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Visualization issues in Telepathology: the role of the Internet Imaging Protocol

Vincenzo Della Mea
Dept. of Medical and Morphological Research, University of Udine, Italy
Dellamea@dimi.uniud.it

Vito Roberto
Dept. of Computer Science, University of Udine, Italy
Roberto@dimi.uniud.it

Carlo A.Beltrami
Dept. of Medical and Morphological Research, University of Udine, Italy
Beltrami@uniud.it

Abstract

Image visualization may become a difficult task in Telemedicine, especially when large data sets are to be delivered through the Internet and selectively analyzed by the physician.

A new protocol -the Internet Imaging Protocol, IIP- has been recently proposed by a Consortium of companies, with the aim of distributing efficiently multiresolution images on the WWW, for both visualization and printing purposes. The proposed protocol is indeed sufficiently general to be considered for a wide range of applications. The present paper analyses it from the point of view of Telepathology, i.e., the transmission of medical images coming from microscopes. We argue that pathology images can be delivered by means of the IIP, with advantages on the visualization interface, which closely reproduces the direct use of a microscope.

A sample application is presented, aimed at delivering pathology cases for second opinion diagnosis as well as for continuing medical education.

1. Introduction

In the last years, digital medical images have been used in a number of applications on the World Wide Web, mainly for continuing medical education and diagnostic purposes.

Visualization on the Internet raises interesting problems whenever large amounts of image/sequence data are to be handled, which happens quite often in Telemedicine.

On the user side, the network interface should enable attentional image visualization, i.e., on selected regions of interest at the desired resolutions. Visualization becomes a complex, dynamic mechanism of focus that should fulfill two basic criteria: fitting to the user needs, i.e., the current practices of physicians, and comply with the limitations of the current browsers.

Another, well-known problem is transmitting image data which often undergoes bandwidth limitations.

In addition, as far as the same data are concerned, the need arises to dynamically access and retrieve the relevant data subsets: a sort of indexing scheme is to be provided. Stated differently, user network interfaces and transmission protocols are not to be considered as independent modules, but tuned to each other, so that selective visualization should correspond to selective image transmission, both grounded on a suitable data model. This is the main topic that will be addressed in the present paper, in the domain of Telepathology.

In fact, the current practices of the pathologists, e.g., when examining microscope images, require attentional visualization mechanisms. In addition, recent digital cameras have resolutions so high, that it becomes difficult to display them on a usual video monitor without the need for scrolling the window, thus making the visualization experience troublesome. Furthermore, also the storage needed for such images can be huge, although usually JPEG compression is accepted; this brings remarkable transfer times, whenever transfer on the Internet is requested.

A new protocol -the IIP, Internet Imaging Protocol - has been recently proposed by a Consortium of companies, for efficiently distributing multiresolution images on the WWW [1]. Such a protocol is primarily aimed at publishing images suitable for both visualization and printing; the former with the low resolution typical of the Web, the latter at the higher resolution of the color printers. Indeed the IIP general enough to be considered for several applications, as we show in this paper in the field of telepathology.

In the rest of the paper, a brief introduction to visualization problems in telepathology is given, followed by a description of the Internet Imaging Protocol and its applicability to such specific field. A prototype application is then described, where the IIP is used for continuing medical education as well as second opinion telediagnosis.

1.1. Visualization issues in telepathology

Following a classical definition, telepathology is a subspecialty of telemedicine aimed at supporting the pathologist's practice by means of telematic tools. Telepathology systems are divided into two categories: static ones, where still images are available on a store-and-forward basis, and dynamic ones, based on realtime video and sometimes on robotized microscopes. The latter are mostly used for intraoperative telediagnosis (i.e., quick diagnosis performed during surgery to guide the surgeon to further tasks), while the former almost for all applications, including continuing medical education, second opinion diagnosis, quality control, remote quantitation.

Although pathologists use different sources of information, the basic one is the light microscope, which allows for exploring biological tissue sections put on glass slides using different objective magnifications, ranging from 2x to 100x (plus a further multiplier conventionally set to 10x). The image exploration patterns are roughly two: an overall observation of the specimen at low magnification, with deeper analysis of apparently meaningful clues, by means of higher magnification objectives [2].

