

TELECONSULTATIONS – SYNERGY OF MEDICINE AND IT TECHNOLOGY

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Abstract: The combination of medical sciences with computer networks and computer telematics creates a wide spectrum of new applications called telemedicine. One of telemedical domains is making digitally represented medical data available to medical technicians and professionals from remote locations. It can improve health care and lower its costs. The application discussed in this article is remote access to patients' medical documentation, and DICOM [1] images in particular, for consultation purposes.

The paper presents the research done so far by Distributed Systems Research Group (DSRG) in the area of telemedicine. It shows the functional evolution of applications designed and developed by the group. Starting from relatively simple Web-based services through dedicated access and consultation applications, DSRG has created a comprehensive and sophisticated environment called TeleDICOM, allowing participants from the distributed consultation team to diagnose patients in collaboration.

Teleconsultation services, demanding as they are, should be designed with deep knowledge and experience in the area of medical data, distributed systems, computer networks and many others. All these issues have been considered in constructing the applications and discussed in the article.

Keywords: telemedicine, teleconsultation, DICOM, medical system's architecture

1. Introduction

The combination of medical sciences with computer networks and computer telematics creates an incredibly wide spectrum of new applications called telemedicine. The main issue addressed by telemedicine is overcoming distance barriers. Hence, medical knowledge may be easily extended to almost any place, giving experts a chance to intervene in most difficult cases, physicians – an opportunity to share knowledge, and patients – a possibility to obtain medical advice. As a developing domain, telemedicine appears more and more frequently in everyday life. The most important factor which propels its expansion is reduction health care costs. Moreover, dissemination of expert knowledge facilitated by medical portals, teleconsultation tools or telesurgery results in improved patient care.

To better understand telemedicine, the whole field of telemedical applications may be divided into three areas [2]:

1. Content, services and community. This category includes health portals. They are organized medical sites that contain information connected with the functioning of medical centers as well as provide expert information to a wide range of recipients. Medical portals may operate in a number of ways. They can improve the level of health service to patients allowing them *e.g.* to make appointments in hospitals or outpatient clinics. More advanced systems can provide users with personalized information and services facilitating access to their medical documents or interaction with medical personnel or equipment tracking their health condition.
2. Connectivity and communications. The second application of telemedicine is a rationalization of the health care operation. Internet-capable applications are able to electronically deliver medical records, claim submissions, referrals, eligibility verification, lab reports, prescriptions and other clinical and administrative data. Moreover on-line remote consultations between medical centers either in the well-known WWW-based style or with the ability to offer collaborative, interactive work on shared medical data can not only considerably reduce costs but also be of great educational importance [3]. Telesurgery, a new and promising application, may also be included in this area. The development of remote surgery is currently inhibited by very high costs of such service and deficiencies of the specialist remotely controlled surgery devices. However, it is only a matter of time before these appliances have the proper level of accuracy and allow surgeons to work freely.
3. E-commerce. The e-commerce segment of the Internet health industry offers the greatest opportunity of generating revenue. Pharmaceutical companies have recognized the value of this alternative marketing and distribution channel, but health-related e-commerce encompasses other products, including health insurance and business-to-business services.

This article is focused on the second segment of telemedicine – connectivity and communications – presenting its evolution from simple web-based applications to advanced multi-user, interactive teleconsultation systems.

With enhanced computer network throughput and system performance, capabilities of telemedical systems have become increasingly sophisticated. Initially they merely offered remote access to static patient data, *e.g.* to images from a radiological database. Gains in performance have given their users access to multimedia resources, while the introduction of wireless networks has added easiness of such access, also from small, handheld devices or even mobile phones. Currently, there are no technical constraints which could stop or restrain the development of telemedicine. The only issue is a financial barrier connected with the costs of migration and implementation of new systems in health care. In Poland, the poor financial condition of health services is the major obstacle to the free development of telemedicine, although sometimes it is the only possibility for ordinary patients to access highly qualified expert knowledge.

The Distributed Systems Research Group has recently been involved in the development of various telemedical systems and remote consultation tools. The

following section presents a brief overview of the group's achievements in the area of telemedicine and teleconsultations in particular. Further sections briefly present the evolution of telemedical systems and describe in more detail the developed tools. The paper ends with conclusions.

