [25] using PDAs and software based on mobile agents. Through several studies of mobile medical information systems at Heidelberg University Medical Center, Haux *et al.* [19], [1] showed that simply transforming existing systems to mobile

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[1] http://scholar.google.com/
[2] http://www.ncbi.nlm.nih.gov/pubmed/
[3] http://highwire.stanford.edu/
[4] http://goldminer.arrs.org/
[5] http://krauthammerlab.med.yale.edu/imagefinder/
[6] http://biosearch.berkeley.edu/

TABLE I
COMPARISON BETWEEN DESKTOP COMPUTERS AND MOBILE ENVIRONMENTS (SOURCE [30]).

	Desktop computer	Smartphone
Screen size	Large	Very small
Input capabilities	Good	Limited
Personalization, targeting	Reasonable	Very good
Connection speed	Fast and improving	Reasonable and improving
Site optimization	Good	Poor but improving
Localization	Reasonable	Very good
Consumption patterns	Extended, stationary	Short, on the move
Pricing	Flat rate	Metered (but changing)
Degree of openness	Completely open	Usually closed (changing)
Reach	Significant	Huge

TABLE II
INDEXED OPEN ACCESS ARTICLES FROM BIOMED CENTRAL.

Number of journals	24
Number of articles	9’403
Min. number of articles per journal	16
Max. number of articles per journal	2’495
Average number of articles per journal	392
Total number of images (after a cleaning step)	37’940
Min. number of images per journal	28
Max. number of images per journal	13’618
Average number of images per journal	567
Average number of images per article	4
Size of all images total	2.81 gigabytes (GB)
Average image size	77 kilobytes (KB)

applications was not sufficient and most user interfaces had to be adapted for access on small screens. The need for simpler interfaces for (visual) information search on small displays, due to the limited screen space available, has been highlighted several times for non–medical applications [26], [27], [28] due to the limited screen space available (see also Table I). For this purpose, medical document summarization was developed in [24] where clusters of documents are returned for textual queries and the user can browse relevant clusters in a second step. By triangulating the signal strength from three WiFi access points, it is also possible to localize hospital workers using PDAs. This can favor contextual medical documents, as proposed in [5], [20]. This use of the location can easily be extended toward the exterior of the hospitals as modern smartphones are almost all equipped with a global positioning system (GPS) unit. Few articles on mobile medical imaging exist. Ubiquitous medical image access within the hospital was proposed by Mohammed *et al.* [29], [6] based on peer–to–peer communication of encrypted extensible markup language (XML) files containing images in scalable vector graphics (SVG) format.

Constraints of mobile information search: Differences between PC–based and smartphone–based information search were evaluated in a recent study from a European commission working group [30]. As observed in Table I, major changes are required for application development in order to cope with the challenging constraints of mobile environments. Still, few solutions to improve mobile information search were found in the literature. User relevance feedback is proposed in [27], [28] to improve the convergence rate of information search on small displays allowing for a limited number of returned documents. However, with touch screens, scrolling has become much easier, and it may become more practical to review long results lists. Finally, it is important to note that smartphone technologies are constantly evolving to improve on board computing power and user interaction capabilities. During the last ten years, mobile technologies have made tremendous progress with high resolution screens (960×640 pixels for Apple’s iPhone 4), 1 gigahertz (GHz) processors, 512 megabytes (MB) of memory and cameras with more than 13 mega pixels, offering sufficient resources for carrying out mobile image analysis and CBIR with comfortable user interaction.

In this paper, MedSearch Mobile, a mobile medical open–access literature search engine based both on textual and visual search using CBIR is proposed for advanced ubiquitous peer–reviewed medical information access. The workflows, architecture and front-ends of mobile content–based medical visual information retrieval are proposed and discussed. The technical description of the retrieval engine MedSearch is recalled. More details on the implementation of MedSearch can be found in [10], [31].

II. METHODS

Datasets and technologies used for web crawling as well as document and image indexing are detailed in Sections II-A and II-B [10], [31]. Solutions to make these techniques mobile are explained in Sections II-C, II-D, II-E and II-F.

