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SECOND GENERATION TELERADIOLOGY

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This paper proceeds from the definition of teleradiology. It identifies three different generations of teleradiology systems and also includes those systems that are not regarded as teleradiology systems by the authors. A list of requirements pertinent to users of first generation teleradiology systems is introduced. Most of the requirements have been realized in a new generation teleradiology system called CHILI.

1. INTRODUCTION

The German Cancer Research Center and the Steinbeis Transfer Center for Medical Informatics in Heidelberg, Germany, cooperatively developed the teleradiology system MEDICUS. This project ran from mid 1994 until mid 1996 and was funded by the DeTeBerkom, a subsidiary of the German Telecom. Since January 1996, the system has been in use in 13 medical institutions. More than 30,000 images have been processed with MEDICUS since then (as of March 1997).

One can see that many different research prototypes and products offer a varying degree of functionality in teleradiology. The users of existing systems have their own understanding of what a good teleradiology system is. Requirements for a good teleradiology system are constantly in flux since the users are asking for more features and functionality all the time.

To obtain at least a rough classification of the systems, we developed the simple three generation model of teleradiology systems.

2. THE GENERATIONS OF TELERADIOLOGY

2.1 What is "Teleradiology"?

Radiologists and vendors of software and hardware in this field do not always share the same definition of teleradiology. Thus, it is probably necessary to point out that we are using the definition given by the American College of Radiology in the "ACR Standard for

Teleradiology” (Res. 21-1994). This resolution includes an initial definition of teleradiology (besides goals, qualifications of personnel, equipment guidelines, licensing, credentialing, liability, communication, quality control, and quality improvement for teleradiology). The ACR definition of teleradiology states the following [1]:

”Teleradiology is the electronic transmission of radiological images from one location to another for the purposes of interpretation and/or consultation. Teleradiology may allow even more timely interpretation of radiological images and give greater access to secondary consultations and to improved continuing education. Users in different locations may simultaneously view images. Appropriately utilized, teleradiology can improve access to quality radiological interpretations and thus significantly improve patient care.

Teleradiology is not appropriate if the available teleradiology system does not provide images of sufficient quality to perform the indicated task. When a teleradiology system is used to produce the official authenticated written interpretation, there should not be a significant loss of spatial or contrast resolution from image acquisition through transmission to final image display. For transmission of images for display use only, the image quality should be sufficient to satisfy the needs of the clinical circumstance.”

Since this standard should serve as a model for all physicians and healthcare workers who utilize teleradiology, we shall refer to it in this paper.

2.2 What is ”Not Teleradiology”?

A number of commercial products for video conferences or computer-supported cooperative work (CSCW) are on the market. The functionality of such products can be summarized as video telephony (see each other and talk to each other), working on a common work area or whiteboard (e.g., drawing, writing, display of images, manipulation of 3D objects) and application sharing. Examples of such products are ProShareTM (Intel) and InPersonTM (Silicon Graphics Inc.). All of these lack domain-specific functionality for the processing of digital radiographic images. They do not support the medical image standards ACR/NEMA or DICOM[2]. It is not possible to handle 12-bit images and they have no specific functions for level/window manipulation or the analysis of gray values. Other functions for image analysis and processing are missing as well. Other drawbacks are that they are not integrated into the existing environment of a radiology department (connection with imaging modality; management of patient data and organizational data). Application sharing systems have the drawback that the submission of a complete image series (up to 30 MB) over narrow band telephone lines, such as ISDN with two channels of 64 KB/sec each, is too slow for efficient interactive teleconferences.

2.3 Teleradiology: Generation Zero

From our point of view, teleradiology systems can be divided into at least three different generations. Generation zero can *not* be regarded as being true teleradiology systems according to the definition of the ACR. These systems can only submit images to another site. Synchronized teleconferences are not possible. Nevertheless, more than 50 vendors at RSNA ‘96 claimed to have a teleradiology solution, although they could not present teleconferences.

2.4 The First Generation

Among others, examples of first generation teleradiology systems are KAMEDIN [3] and MEDICUS [4]. The development of both systems has been funded by the German Telecom. Both systems are able to submit images to another location and to establish teleconferences with synchronized images and functions on both sides.

The ACR resolution also requires that the data transfer be conducted via the DICOM standard. This includes the DICOM file format and the communication protocol. The user should have access to the images via a patient database. MEDICUS is able to submit images to another location and to establish teleconferences with synchronized images and functions on both sides. Furthermore, MEDICUS can read DICOM files and receive images via the DICOM protocol (as C-Store Provider). A patient database gives access to the available image data.

The main disadvantage of first generation systems is that they emphasize the teleradiology component. But experience shows that a strong teleradiology solution must include more than this.