2. Overview of our research in telemedicine and teleconsultations

The Distributed Systems Research Group was one of the first research groups in the south of Poland involved in telemedicine. The group's interest was started by a European-funded project, 6WINIT, which focused on validation of the use of IPv6 and 3G mobile and wireless technologies in various areas of life, especially in health care. The project resulted in the development of the DICOM Viewer tool, an application which addresses the issues of emergency access to radiology databases over IPv4 and IPv6 networks. The viewer was dedicated to handheld devices enabling users to remotely browse radiology database, based on the NetRAAD and, later, the RADAS system.

The next step in extending the group's research in the area of telemedicine was its participation in the KCT project (the Cracow Centre of Telemedicine and Preventive Medicine). The aim of the project was to rationalize the work of medical centers by introducing modern information and telecommunication systems to their daily work routines. The project put strong emphasis on teleconsultation systems and tools and – as a result – the RADAS, TeleNegatoscope and Konsul system were developed. RADAS offers easy access to a radiology database through a WWW service. TeleNegatoscope is a tool for interactive remote medical consultations over low bandwidth networks, while Konsul is a web-based system providing non-interactive mechanisms for medical teleconsultations. The KCT project was supported by Cracow's John Paul 2nd Hospital and the Department of Internal Medicine of the Jagiellonian University's Collegium Medicum.

The group is currently involved in the development of a system for efficient, multi-user, interactive medical teleconsultation called TeleDICOM. The system extends and integrates the functionality of TeleNegatoscope and Konsul into one powerful application.

The group's state of research was presented at many national and international conferences, including the 1st and 2nd E-Health in Common Europe Conference, organized by the group itself. Its activity in the promotion of telemedicine has been supported by the ProAccess project, focused on creating a platform for the promotion, dissemination and transfer of advanced health telematics concepts and experience from development and deployment of telemedicine solutions to the Newly Associated States of the EU.

3. Technical and architectural background of modern consultation systems

Medicine, like other aspects of our lives, benefits from electronic exchange of information, which can support better organization of medical data and improve health care especially when a distance separates the participants (*i.e.* doctors and patients or

doctors, themselves). Today, Internet-capable applications are able to electronically deliver almost any kind of medical information. Internet health services have branched into many categories, including systems monitoring patients' state, providing expert information to patients, providing medical professionals with consultation tools and e-commerce services.

As this article is focused on accessing medical data, *e.g.* for consultation purposes, we shall not discuss other forms of contemporary telemedicine here. This chapter presents the requirements of telemedical consultation systems taking into account their various aspects. The most important factors described are representation of medical data, technical issues of remote access and the importance of proper architecture choice for a developed system.

An Electronic Health Record (EHR) is defined as a digitally stored health care information and should include all medical data (such as observations, laboratory tests, treatments, medicine allergies *etc.*) collected throughout a patient's lifetime. The main purpose of EHR is supporting continuity of care and its effectiveness, although the research and educational aspects are significant as well. An important part of EHR are medical images. They may contain various graphs, such as EEG, ECG or specialized images (radiology, USG *etc.*). Medical images can be represented in various general-purpose formats such as JPEG, but to achieve truly diagnostic quality they need to be stored in a special, dedicated format. DICOM [1] is the *de facto* standard in representing medical data. Apart from consisting of one or more images (which can be animated), a DICOM document stores much more other information precisely characterizing the examination conditions and the patient. The DICOM format is extensively used in today's medicine and a majority of modern medical equipment support this format, generating examination results directly in DICOM. DICOM browsers, *i.e.* applications designed to access and display information stored in DICOM documents, eliminate completely the need to print images or develop them on films.

EHR data in hospitals or any other medical centers providing health care should be easily accessible¹ when necessary in many places, such as an outpatient clinic or an operation theatre. Systems providing such services use hospital intranet networks. The traditional wired local network can be supported by a wireless local area network (WLAN), whose range may be useful *e.g.* during a visit at a patient's bed.

Data stored in EHR records will sometimes need to be transferred outside the medical center. This is necessary when EHR data is stored in central repositories (possibly serving an extensive geographical area) and must be downloaded to a particular hospital. When implementing cooperation between medical centers in exchanging medical data many issues arise which must be solved. They are listed below, although some of them are beyond the scope of this article:

1. the need for compatibility of particular hospitals' EHR systems;
2. the need to apply strong security mechanisms and measures ensuring data consistency;
3. organizational and legal problems;

1. Without compromising their confidentiality.

4. demand for existence of effective means of data searching and selecting, as EHR's usually contain large volumes of patients' medical history;
5. the need for broadband network links² essential for remote access. (One need be aware that DICOM, despite its benefits, is very requiring in terms of bandwidth and may thus be difficult to use in remote access scenarios. A single DICOM examination can be several megabytes of data. A possible solution, when bandwidth is an issue, is providing lossy-compressed counterparts instead.)