A. Datasets

Articles from 24 journals from the online open access publisher BioMed Central[7] in the fields of medical informatics and medical imaging were used as the literature database of our system (see Table II) available on the Internet. A second database using articles from the two radiology journals Radiographics[8] and Radiology[9] were also indexed in the context of the ImageCLEF[10] benchmark. This second database is copyrighted and thus not publicly available but on the other hand quantitative performance measures of the tools are available [32]. Textual information was parsed in the hypertext markup language (HTML) format from the description of each article on BioMed Central’s webpage consisting of the title, abstract, journal name, publication date, author names and the uniform resource locator (URL) of portable document format (PDF) documents. Extracted information of the PDF documents consists of the entire text in the document and the contained images.

B. Indexing the medical open access literature

Our retrieval engine MedSearch [10], [31] is based on existing open–source tools for information retrieval. For text

[7] http://www.biomedcentral.com/
[8] http://radiographics.rsna.org/
[9] http://radiology.rsna.org/
[10] http://www.imageclef.org/

retrieval, the open source Java library Lucene[11] was used. Lucene is flexible and provides the possibility to index more than one field per document, which enables searching in several data fields such as text content, author name, and article title. For visual retrieval, the GNU image finding tool (GIFT) was chosen that has equally been used for almost ten years and has shown to deliver stable visual search results. Implementation details are given in Section III-A.

C. Smartphone technologies

Smartphones concentrate various technologies in a mobile phone. Besides classical communication functionalities (i.e. voice, short message service (SMS), multimedia messaging service (MMS), ...) via the global system for mobile communication (GSM) network, smartphones integrate novel capabilities such as:

- ubiquitous Internet connection via high speed networks (GPRS – global packet radio service, EDGE – enhanced data rate for GSM evolution, UMTS – universal mobile telecommunications system, LTE – long term evolution) and local wireless WiFi protocols,
- Web browser,
- personal data management (contacts, calendar, notes),
- email management software,
- a GPS unit,
- multimedia content (music, pictures, videos) and associated software.

In addition, most mobile operating systems (OSs) offer the possibility to install additional software, which completely revolutionized the mobile phone. The smartphone market is clearly distinct from the market of classical mobile phones, where both products and manufacturers are different. Apple[12], High Tech Computer Corporation[13] (HTC), and Research in Motion[14] (RIM, Blackberry) only manufacture smartphones whereas Nokia[15] and Motorola[16] are present in both markets. Statistical agencies such as Gartner Inc. showed a dazzling growth of the smartphone market over the past five years, which was notably boosted by the arrival of Apple's iPhone on the market four years ago. With more than half of the market (52%), the Symbian mobile OS developed by Nokia was the leader of the market in 2009. Blackberry also holds an important part of the world market with 21% but most of the customers are from the United States (US) where it is well–spread, which is not the case in Europe and Asia. Apple's iPhone is expected to take the market lead quite soon [33]. Android developed by Google is also expected to have a considerable growth in the coming years because it is used by several smartphone manufacturers such as Motorola and HTC. The major novelty enabled by smart phones is ubiquitous Internet access, which was supported by telecommunication providers who modernized their telephone networks to the second and third generation (2G, 3G) and by mobile phone manufacturers with the integration of WiFi receivers. Gartner Inc. predicts that mobile web access will exceed PC–based web access by 2013 [34]. From the perspective of building mobile web applications for medical image retrieval, the identification of main actors in mobile web browsers is important. Mobile browsers usually come with the OS but the user can install additional independent ones. For instance, Opera is not distributed by any OS and is available for most mobile platforms. Safari and Opera are leaders in mobile web access. Web browsers associated with RIM, Blackberry and Symbian OS generate only a small part of the web traffic when compared to their position on the market of mobile OS.

This study of the smartphone market shares shows that iPhone's OS from Apple as well as Android from Google clearly appear as the best basis for the development of web–based mobile medical visual information retrieval.