On the microscope, an analog or digital camera may be connected, for digitizing the images.

Regarding the choice of the camera, different features for analog and digital are available. An analog camera (with one or three CCD chips) allows to show live images on a monitor, or in the window of the acquisition software on a computer; this way, focussing and selecting the right fields is easy, and acquisition is fast. The maximum resolution is limited to the PAL/NTSC standards, which means images up to around 800x600 pixels for a 3CCD camera. Such images will occupy 1.4 MB uncompressed.

Digital cameras are currently available in two kinds: consumer cameras with usual serial interface and microscope adapters, and specifically designed cameras with fast interfaces (i.e., SCSI or proprietary). The former, with resolutions growing fast and currently set up to 1800x1200 pixels, are very cost-effective, but they do not allow live images (as they are photocameras) except for low resolution LCD display, sometimes with a video-composite output. The latter are more espensive, but have higher resolutions and also the possibility of displaying a near-live image on the computer screen. A further and less diffused category is such of photoscanners, which are acquisition devices based on a linear CCD slowly scanning the field of view, exactly as in flatbed scanners. Such devices allow for very high resolutions (6-8 millions of pixels) but are comparatively slow in acquisition, thus making their use difficult. Consumer-level digital cameras generate images up to 6-7 MB uncompressed; photoscanners (as professional digital cameras reach up to 20-30 MB.

Apart from analog cameras, all other devices produce images greater than the screens usually available on personal computers. However, analog cameras are still used in systems in which real-time video and fast acquisition are needed, that is, almost all dynamic telepathology systems. In the following, we focus on static telepathology, because it is often carried out on the Internet and based on the use of digital cameras.

About the features of the microscope images, there are no established standards, but at the present time no particularly high color-sampling levels are needed (i.e., RGB with 8bits/channel is sufficient, and some Author reports even 256 colors), and JPEG compression up to 15:1 ratios is acceptable [3,4]. Compression allows thus to reduce the above mentioned storage amounts respectively to about 100 KB (analog cameras), 450 KB (consumer digital cameras), and 1.5 MB (photoscanners).

A typical static telepathology application is centered on a specialized patient record, containing patient data useful to the specific application (e.g. a short clinical history for diagnostic use, or more accurate descriptions for education purposes) and images, mainly coming from microscope, but sometimes also macroscopic pictures of the sampled organ. Such patient record may be sent directly by a pathologist to another pathologist for second opinion consultation, or may be put on a server, to which a pathologist may connect for consultation or for continuing medical education. The patient record may obviously be also intended for support to the student self-education.

While some years ago only relatively small images were available, now accessing high-resolution images within the patient record is feasible, but it introduces two weaknesses into the interface:

- the whole image may not be fully displayed on the screen, which does not easily allow for the first image exploration pattern, i.e., the overall observation;
- the accurate observation of high magnification details (second pattern) can be made only by downloading the whole image in which the details are present. As images, even compressed, occupy hundreds of Kbytes, the process becomes slow.

The latter problem is also connected to the need of digitizing whole glass slides, in order not to limit the observation to some selected field. In this case, the equivalent of an extremely large image becomes available, with serious problems of substantially the same kind.

1.2. The Internet Imaging Protocol

The Internet Imaging Protocol was firstly proposed by Hewlett-Packard, Live Picture and Eastman Kodak; then, the Digital Imaging Group was founded, and many other companies joined it. The protocol, together with the companion Flashpix file format specification, is mainly targeted at the photographic market.

The basis of the protocol is a tiled, multiresolution image representation, which allows for an efficient delivery of rectangular subsets of images at the desired resolution. Each resolution is usually a half of the immediately higher one. Other image-related information is also available via the protocol, including image technical features, author information and descriptive notes. Such information is organized into a rich object model.

Although the IIP takes advantage of the Flashpix image format (where images are stored into square tiles at multiple resolutions), it can be seen as a uniform way of presenting images on the Internet, independently from the file format on the server side.

The basic protocol commands are only three, and allow for requesting tiles at a specific resolution (one or more, on rectangular subsets), for requesting objects (i.e., information on images), and to set the data object storage, i.e., where to bring the information, thus allowing even extensions to the basic object model. Optional protocol commands allow to perform some image processing on the server (i.e., affine transforms, contrast adjustments, rotations, etc.); in this way also intermediate resolutions may be obtained. Further details are available on the protocol specifications [1].