There are other reasons for transferring EHR records between medical centers than to share them and keep consistent. Access to the data may be required in a number of situations, including the following:

1. general practitioners (GP), nurses or paramedics need to immediately view a summary medical record of an accident victim or other emergency care patient;
2. a GP may want to review the medical data of a patient during a home visit;
3. a patient's case sometimes cannot be diagnosed by the doctor to which the patient has been directed. The patient's documentation is transferred to a local hospital or to a high-level specialists from a central clinic in order to be consulted. The procedure can eliminate the need of additional appointments;
4. a patient's case could be urgently consulted by a specialist who is temporarily outside the hospital but is provided with a wireless handheld device able to download and display the patient's medical information.

The progress in the electronic and the communication industries has made the above scenarios technically realistic at almost all locations. The range of GPRS service (and UMTS in the near future) provided by GSM/GPRS operators encompasses virtually the whole territory of all European countries. In some public places such as universities, airports or commercial centers a public wireless LAN has become available, offering much faster access to the Internet. The use of a public network requires, among other things, paying special attention to security issues to protect medical data from being captured or modified by unauthorized persons.

Wireless appliances, such as Personal Digital Assistants (PDA's), have become more and more technically advanced and financially affordable. It is possible to use such equipment to download and process DICOM images when necessary. PDA devices are very handy and in many cases sufficient (see again example 4 above). Portable devices should be provided with a wireless (ideally multi-technology) card able to work in WLAN, Bluetooth³, GPRS and other networks.

Despite the impressive progress in wireless communication, remote access to medical documentation from an accident scene using a PDA device differs considerably from local access from a desktop computer. The public network infrastructure cannot currently provide as good bandwidth and quality of service as dedicated intra- or inter-hospital networks (*e.g.* the maximum speed of GPRS is about 170kbps). Moreover, due to insufficient size and quality of their displays, handheld devices provide referential

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2. Which may be problematic in many countries due to financial constraints.
 3. Bluetooth is a personal network standard operating on short distances.

quality of examination only (even those stored in DICOM format); diagnosis must be performed using better screens.

Scenarios enumerated in the preceding paragraphs can be implemented in a number of ways using either general-purpose tools or specialized applications with or without regard to specific kinds of access. Systems' functionality and user friendliness of interfaces may vary as well.

A medical system's proper construction is a crucial issue and should be preceded by a detailed analysis and supported with knowledge and experience in the area of medical data, distributed systems, computer networks, *etc.* Software architectures and styles of programming of computer systems change continuously, and it is important to follow these trends to develop an efficiently-working application built according to state-of-the-art technologies. The analysis presented below is quite general in terms, but can nevertheless be successfully applied to the discussed problem.

In mainframe systems popular a few decades ago, programs were usually monoliths with batch data processing. Progress made in the electronic industry led to popular use of the personal computer, which, while initially working as a stand-alone device, later became a part of distributed software systems communicating via computer networks. The developed client-server architectures, in which clients were requestors of services and servers were their providers, were implemented in several ways, using various techniques and mechanisms. The clients software tended to become thinner and thinner, in that business functionality initially implemented on the client side was gradually moved towards the server, allowing clients to fully rely on functions being available on the server.

The modern design approach recommends building systems according to a service-oriented architecture (SOA). In this style, the main functional software components are packaged as separate, loosely coupled service implementations providing simple and well-known interfaces used by other architectural components. SOA is an architectural style that formally separates services into two categories: services which are the functionality that a system can provide, and service consumers which need that functionality. This separation is accomplished by a mechanism known as a service contract, which is coupled with a mechanism allowing providers to publish contracts and consumers to locate the contracts that provide the service they desire [4].

The functional components being developed should be supported by the so-called infrastructure components (already in existence), which provide a set of common services needed by the service implementations of functional components. The reusable entities offer remote communication between components (*e.g.* CORBA, J2EE, Web Services, COM/DCOM, JMX), data and event logging, security mechanisms, thread management, user interfaces, *etc.* The use of the rich services available guarantees considerable savings in system development time and increases code reusability. An extremely popular approach is to provide contemporary systems with a user interface based on a WWW browser. WWW interfaces for systems of enterprise scale should be delivered by a portal [5].