D. Application types

Three options are available for the implementation of a mobile information retrieval application. The application can be either native, web–based or mixed. The more native the application is, the less portable among mobile OS it will be. The advantages and drawbacks of the various application types are discussed in this section.

1) Native applications: Native applications are applications that are installed on the OS and are subject to compatibility constraints. Usually, these are not portable from one OS to another. Considerable efforts are required to translate a native application because compilable programming languages strongly differ among mobile OS (e.g., Objective–C for iPhone OS versus Java for Android). The major advantage of native applications is the execution speed, since they are based on low–level programming languages, allowing memory management and flexible task orchestration. They also have unrestricted access to sensors such as the camera, microphone, GPS and accelerators. In summary, native applications offer more flexibility at the price of being limited to a single OS.

2) Web–based applications: Web–based applications entirely rely on web programming languages. Using existing JavaScript libraries, advanced web applications can be developed with interfaces similar to native applications. A major limitation of web applications is the restricted access to physical resources of the mobile device. Manufacturers intentionally block interaction with sensors except with the GPS unit and the compass. This type of application blocks the use of the camera for taking a picture and submitting it as a query to the GIFT system for retrieving similar images. The advantage of web–based applications is that no deployment of the software is needed as the user only has to enter the URL of the main page in the browser. Web applications use the HTML rendering engine of the browser to create visual effects such as transparency or movement. Both Safari and Android use the WebKit[17] HTML rendering engine whereas Symbian and RIM plan to base the next versions of their web browser on it.

[11] http://lucene.apache.org/
[12] http://www.apple.com/
[13] http://www.htc.com/
[14] http://www.rim.com/
[15] http://www.nokia.com/
[16] http://www.motorola.com/
[17] http://webkit.org/

Only Opera is using its own rendering engine Presto[18]. Web–based applications using WebKit will be compatible with most mobile web browsers of the market, except potentially Opera.

3) Mixed applications: Another type of applications are mixed applications, which are based on web technologies (HTML, cascading style sheets (CSS), JavaScript) to generate a native application with the help of a specific compiler (e.g., PhoneGap[19], Titanium Mobile[20], Rhodes[21]). Such compilers exist for three platforms: Android, iPhone and Blackberry. Mixed applications have several advantages, such as being multi–platform and allowing access to sensors such as the camera. However, the development of mixed application is currently difficult due to the novelty of the technology as well as the lack of documentation and source code. Moreover, a mixed application would still need to go through Apple's App store approval for distribution; this approval is not necessary for web–based applications.

E. Mobile web application frameworks

Tools for building mobile web–based applications are still sparse. Three frameworks are candidates for the development of mobile medical visual information retrieval: iui[22], jQ-Touch[23] and iWebKit[24]. These frameworks are conceived similarly to websites and are based on a JavaScript library, HTML and CSS. JavaScript is essential for web–based applications as it allows sending asynchronous queries to servers and enables interface functionalities comparable to native applications. The three frameworks are compared based on five axes in Figure 1. Although none of the frameworks fulfills all five criteria, jQTouch, based on the widely–used jQuery JavaSript library[25], offers many possibilities. The price for the diversity of functionalities offered by jQTouch is a low compatibility with web browsers. Iui is a very simple framework aiming at building interfaces similar to iPhone native applications; it has limited functionalities and support. Conversely, iWebKit is very well documented, but has the drawback of having little source code, and that is of poor quality.

F. Web services

Web services constitute an attractive way of establishing the communication between the mobile interface and the literature retrieval engine. Two web service technologies were investigated: representational state transfer (REST) and simple object access protocol (SOAP). REST is based on the hypertext transfer protocol (HTTP) whereas SOAP creates a new protocol for communication with the client. This has the undesirable consequence of increasing data exchange as it requires importing a library with communication protocols. Since telecommunication operators usually fix a quota for a data volume in a mobile contract, SOAP web services may not be constituting an appropriate solution. REST is simpler: the web service is called with a URL and returns data to the client in XML format. Passing parameters to the web service is straightforward, and the parameters may be integrated directly into the URL.

