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Report

Transmission of Digital Ultrasound Images

Report no 1003

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Abstract

The **DISSH** project is a project of the Høykom program in Norway in 2003 and 2004, in which a prototype service for the transfer of cardiology images between hospitals in Norway is implemented. This report describes the design, implementation and evaluation of the *PACSflow*-application, which controls the entire process, and provides a user interface for the medical personnel. As much as possible of the existing infrastructure of the hospitals is used by *PACSflow*, which uses information from RIS and PACS systems. *PACSflow* was tested in a medical setting between Rikshospitalet (RH) and Sørlanded Sykehus in Arendal (SSiA), using broadband infrastructure. The report also gives an overview of relevant standards and procedures used in health care.

Keywords	medical images transfer, DICOM, PACS, RIS, cardiologic ultrasound images
Target group	Hospitals, Høykom program
Availability	
Project	DISSH
Project number	320306
Research field	distributed systems, medical image transfer, multimedia-multichannel
Number of pages	37

Foreword

This document describes the results of the project DISSH, which was funded, in part, by the Research Council of Norway under the Høykom program in 2003 and 2004. The participating institutions in the project include Interventional Center at Rikshospitalet, Norsk Regnesentral, and the Sørlandet Sykehus i Arendal. Commercial participants were GE Healthcare (Vingmed), Sectra Norge AS, and Communicate Norge AS, who deliver and maintain technical equipments and servers used in the project.

The main objective of the DISSH project was to enable for transfering medical data, e.g., cardiologic ultrasound images, between hospitals, while at the same time sending patient data and information on the medical case. At the same time the strict information security policies of the hospitals must be obeyed, and the medical personnel is given a user-friendly interface for sending and accessing the data. The project resulted in the implementation of the prototype PACSflow, which now will be taken into rigorous clinical testing.

The participants at the institutions were: Prof. Halfdan Ihlen at Rikshospitalet is the owner of the idea from the medical perspective. Ilangko Balasingham at Rikshospitalet is the project leader. From technical research and development Wolfgang Leister and Per Røe from Norsk Regnesentral participated. Other participants include Håvard Roterud from the department of radiology at Rikshospitalet, and Kjell Rune Haugland and Ola Morten Hauen from the department of information technology at Rikshospitalet. From the Sørlandet Sykehus i Arendal, Harald Brunvand had the medical supervision, while Morten Kaland and Ronald Bosgraaf contributed from the technical perspective. Participations of Olaug Råd from Rikshospitalet and Gunnar Gisleberg, Anders Hanke, and Bjørn Svalastoga from GE Vingmed Ultrasound AS are acknowledged.

Contents

1 Objectives

Ultrasound images are used for many different diagnostic purposes. One area of interest is diagnosis of heart diseases. Rikshospitalet (RH) has an expert team under Prof. Ihlen and serves as a national centre for diagnosis of difficult heart cases. The patients are often from remote regions, and most of them are small children. Most of the local hospitals have ultrasound scanners and can produce digitally encoded ultrasound images. On-line transfer of high quality ultrasound images from the local hospitals to Rikshospitalet will provide quick and better diagnosis and will be a great help for very sick patients.

1.1 Technology and Application

The new health reforms adopted by the Norwegian Government will probably increase the tendency for hospitals specialising in certain types of clinical procedures. It is expected that resources will be pooled and yet be geographically dispersed. Examples of such resources are specialised personnel and medical equipment. In practice, general hospitals today use more and more advanced diagnostic imaging of different organs in the body. Due to this there is an increasing need for discussing the images with highly specialised personnel. The advent of broadband communication facilities have opened for communication of such resource pools between hospitals despite the geographical distances involved. This has already been tested with success for example in radiology. By using this communication the correct diagnosis may be obtained in the local hospital and a decision can be made about treatment and where to do it. It is obvious that multimedia communication between hospitals has important impact on efficiency and quality in health care. We believe that there will be an increasing demand for this form of communication in the future.