Portal platforms provide many ready-to-use mechanisms such as:

- access to databases,

- personalization of user interfaces,
- security of access, including authentication and authorization of users and encryption of data,
- support for different types of display devices, allowing users to access portal services both from PDA devices and desktop computers,

and many others. The portal technology allows all these aspects to be integrated and managed in a consistent manner⁴.

Given the advantages of SOA and component-based environments one could also consider adjusting systems developed with older (legacy) software architectures to new paradigms. However, the cost hundreds or even thousands of man-months (depending on a system's scale) is prohibitive. Modernization of non-trivial systems is usually so complex that it is only performed when there is a critically important reason. The stimulus is mainly lack of crucial features, necessity of integration with other systems or porting to other platforms.

There is however more possibilities than rewriting the system from scratch. It may suffice to replace its malfunctioning parts or satisfy the new needs within the existing architecture. If the system is composed of loosely coupled components with well-defined and documented functionality, it may be relatively simple. Unfortunately, legacy systems are often heavy monoliths, which complicates the problem considerably.

The above remarks do not refer to any particular medical computer systems. These are simply computer systems and the architecture or implementation requirements are the same as for other systems. At the same time, they are usually mission-critical applications with very high reliability and accessibility requirements thus requiring particular attention to proper software architecture.

Unfortunately, according to the authors' knowledge, most of the medical systems have been built using legacy architectures. They are rather monolithic constructions, very hard to enhance and modernize. This is certainly due to financial factors, but also to decision-makers not keeping abreast with the current trends in computer science. The following case study will briefly⁵ describe problems of functionally enhancing legacy systems and will present a few systems developed during our research in the area of telemedicine.

4. RADAS – a Radiology Database System

RADAS is a database system providing access to medical examinations in the form of DICOM files and associated simple textual descriptions via an ordinary WWW browser. It aims to support doctors working inside a hospital by enabling them to view patients' examination results using a lightweight application. Nevertheless, RADAS can be also used for teleconsultations – in such scenario – the party who wants its medical images to be consulted enters the images into a database and provides read access to external users. In inter-hospital consultations data can be stored either in

4. There are many portal servers available on the market, such as Oracle 9ias Portal, Sun Java Enterprise Portal System, IBM WebSphere Portal and Microsoft SharePoint.

5. For a detailed discussion about migrating medical systems to a new architecture, see [6].

a local hospital database or uploaded into a remote hospital, usually using external means. A serious shortcoming of this approach is that the RADAS user interface provides read-only access, preventing users from making any changes. This makes it rather poorly suited for consultation purposes.

The information presented by RADAS is organized hierarchically: there are many patients with many examinations. Each examination may contain many images. The structure of information is inherited from the NetRAAD system developed by UHC, on which the system is partially based. Moreover, the RADAS system enables its users to easily search through the resources using various criteria.

RADAS databases store two kinds of images: DICOM documents of high diagnostic quality and referential, lossy-compressed JPEG images used for initial diagnosis, useful for browsing through the database. The conversion from original DICOMs to their JPEG counterparts is made automatically during placement in the system's database.

Compared with its predecessor, NetRAAD, the architecture of RADAS has been thoroughly changed. RADAS was built using the Java 2 Enterprise Edition (J2EE) technology according to the multitier paradigm, with a clear separation between the business logic and the presentation layer (which NetRAAD is lacking). The business logic of RADAS performs only data accessing and processing. The presentation layer, realized using JSP and Struts, constitutes a user interface, which has also been rebuilt to look nicer and be more user-friendly.

A screenshot of RADAS is presented in Figure 1.