[18]`http://www.opera.com/`
[19]`http://www.phonegap.com/`
[20]`http://www.appcelerator.com/`
[21]`http://rhomobile.com/products/rhodes/`
[22]`http://code.google.com/p/iui/`
[23]`http://jqtouch.com/`
[24]`http://iwebkit.net/`
[25]`http://jquery.com/`

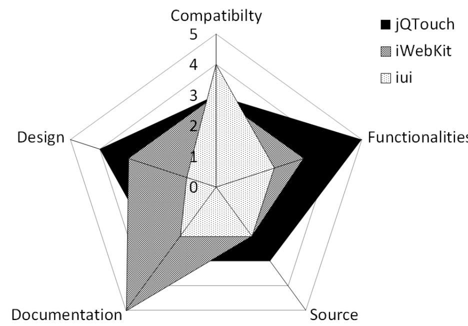

Fig. 1. A comparison of the most popular web application frameworks.

III. Results

The first part of this section details the implementation of the literature retrieval engine MedSearch (see Section III-A). The evolution of MedSearch to MedSearch Mobile is then described. The architecture of MedSearch Mobile is detailed in Section III-B. The implementation details and design of the interface are described in Section III-C and its functionalities in Section III-D.

A. MedSearch implementation

The architecture of MedSearch is divided into six parts (see Figure 2). First, HTML pages of BioMed Central are crawled and parsed based on the journal's starting URL. The collected information is then stored in XML files (one file per journal with information on each article in a journal) using the Java open source HTML parser NekoHTML[26]. Second, all PDF versions of the articles are downloaded from the URLs stored in the XML files. Third, text and images are extracted from PDF documents using Apache PDFBox[27]. Fourth, meta–information of the articles stored in the XML files is added to the Lucene index. Metadata are: title, abstract background, abstract methods, abstract results, abstract conclusions, online article URL (if available), PDF document URL, authors, journal name, publication date, text content, image names and homepage URL. The images are stored directly on the hard disk in the portable network graphics (PNG) format, which is compatible with all web browsers. Images with height or width smaller than 32 pixels as well as BioMed Central logos were discarded. Fifth, the stored images are indexed visually using GIFT. At the end, a web interface using JavaServer Faces (JSF), JavaScript and Asynchronous Javascript and XML (AJAX) combines the extraction and retrieval systems in a single interface.

[26]`http://sourceforge.net/projects/nekohtml/`
[27]`http://incubator.apache.org/pdfbox/`

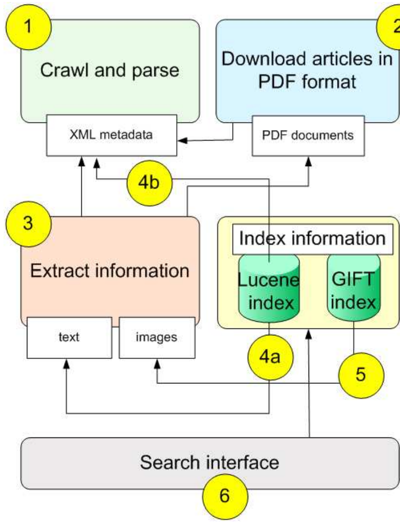

Fig. 2. Architecture of the MedSearch application.

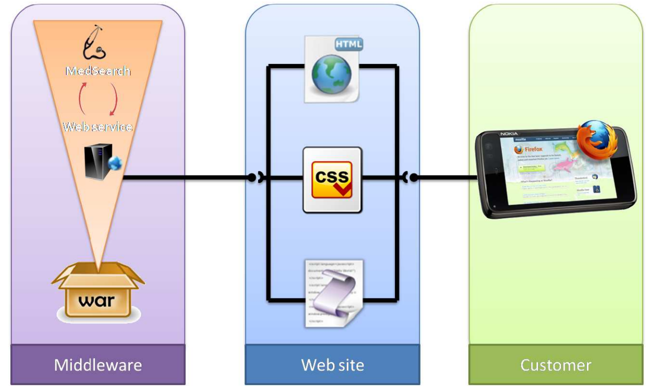

Fig. 3. Global architecture of retrieval with MedSearch Mobile.