In practice, the IIP may be used to request just a section of an image at a definite resolution, by means of specified client software.

The protocol is also independent from the transport layer, although guidelines are provided for its implementation on the HTTP and the sockets layer. In its HTTP form, the implementation may be realized by means of the CGI, and thus parameter passing occurs following the usual HTTP "GET" and "POST" methods.

There is server and client software already available for the IIP and Flashpix; furthermore, recently the Digital Imaging group released an open-source reference implementation of both server and client, developed in Java [5]. Clients usually have a common set of features, for easy image exploration through pan/scroll functions (free and not restricted to the tile dimensions), and resolution browsing. Furthermore, caching schemes are implemented in order to avoid duplicate download of the same image tiles, although duplication occurs through different resolutions.

2. Advantages and limitations of the IIP

The main interest of the IIP for pathology lies in the fact that the two interaction functions provided by IIP - pan/scroll image exploration and resolution browsing- closely resemble the two main ways the pathologist uses to navigate the glass specimen at the microscope. In fact, the microscope stage movement may be emulated by the pan and scroll functions, while the change of the microscope objective may be easily put into correspondence with the multiresolution browsing, provided that the highest resolution image has been obtained by a high magnification image (e.g., 40x). Considering that many microscopes have objective magnifications one twice the other (e.g. 2.5x, 5x, 10x, 20x, 40x), lower resolutions inside an IIP-served image exactly correspond -and can be identified with- lower magnification images.

The highest resolution images may be also obtained by collating together multiple high magnification images, eventually acquired with a robotic microscope, in order to obtain a larger field of view.

The pathologist may start the visualization with the lowest resolution image, selecting details to be observed at higher resolutions, and requesting just the needed sections of the images. In this way, a faster interaction is provided, and the interface is more suitable for emulating the use of the microscope, with the usual patterns of visualization.

At the present time, one limitation may be envisaged for the specific field of Cytology, in which specimens are not cut in thin sections, as in Histology, but are made by complete cells with variable thicknesses. In fact, histologic specimens usually have a single focus plane, while cytologic ones need also the observation of different planes, due to their larger thicknesses; pathologists do this by slightly moving the focus (+/- 3 micron), in order to observe details otherwise not available. The latter case is not directly manageable by the IIP as it is.

Flashpix - the IIP companion file format - has been already tested in telepathology for educational applications [6]; a comparison of FPX versus other image formats is also available [7]. An experience on the use wavelets for multiresolution image browsing has been reported also [8].

3. A sample application

The Italian Ministry of University and Research selected and funded the project entitled "Italian Network of Telemedicine for Research Education and Quality Control in Anatomic Pathology" as a project of relevant national interest [9].

The main network activities are: the remote expert consultation; the multimedia case archives for education and continuing education; the collaborative authoring of multimedia educational material.

The project is headed by the Institute of Pathology at the University of Udine, and currently involves five italian universities (Ancona, Bari, Ferrara, Sassari, Udine).

3.1. The system

As the technological basis for the Network, a Web-based case archive has been developed, in which are stored patient records for second opinion consultation as well as for education (with different features). The archive was implemented on a three-tier architecture, with a SQL data base management system (currently MySQL) accessed through an independent API, an interface level based on HTML and PHP, and the client application made by a Java-enabled browser.

Images from the archive are accessible by means of two interfaces: a traditional one (i.e., by displaying the image on a web page) and another based on the IIP, at the users' choice.

The latter interface has been preliminarily grounded on the Digital Imaging Group's reference implementation, which in turn was designed as a Java servlet to be run in conjunction with a HTTP server. Following the latter specifications, images were stored using JPEG.

The system has been implemented on a Sun/Ultra, with the Apache web server and the Apache-Jserv engine.