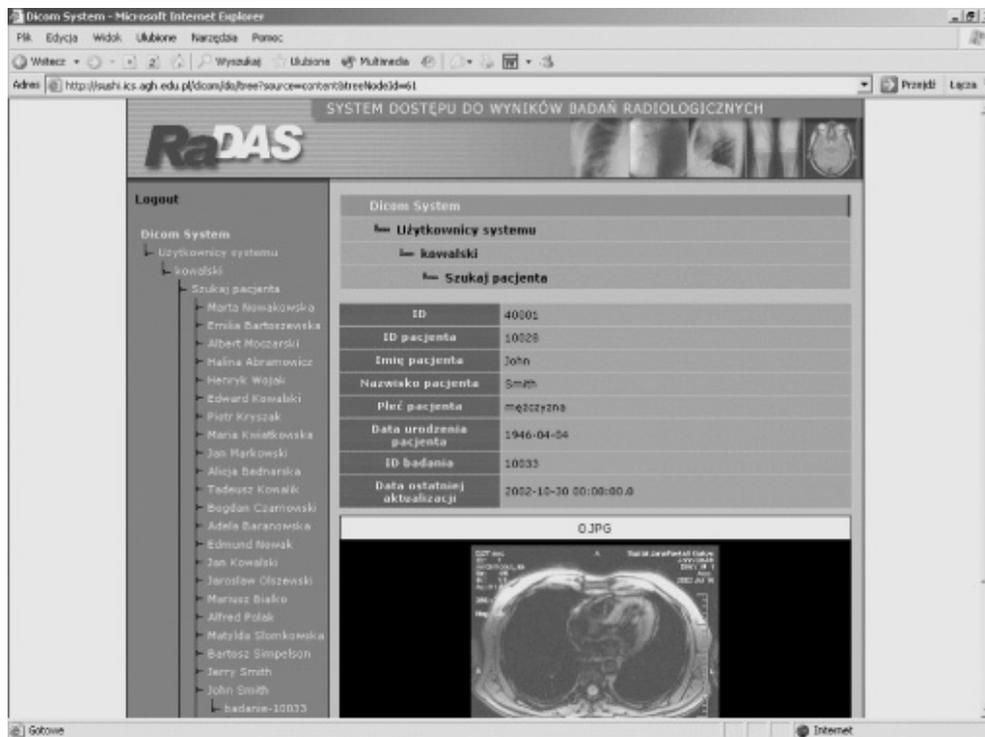


Figure 1. A screenshot of RADAS

5. DICOM Viewer – access to RADAS resources from PDA devices

Wireless handheld devices (PDA's) have become better and better equipped, providing not only for simple local applications such as games and spreadsheets but also implementing applications to communicate via wireless networks and performing non-trivial data processing. These growing possibilities we allowed the authors to design and develop an application remotely accessing DICOM images.

The application addresses the issue of home/street emergency access to a patient's medical radiology database over an IP network. In case of emergency (*e.g.* a road accident) or during home visits, medical personnel can review (but not change) DICOM-encoded radiology data and a basic medical summary. In these scenarios, the hospital's data would be helpful when accessed for reference. Small wireless appliances would be the most frequently used devices, although laptop computers could occasionally be applied.

The idea of providing access through a WWW browser (as RADAS does) was abandoned during the design phase. Small size of PDA displays made using the system hardly possible, although – thanks to the multitier architecture of RADAS – its presentation layer could be easily suited to the new resolution. However, we chose to develop a stand-alone application instead. This helped to organize the user interface optimally, with no overheads of a WWW browser or limitations of the HTML access strategy.

The layout of the application consists of a few tabs devoted to different functions. First of the tabs was designed for searching for patients in the database, the following ones – for browsing through the chosen patient's examinations and, finally, viewing the selected image. The user interface has been so constructed to be as well suited to the PDA characteristics as possible. Handheld devices are usually provided with no keyboard and the virtual keyboard occupies a lot of display space. This is why most actions can only be performed with an easy-to-use stick.

A functional design of the viewer had to take into consideration its specified goals and the limited resources available. Nevertheless, the resulting functionality is quite rich and has been favourably assessed by radiology specialists from the John Paul 2nd Hospital in Cracow. A few transformations can be performed on a downloaded DICOM image, such as zooming or adjusting the Hounsfield window. Dynamic images can be animated. The user is also able to display the most important DICOM tags with details of the patient and the examination, which are associated with the image. The volume of radiology data may result in very large DICOM files, thus making bandwidth a critical issue. In order not to make the client highly bandwidth-consuming (especially due to low bandwidths of GPRS networks), the database provides them with lower quality (JPEG compressed) reference images useful for browsing.

The application has been implemented in the Java programming language, which makes it fully platform-independent and able to be run on a number of devices. The only action required upon porting is reconfiguration of the device's display size

and resolution. The professional Java DICOM toolkit from Softlink⁶ was used in the part responsible for DICOM file processing. The connection with the hospital database was realized using a next generation IPv6 protocol, although traditional IP can also be used. Due to public network usage, the security mechanisms had to be very strong. The user needs to be authenticated and verified (*e.g.* via a token or PKI), and the connection needs to be secure (*i.e.* encrypted). The transmission path's encryption is assured by means of a HTTPS protocol suite performed by a HTTP server of the RADAS system.