B. Architecture of MedSearch Mobile

The review and qualitative evaluation of the existing smartphone technologies in Section II determined our decision to build a web application using the jQTouch framework and REST web services. The architecture of MedSearch Mobile is depicted in Figure 3. It allows performing all processing steps on the server side and thus limits processing delays, power consumption and memory, since the index file size with the current database is about 5 gigabytes. MedSearch Mobile is divided into three subsystems: the middleware, the web site, and the client. The middleware contains all information retrieval routines that are shared with the standard MedSearch. This includes text search using Lucene and visual image search using GIFT. The middleware is implemented as a Java Servlet. The main changes when compared to MedSearch are the communication methods between the middleware and the client. MedSearch uses JavaServer Faces (JSF), which enable direct interactions with the Java code of the Servlet. This was not possible for the mobile client based on JavaScript; instead, the communication is performed by a web service. The second part of the architecture is the web server that hosts the HTML, JavaScript and CSS code of the web site. The communication between JavaScript and the web service is carried out using XML streams. The third architecture part in Figure 3 symbolizes the user who connects to MedSearch Mobile using a mobile web browser.

REST web services are implemented using the Jersey[28] library in Java. Just as HTML, Jersey allows passing parameters to methods on the server side either through the URL or inside the query with POST, where variables are not visible. Methods return results to the client in the form of an XML stream. A pre–defined XML structure is used to optimize the size of the XML stream in order to reduce the Internet traffic limited by telecommunication providers. JQuery manages asynchronous calls, which allows sending queries to the web service without refreshing the web page. For security reasons, web browsers block asynchronous queries (cross–domain AJAX calls) sent to a server different from the one hosting the application (same origin policy); this is an obstacle for MedSearch Mobile, since the web service is hosted on another server. To overcome this limitation, a proxy in Hypertext Processor[29] (PHP) on the web server was used. The calls to the web service are redirected by the proxy using the PHP *curl* extension.

C. Interface design and implementation

The jQuery and jQTouch libraries offer a wide range of functionalities for designing mobile web interfaces including:

- Dynamic identification and change of HTML sections,
- Event management (mouse, page, window),
- Dynamic style sheet management,
- AJAX communication,
- Extension addition (drag–and–drop effects, widgets, multimedias, interactive forms).

jQTouch was used as being the mobile version of jQuery. It contains several functionalities related to mobile applications such as the creation of an icon on the desktop to create a direct link to the web application. As highlighted in Section I, design in mobile applications is a key for usability due to the constraints imposed by small screens. A design challenge was to create an optimal search bar (see Figure 4). Search bars are tightly located at the top of the screen in order to keep as much space as possible for displaying the results. Icons were used as much as possible to gain space.

D. Medical textual and visual search functionalities

Textual search allows using keywords or expressions to retrieve documents in the indexed collection. To limit data transfer, only 20 results are returned; the user can have access to more if desired, for example, when using a WiFi connection. Figure 5 depicts a use case of textual search. The left screen space on Figure 5 contains the title, the publication date, the names of the first two authors with links to their other publication and the first words of the abstract. The goal is to provide sufficient information to the user to decide quickly whether the article is relevant or not. If relevant, a

[28] `https://jersey.dev.java.net/`

[29] `http://www.php.net/`

Fig. 5. Results of textual search with MedSearch Mobile.

Fig. 4. Textual and visual search interfaces.