2.5 Second Generation Teleradiology

Based on the experience of first generation users, it is possible to specify a list of requirements for the next generation. Such requirements have been collected from different sources; the most important ones originate with users participating in the MEDICUS field test [8]. For more than one year now (as of March 1997), thirteen radiological institutions have been using the MEDICUS system. More than 30,000 images have been transmitted to other locations in this German field test [9] [10]. Additional requirements were obtained from a German study [12].

We started with the basic feature set of the MEDICUS system of the first generation. This cannot be repeated here, but specifics have been published by Engelmann [4]. Additional system features of the second generation can be divided into several groups:

DICOM Functionality

- DICOM is the basic communication protocol and image file format for receiving images from the imaging modalities.
- Images can be sent to imaging modalities, film printers and other devices via DICOM.
- The DICOM protocol should also be used for the distribution of images to other teleradiology systems.
- Query and Retrieve functions are available to get images from modalities and digital archives.
- Image printouts on film and paper are supported (via DICOM as well).

Viewing Functionality

- The second generation system is based on a general purpose radiology image workstation that can be used for reporting and viewing images, is connected to imaging modalities and has access to a digital image archive.
- The ergonomic user interface is based on results obtained in human computer interface research. The interface supports both inexperienced beginners and skilled experts who use the system in their daily routine [11].
- Data and functions are synchronized during teleconferences. The communication partner’s cursor is also visible on the screen. Both users have full access to all viewing functions.
- Advanced review/viewing functionality including image analysis and annotations with graphics, text and sound are available.
- Basic image manipulation functions are: interactive level/window functions, magnification, inversion of gray values, image rotation and flipping, and linear

measurements.

- Series of 2D images can also be displayed as cine sequences.
- Modularity: Since different users have different needs, the systems should be modular in the sense that a user can configure (and pay for) only the software modules he needs.
- As much screen space as possible is available for images.
- The database interface is easy to use both for query/retrieval of local data on the workstation and for external data in digital archives or imaging modalities.
- The system is capable of displaying small-matrix images (CT, MRI, ultrasound, nuclear medicine, digital fluorography), large-matrix images (e.g., digitized radiographic films or computed radiography) and image sequences such as cardiac image sequences.
- High resolution images (digitized radiographic films or computed radiography) must be supported by both the software and the screen resolution.
- Different monitor options should be available to match the actual requirements of the application scenario.
- The monitors should offer sufficient luminance (at least 50 foot-lamberts). Multiple monitor configurations should be available where necessary. A flexible concept allows the user to select the monitor which is appropriate to his actual needs (e.g., reporting, reviewing, presentation).
- Video capture: The system should be able to capture videos from connected video cameras or other video sources. It should be possible to capture and transmit video images during teleconferences. It is only necessary to capture still images. The transfer of live video images is not important for teleradiology [4][12].

Patient Database

- The patient database includes at least patient name, identification number, date, type of examination, type of images. These data are extracted from the DICOM files.
- The order of the data fields and the sorting order of the data should be customizable by the end user.
- The database should be based on the SQL standard to be able to use database management systems from different vendors. Support of the ODBC database standard, which is an emerging standard in the Microsoft world and in the World Wide Web, should also be considered.

General System Features

- A client/server solution should prove possible in a local area network where one workstation can act as a central server for data storage and distribution and a number of smaller clients can access the central server for viewing and teleconferences without prior image distribution to the conference partners.
- Multiple platforms: The system supports the UNIX world as well as the PC world (MS Windows, Windows 95 and Windows NT). Image transfer and teleconferences are possible across both worlds.
- Extensibility: New modules (plug-ins) can be added for additional software functions (e.g., dynamic MRI, 3D reconstruction, etc.). A developer toolkit allows the users (or other software vendors) to write their own plug-ins.
- Internationalization: The teleradiology systems of the second generation are customizable for different countries with respect to languages, data representation and specific cultural

differences.

- Good user documentation is a key feature of a good software system. The European tecom requirements can serve as a good guideline for user documentation, because they take into account international (ISO), national (ANSI, DIN) and industry standards for user documentation [13].

Security

- The systems should provide network and software security protocols to protect the confidentiality of the patient images and data. National laws must be respected.
- DICOM does not fulfill all security needs. Initial discussions about security concerns have now begun in the ACR and the NEMA.
- Technical, educational, organizational and software requirements must be taken into account when formulating security concepts. A good guideline in Europe is the Information Technology Security Evaluation Manual of the Commission of the European Union [5] [6]. An example of a an already realized security concept has been developed and implemented as part of the MEDICUS project [7].

Future Challenges

- The software development process should be certified by the ISO 9000 standard to guarantee the quality of the software production process.
- Cross-System Communication: Future teleradiology systems should permit communication between systems from different vendors.
- Interfaces to RIS/HIS have to be realized (although the users of a German study indicate that it is less important to them [12]).