Figure 2. View of an iPAQ device with DICOM viewer running

The DICOM viewer was tested on Compaq's iPAQ PDA devices provided with strongARM 206MHz processors and 64MB of RAM, working under the Linux operating system's control. Their computational power was sufficient for this purpose and the DICOM viewer worked very stably. The most troublesome feature of the appliances was their high power consumption, especially when working in a WLAN environment. An iPAQ device with the running DICOM viewer is shown in Figure 2.

6. Konsul – easy non-interactive consultations

The Konsul system, developed at the John Paul 2nd Hospital in Cracow, is a prototype system providing medical teleconsultations for small, peripheral hospitals. The main idea of the system is to reduce costs and effort required to perform medical consultations. Some difficult cases need to be consulted with specialists from a referential center. Previously, the physician who wanted to obtain such advice had to drive from his hospital to the center and wait for consultation. Moreover, it is difficult to assess whether the patient should go with the doctor or the case was simple enough for a diagnosis to be based on the medical documentation only.

Konsul allows physicians to exchange medical documentation using a web browser. Documentation is uploaded onto a server in a referential center and the case is consulted by the center's medical professionals. Results are then sent using e-mail

6. See: <http://www.softlink.be/>

or other conventional means of communication. In the case of a tentative diagnosis, the patient is directed to the referential center for detailed examinations.

Since the idea of Konsul was accepted and the system was installed in several hospitals, it has been completely rebuilt to extend its functionality and provide the proper level of security required of such solutions [6]. The advantage of the system lies in its user-friendliness and in combining DICOM files with other medical data in the electronic form (*e.g.* Patient Information Cards, raster image files, textual data).

The architectural model of the Konsul system is very simple and consists of three main components running according to a client-server scheme. Each component has been briefly described below; their interaction is presented in Figure 3.

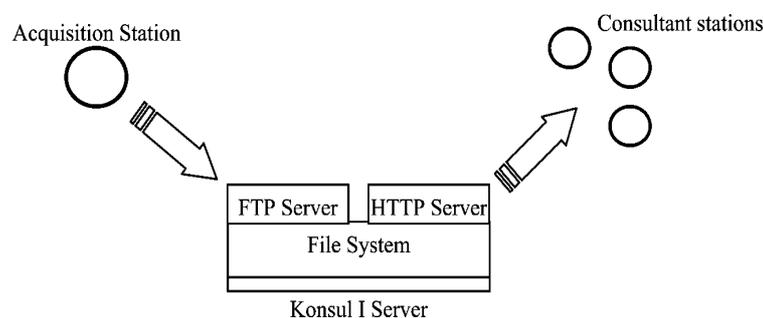


Figure 3. Architecture of the Konsul system

- **The acquisition station** runs FPIImage, one of many existing DICOM viewers, which can convert DICOM images to various general-purpose data formats. The main advantage of the tool, compared with other similar viewers, is its built-in simple proprietary scripting language, which allows users to customize the application's behavior by writing their own programs. The language facilitates the processing of loaded DICOM images, invoking operating system scripts and also contains an embedded FTP client. One of the scripts supplied with FPIImage converts DICOM files to AVI or JPEG format, links the converted files to the generated HTML pages and sends everything to a desired FTP server. After a few cosmetic changes the script could be used for data acquisition.
- **The Konsul system server** consists of an FTP server and an HTTP server. Patient examinations sent via FTP are stored in a file system, which is the interface used by HTTP server. Finally, the HTTP server allows users to access data using web browsers.
- **A consultant station** of the Konsul system is just a web browser. Doctors consulting the delivered cases use it to download and display the files on their personal computers. Occasionally phone calls are made from the ordering hospital to provide the consulting specialists with additional information regarding the discussed case. The computer used for consultations is expected to have only a graphical web browser and an AVI player installed, which is common in ordinary PC systems.

Although the proposed model of consultation is acceptable and Konsul is functioning well in three cities (as a client in peripheral centers) and in Cracow

(as a server in the consulting center) the need for interaction is constantly growing. Using Konsul, the consultee and consulting teams work independently and there is no communication between them in the process of diagnosing. This gives the physician from a peripheral hospital no chance to take an active part in consultation and describe their problem online. Generally, WWW services are not appropriate for interactive communication, so other, more efficient tools need to be developed to make better use of the faster and faster Internet connections.