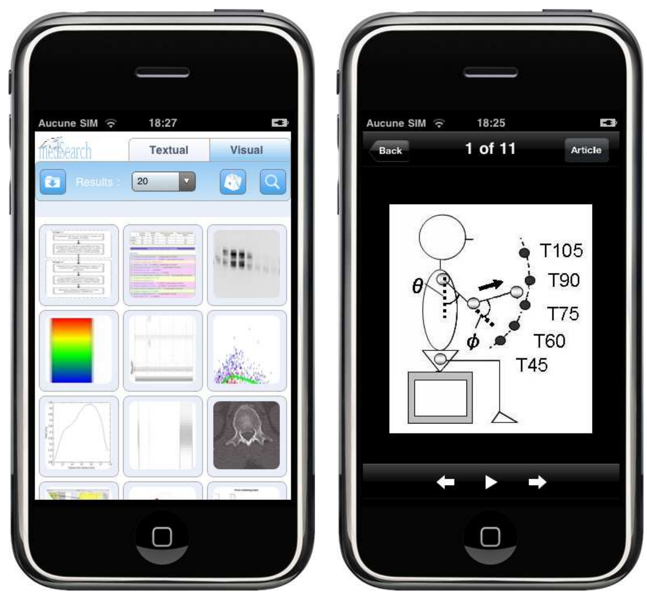

Fig. 6. Visual search with MedSearch Mobile.

dedicated page can be opened with full author list, abstract and illustrations (see Figures 5 middle and right).

The visual search uses CBIR to return similar images from articles (see Section II-B). The user can browse randomly drawn images and choose cases of interest for querying the system (see Figure 6 left). Alternately, pictures from the camera of the smartphone can be used as query images. This is currently impossible with a simple web application as the camera access is blocked but we expect (and hope) this to change in the future with the release of HTML5[30]. A temporary solution for the iPhone was used to overcome this limitation by using a freely available native application called *Picup*[31] This allows uploading pictures from the camera to a server. *Picup* is automatically launched by Safari, returning to MedSearch Mobile as soon as the picture is uploaded. jQTouchPhotoGallery was used to enable easy image browsing as well as full screen display. A link to the article to which the image belongs is shown in Figure 6 right. Because of standards for mobile development integrated in jQTouch, MedSearch Mobile is compatible with the iPad interface, which can be adapted to a medical environment within a wireless network (see Figure 7).

E. Optimization

Compressed versions of CSS and JavaScript files using the YUI Compressor[32] allowed reducing the size of JavaScript and

[30]http://www.w3.org/TR/capture-api/
[31]http://picupapp.com/
[32]http://refresh-sf.com/yui/