3. CHILI: A SECOND GENERATION SYSTEM

How far away are we from a running second generation system? By mid-1996, the Steinbeis Transfer Center for Medical Informatics in Heidelberg, Germany, began developing such a system, as described above, in cooperation with the German Cancer Research Center. System design and development were based on the concepts and experiences of the MEDICUS project. The requirements for the second generation system have carefully been collected and integrated into the new concept. CHILI is a completely new implementation; the data model has been changed to be as DICOM compliant as possible. The result is a modular architecture of components that can be integrated into packages for the specific needs of users.

Realizing the future challenges requires a great deal of time and effort. Especially cross-system communications for teleconferences demands the participation and cooperation of many vendors and institutions. Existing standards must be extended. They are the subject of a work that is still in progress.

4. SUMMARY

A three generation model of teleradiology has been introduced. The requirements for the second generation system are discussed in detail. CHILI is a second generation teleradiology system which meets most of the user requirements for a second generation teleradiology system.

It is an open and portable system. At the core of the system is a general radiological workstation that possesses additional functions for teleradiology. The system is fully DICOM oriented and is, in fact, more a general radiological viewing station than a pure teleradiology system.

REFERENCES

[1] American College of Radiology: ACR Standard for Teleradiology. Res. 21-1994. http://www.acr.org/standards.new/teleradiology_standard.html.

[2] American College of Radiology, National Electrical Manufacturers Association. Digital Imaging and Communications in Medicine (DICOM): Version 3.0. In ACR/NEMA Standards Publication No. PS3. ACR/NEMA Committee, Working Group.

[3] Handels H, Busch Ch, Encarnacao J, Hahn Ch, Kühn V, Miehe J, Pöppl SI, Rinast E, Roßmanith Ch, Seibert F, Will A. KAMEDIN: A telemedicine system for computer supported cooperative work and remote image analysis in radiology. Computer Methods and Program in Biomedicine 52 (1997) 175-183

[4] Engelmann U, Schröter A, Baur U, Schroeder A., Werner O, Wolsiffer K, Baur HJ, Göransson B, Borälv E, Meinzer HP. Teleradiology system MEDICUS. In: Lemke HU, Vannier MW, Inamura K, Farman AG (Ed): *CAR ‘96: Computer Assisted Radiology,* 10th International Symposium and Exhibition. Amsterdam: Elsevier (1996) 537-542.

[5] Information Technology Security Evaluation Criteria, ITSEC, Brussels and Luxembourg 1991, DGXIII, ISBN 92-826-3004-8.

[6] Information Technology Security Evaluation Manual, ITSEM, Brussels and Luxembourg 1994, DGXIII, ISBN 92-826-7087-2.

[7] Baur HJ, Saurbier F, Engelmann U, Schröter A, Baur U, Meinzer HP. Aspects of Data Security and Privacy in Teleradiology. In: Lemke HU, Vannier MW, Inamura K, Farman AG (Eds): *CAR ‘96: Computer Assisted Radiology*, 10th International Symposium and Exhibition, Paris. Amsterdam: Elsevier (1996) 525-530.

[8] Engelmann U, Bahner ML, Schröter A, Baur U, Schroeder A, Werner O, Baur HJ, Meinzer HP. Practical and Clinical Experiences with a Teleradiology System. In: Orphanoudakis S (Ed): EuroPACS’96 Proceedings *14th International EuroPACS Meeting*: Institute of Computer Science, Foundation for Research and Technology - Hellas: Heraklion (1996) 78-82.

[9] Engelmann U, Schröter A, Baur U, Werner O, Schwab M, Müller H, Bahner ML, Meinzer HP. The German Teleradiology System MEDICUS - System Description and Experiences in a German Field Test. *European Journal of Radiology* 1997 (in print).

[10] Bahner M L, Engelmann U, Meinzer H-P, van Kaick G. Design necessities for future teleradiology systems - Conclusion from a field test. *Eur Radiol* (1997); 7:S17.

[11] Borälv E, Göransson B, Olsson E, Sandblad B. Usability and efficiency. The HELIOS approach to development of user interfaces. CMPBEK Vol. 45 (Suppl.) 47-64.

[12] Walz M, Bolte R, Lehmann KJ, Hothorn T,Brill C, Hothorn L, Georgi M. ANARAD: Requirements to teleradiology from German users’ point of view. In: Lemke HU, Inamura K, Vannier MW (Eds): *CAR ‘97: Computer Assisted Radiology,* 11th International Symposium and Exhibition, Berlin. Amsterdam: Elsevier (1997).

[13] Hoffmann, Hoelscher. Erfolgreich beschreiben - Praxis des Technischen Redakteurs, VDE-Verlag GmbH, Berlin und Offenbach, ISBN 3-8007-1987-8.