7. Supporting teleconsultations with TeleNegatoscope

The KCT project benefited from the creation of TeleNegatoscope, a tool for interactive medical consultation [7]. The name of the tool is connected with its initial purpose – remote access to a negatoscope – but it quickly turned out that TeleNegatoscope may be successfully used not only to transfer radiological images but also other medical documentation like ECG, paper forms, *etc.* (see Figure 4).

The tool allows two sides, the peripheral and the referential, to work on the same data at the same time and exchange opinions and comments. The data utilized by the application are compressed digital images and annotations. Annotations are made using simple shapes: ellipses and rectangles which are shared between the two sides. Consultation is also supported by shared pointers owned by participants. Thanks to these only small amount of data is transferred during a consultation conserving network bandwidth.

As an efficient tool for peripheral medical centers with poor connection to the Internet, TeleNegatoscope is limited to working with ordinary graphical formats representing medical documentation. Unfortunately, the image quality is not sufficient for some examinations (esp. CT or coronarography).

8. TeleDICOM – a sophisticated teleconsultation environment

The idea of TeleDICOM originated from the previous work concerning telemedicine and teleconsultations performed by DSRG. The DICOM format and means of storing medical data were investigated during the development of the RADAS system. We have come to the conclusion that DICOM is the preferred format, offering integration of data and easiness of searching, but medical documentation is often also stored in textual, graphical or other formats, appropriate to the device generating the data.

Closely tied with the RADAS and NetRAAD systems is a DICOM Viewer, showing how to display DICOM images and tags and what kind of graphical tools are necessary to effectively browse through a database and view an image. When developing the viewer, we faced the problem of transferring a DICOM file through low-bandwidth networks and the need to overcome such obstacle, *e.g.* in the way the NetRAAD system does – using JPEG thumbnails.

The Konsul system was the first attempt to provide remote consultations. Despite its non-interactive characteristics, hospitals are interested in such communication. The system's most important advantage is easiness of installation and use, mainly because the consultation team uses a web browser to access medical data.

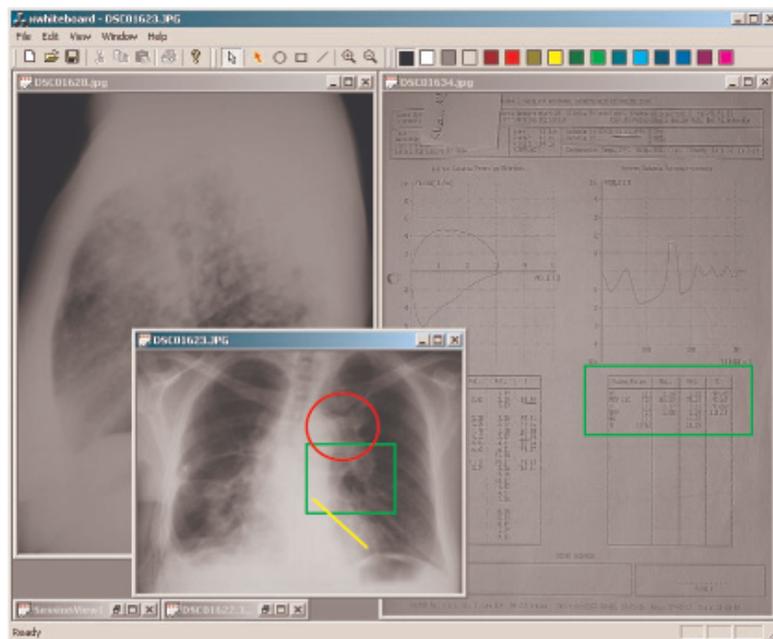


Figure 4. One side of a sample TeleNegatoscope session

Another form of teleconsultations is offered by TeleNegatoscope, which is the predecessor of parts of the TeleDICOM system. The concept of interactive remote consultations, *i.e.* sharing a display of medical documentation and cooperating by pointing and drawing shapes, enables the participants to conduct consultations in a natural way. Experiments with TeleNegatoscope have also proved that a voice channel should be integrated into the system instead of providing it as a separate tool. It makes the system easier to use and enables storage of voice data as evidence for later review.