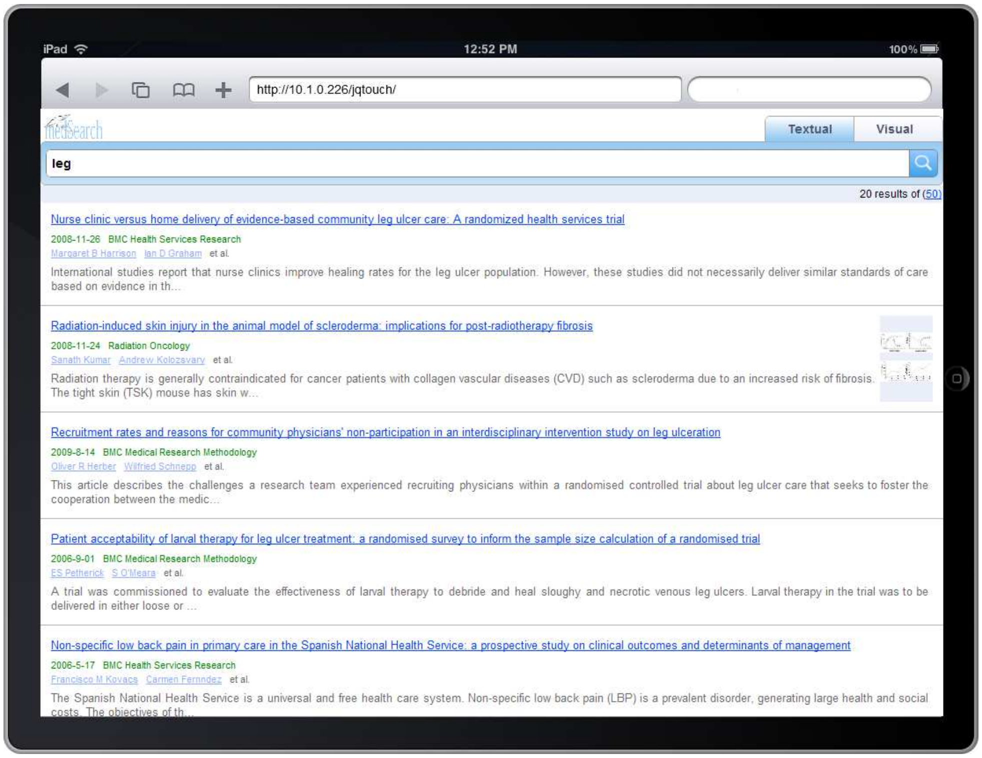

Fig. 7. MedSearch Mobile from Apple's iPad.

CSS files by 37% and 28% by removing redundant data such as comments, spaces and carriage returns. Either the standard or mobile interface is used by the client based on automatic detection of the type of web browser and resolution used.

F. Retrieval quality of MedSearch

No direct quantitative evaluation of the retrieval quality of MedSearch Mobile has been carried out on the database of open access journals but a performance comparison based on a similar database of the medical literature exists in the context of the international ImageCLEF benchmark [13], [32]. In this context, 77'500 images from the scientific literature in radiology are used. 30 search tasks were developed and assessed by clinicians. 17 research groups worldwide participated in the medical task in 2009 and 16 in 2010. GIFT is among the average systems for purely visual retrieval with a mean average precision (MAP) of 0.025 in 2009 and 0.023 in 2010 [35], [32]. For case–based tasks it was the best system in 2009 and 2010 with a MAP of 0.0358 in 2010. Lucene was among the the best systems for purely textual retrieval in 2009 (MAP of 0.27) and among the average in 2010 (0.26). It had the highest early precision [36]. For the case–based topics Lucene had the third best performance in 2010. This shows that the retrieval quality is comparable to that reported in current research of other research groups.

IV. Discussions and Conclusions

Medical visual information retrieval on mobile devices was made possible with the MedSearch Mobile prototype described in this paper. The initial MedSearch information retrieval engine was successfully adapted to the various constraints imposed by mobile devices. Enhanced ease of use of the interface and optimized screen space were achieved using open source libraries for the development of mobile web applications. The results is a web application that is visually similar to native applications, with good execution speed and optimized communication bandwidth. The current state of the constantly evolving smartphone market shares was studied to identify the most durable software solution. Durability and portability among smartphone manufacturers is enabled by using mobile web technologies. The latter is nevertheless limited to mobile web browsers based on the WebKit HTML rendering engine, which is the most widespread being used by most popular mobile phones (e.g., iPhone, Android, Blackberry). In addition, maintenance is facilitated by web–based applications, since the user automatically accesses the latest version at each application launch.

This study is limited to a qualitative evaluation of the workflows and front–ends of mobile visual information retrieval, and no systematic evaluation of MedSearch Mobile has yet been performed in a clinical environment. Another limitation of the prototype is the blocked access to the camera. A temporary solution was implemented for the iPhone to enable CBIR from the camera using a near–transparent call to a native application. We believe however that manufacturers will enable access from web applications to most physical resources in the near future, since it is already the case for GPS and accelerators. Currently, only open access journals were indexed because of copyright. However, the indexing of broader literature bases was investigated, and we are internally working with articles from Radiographics and Radiology journals in the context of the ImageCLEF benchmark.

We believe that MedSearch Mobile has the potential to facilitate information access and increase quality of patient care in a clinical environment by making essential information available. It is also important to note that mobile access to the literature will not replace regular consultations on desktop PCs and paper for in–depth reading. Both accesses are complementary: reasoning is initiated at the bedside and is then deepened in the office after the patient visit.

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