3.2. Preliminary results

Three main archives are being developed within the framework of the Italian Network of Telepathology:

- a second-opinion telediagnosis archive, in which rare and difficult cases are inserted by pathologists for receiving consultation from the network partners. At the present time, the archive contains 19 cases.
- a continuing education archive, in which interesting cases are put by postgraduate students in pathology and other pathologists, with the aim of giving CME material for postgraduate students as well as for specialists. Compared to the consultation cases, the latter contain more detailed clinical histories, and often images from different medical fields (mostly radiographs, CT, NMR). The current archive hosts 27 cases.
- an educational archive, where paradigmatic cases have been stored, to be used as an educational support during regular lessons in the pathology courses for the degree in Medicine. Such cases are less detailed at the level of patient histories, but with image descriptions (often not needed in the other archives) and with simple questions and answers, which the student should become able to respond to. At present, 5 cases are available.

Still at the present time, the archives contain 51 cases for a total of 300 images. The average dimension of the images is 355 Kbytes (SD: 157 Kbytes). However, such relatively low dimension is due to the fact that some images were acquired in the past with low resolutions, and thus low storage needs.

Figure 1 shows a sample image displayed through the IIP interface.

Different browsers have been tested against portability of the client program, which revealed execution problems only on Netscape v4.7 on the Apple Macintosh (due to the Netscape implementation of the Java virtual machine, and solved in the most recent version 6.0).

4. Conclusions

The availability of refined imaging technology - namely digital cameras - has brought new problems to the user interfaces, because larger images capture diagnostic information more precisely (e.g., in microscope images), but are difficult to display using the available software - such as web browsers- which, in turn, are more and more popular in Telemedicine systems.

A quite similar problem arose in the digital photography field: higher quality images are available, and printing devices too, but the WWW delivers more easily lower resolution images. For the latter problem, a viable solution is given by the Internet Imaging Protocol.

By analysing the features of such a protocol, its suitability for telemedicine applications is apparent. More specifically, we have proposed and applied it in the domain of Telepathology, where images come from a microscope. A direct relationship exists between the functionalities provided by the protocol and the microscope actions.

In the Telemedicine field, the role of the IIP might thus be that of an attentional tool, capable to support the physician in efficiently selecting the right clues and the adequate level of detail out of large, difficult to manage images.

Although the system we presented delivers static images through the IIP, the latter can be readily used as a communication protocol for dynamic systems, i.e., by having the IIP server directly connected to a robotic microscope and an acquisition device. In fact, the localization of the image subset may occur moving the microscope stage on the desired location, while the resolution change may be implemented as objective change.

In this way, the real-time operation of the microscope may be realized, as already attempted by other Authors with proprietary protocols [10,11]. The advantage of eventually using IIP is the availability of different client software, the likely growth of its use on the Internet, and also the possibility of using the same client for accessing either static and dynamic image sources.

From the latter point of view, a main pitfall may be recognized in the protocol, which regards its purely bidimensional nature. In fact, not always microscope images expose all diagnostic information on the same focal plane, although usually they do. In some fields, namely Cytology, the pathologist explores the nearby focal planes, thus introducing a third dimension in the image data, which could be seen as a volume (although extremely thin). This behaviour may not be directly reproduced with the IIP and the current software, but specialized clients may be developed to browse through different images, each one devoted to a single focal plane, by maintaining the same coordinates.

Although the visualization experience through the IIP appears faster and closer to the usual pathologists' habits, further investigations should be made in order to verify whether the data effectively transmitted is truly less than the highest resolution file size.