The experience gained in the development of the above applications has given us a better understanding of the real needs and constraints of the medical environment. TeleDICOM integrates most of the features of the above-mentioned applications into one compound teleconsultation environment [8]. In fact, the system is a combination of a data storage and access system – called Konsul III – and an interactive tool for remote medical consultations based on TeleNegatoscope, shown in Figure 5. The name of the data storage part is not accidental; Konsul III of TeleDICOM is an extension of the previous, second version of the Konsul system. TeleDICOM can be used in two consultation modes: interactive and non-interactive. Whenever possible, *i.e.* when the computer network connecting the participants has a proper level of QoS, the interactive mode should be used. In less efficient environments, TeleDICOM enables performance of old-style non-interactive consultations using the same system.

8.1. Functionality of the interactive part

TeleDICOM operates on the so-called *sessions* (or *consultations*) tied to a particular patient. A session may consist of multiple *examinations*. An examination is usually a DICOM image, static or animated, but it can also be other graphical, textual



Figure 5. A TeleDICOM client during sample session

or media document. As yet, medical documentation often exists only in paper form and the fastest way to make it available to others via computer network is either to scan it or simply make a photograph with a digital camera. All these documents can be simultaneously opened and placed inside the application window.

Each of such images can be operated on a way analogous to whiteboard-like applications, treating the medical document as a background. TeleDICOM allows participants to draw basic geometric shapes such as lines, rectangles, circles and arrows, and to use specialized tools such as a magnifying glass or the Hounsfield window adjustment tool. The shapes mark the region of interest and may be moved, modified or deleted by every participant subject to the others' permission. Together with the tools they provide an intuitive and efficient way of performing remote consultations.

The interactive part of the TeleDICOM system is a specialized teleconference application, thus participant management is a feature worth implementing (notification of participants' appearance/disappearance and connecting/disconnecting). As already mentioned, it is desirable to integrate additional media with the TeleDICOM client application to enhance its user-friendliness. Support for live audio and text channels (like chat) is crucial and a video channel is an option. Additional features important in medical applications are the following:

- **data anonymizing** – apart from consultations between hospitals, the goal of TeleDICOM is to become a useful tool for teaching medicine students. They get an opportunity to see cases interesting from the medical point of view and may be instructed by their supervisor. Each student has direct and convenient access to the examinations from their personal computers. Such dedicated sessions would not differ from ordinary consulting sessions at all. To oblige

with the requirements of personal data protection, the medical documentation is anonymized, *i.e.* all personal data are removed;

- **data filtering** – moreover, it would be instructive to allow students to participate in real consultations as well. This implies introducing a set of permissions for various participant roles, *e.g.* allowing students just for observation. A data filtering mechanism can easily be extended as bandwidth available for users can vary. Media filtering has been considered enabling users with a lesser network throughput either to cut off completely particular streams (*e.g.* video) or downgrade their quality;
- **session logging** – some sessions should be recorded to serve as evidence or to be interrupted and resumed later.

8.2. Functionality of the data storage and access part – the Konsul III subsystem

Examinations which are going to be used in consultations must be first delivered to a central database forming a patient's evidence. From there they are redistributed to computers of session participants whenever necessary (the same data can serve in many consultations). Since the volume of data designated for a consultation can sometimes be as huge as several hundreds of megabytes it is better delivered to the participants' computers before the session, *e.g.* at night, when the available network bandwidth is better and cheaper. However, it should also be possible to send required but overlooked examinations during the session.

The resulting diagnosis and recording of the session should be stored in the Konsul III database as evidence and extension of the patient's file.

Konsul III may work as a stand-alone system providing non-interactive consultations. Compared with its previous version, the main changes concern reorganization of the architecture according to the SOA paradigm and an extension of functionality, with minor improvements.

9. Conclusions

The article has reviewed applications developed or co-developed by DSRG in a few telemedical projects. They have been found of interest by the medical community in the south of Poland and participants of medical conferences, which shows that there is substantial acceptance and demand for such services. The Konsul system has been applied at a few hospitals. Implementation of the interactive part of TeleDICOM has already been completed, but its storage part is still under development. Here, the main issues are integration with Hospital Information Systems (HIS) and their representation of EHR. The lack of generally applied interfaces and problems with systems' interoperability may constitute major obstacles. Unfortunately, these organizational problems with integration of medical systems are not the only ones. Financial barriers resulting in the lack of modern medical and computer equipment and/or broadband access to the Internet delay the introduction of modern telemedical applications into common use. Hopefully, there are no technical constraints which could stop the development of this area of medicine.

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