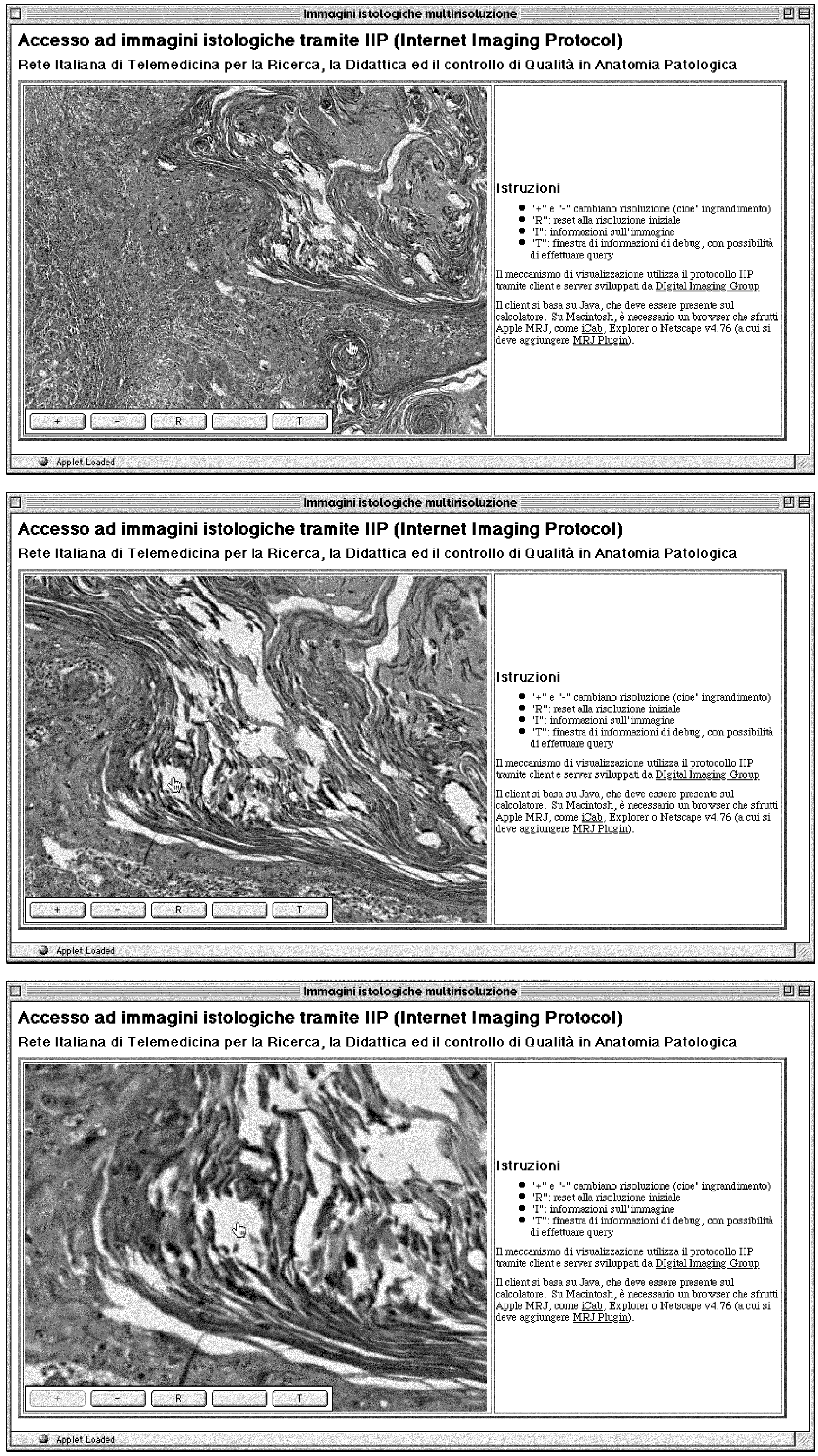

Figure 1. A histologic image shown at three resolution levels through the IIP interface. The original image was 3200x2175 pixels, 24-bit color, acquired with a Leasfscan Microlumina Photoscanner. Uncompressed, the image occupies about 19.9 MB; after JPEG compression, about 1.4 MB.

In fact, lower resolutions are generated and transmitted from the highest one, thus, if the image is fully displayed at every resolution, the total data transmitted may be greater than that of the highest resolution image alone (e.g., in the case of five resolutions, (1+1/2+1/4+ 1/8+1/16)*image-size).

Further features of the protocol are still to be experimented. In particular, the object model accessible through the IIP may be used for adding descriptive information and even, with a recent extension [12], audio data. Such objects may be of interest for educational applications, although when images are kept into a database system, support for that is already present.

It should be noted also that the IIP may be applied to different medical fields where high resolution can make difficult the transmission and display of images, i.e., Radiology, Ophtalmology, etc.

We conclude that attentional capabilities like selective and/or lower resolution transmission of tiles; hierarchical, multi-resolution transmission, via the IIP protocol and Flashpix format, greatly help in addressing the needs of image exchange in Telemedicine.

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