Until now the data volume needed in the transfer of images between the hospitals have been relatively small. Recent diagnostic imaging in medicine is more and more advanced creating much higher data volume. A typical example is ultrasonic examination of heart disease. Ultrasonic scanners are present in most hospitals in the country, but it is not possible to transfer the digital ultrasonic data between hospitals today due to the current capacity and architecture of the data communication infrastructure. The aim of the DISSH project is to develop a technique that allows transfer of large amounts of digital data through the Internet without a reduction in the quality of the data. Ultrasonic digital data obtained during imaging of the heart contain high volumes, and are therefore chosen for the project.

The Internet and the World Wide Web are just a special cases of the ability for communities to share resources as they tackle common goals. Science today is increasingly collaborative and multidisciplinary, and it is not unusual for teams to span institutions, states, countries and continents. Grid technologies [1] envision that such groups connect their data, computers, sensors and other resources into a single virtual laboratory or organisation.

Practical use of new communication technologies will enable the health sector to utilise broadband in a cost-effective manner. In essence, large computing facilities will be made available to all relevant health personnel. This will enable access to geographically dispersed facilities, provide support for distributed research collaboration, and provide an infrastructure to support communication and learning – all this at reasonable cost.

1.2 The Clinical Application and its Key Benefits

1.2.1 Current situation and experience

The Echocardiographic Laboratory, Department of Cardiology, Rikshospitalet has, in cooperation with GE Vingmed Ultrasound, developed a system for complete digitisation of ultrasonic examination of the heart. Rikshospitalet has a high capacity broadband network, which is a prerequisite for delivering high volume data. Each cineloop of a heartbeat makes data amounts 2-10 MB and a complete examination of the patient produces 50-150 MB. The network of Rikshospitalet has shown able to handle such large amounts of data. Cardiac ultrasonic data obtained by an ultrasonic scanner are sent through the network from all sites in the hospital including the operating theatres and are saved on central servers together with other hospital data. Older patient data can very quickly be taken out from the servers for comparison with a new examination.

Our experience during the last five years is that this internal broadband communication of ultrasonic data between different parts of the hospital is an immense success. The efficacy of the ultrasonic main laboratory has increased significantly. Ultrasonic examinations are now performed routinely during heart surgery to evaluate the quality of the surgical treatment. Frequently the ultrasonic examinations reveal problems coming up during the operation procedure leading to resumption of the operation or changes in the procedure. We have several cases where the life of the patient was saved due to this ultrasonic monitoring of the surgery.

An important aspect of this monitoring is that we can compare ultrasonic registrations done during surgery with the preoperative registrations that are brought up from the central server to the operating room for direct comparison. Ultrasonic examination is now the most important technique treatment in our hospital for the diagnosis and surgical treatment of valvar heart disease. It is important that the network communication enables us as a daily routine to present the examinations for the cardiologists and surgeons. Generally, the doctors have now immediate and direct access to the images, which have improved their decision making in how to treat the patient. Because we do not lose quality of the images when they are saved digitally, we also got a very successful new tool for scientific work and education.

1.2.2 Future Situation and Key Benefits

Ultrasonic scanners for diagnosis of heart disease are now present in almost all hospitals in Norway. The next natural step now is to develop a system for communicating ultrasonic examination between hospitals. We believe that in adult cardiology it is very important to see the recordings with the same quality as obtained in the local hospital because poor acoustic conditions are often present in adults and reduce the diagnostic precision.

Today on-line communication between different hospitals is only possible using video technique. We consider high quality of the recordings to have higher priority than seeing on-line recordings that must have lower quality. Quick export of ultrasonic recordings from one echocardiographic laboratory to another will be of great clinical help particularly when treating very sick patients, but also when findings of uncertain significance need discussion with other experts. In addition, digital communication between hospitals will reduce the need for repeating the ultrasonic examination when patients are transferred to our hospital for further evaluation. This is particularly important for the examinations through the throat, which is a painful procedure for the patient, but extremely important in many very sick patients.

1.2.3 A clinical example

The following example illustrates the importance of digital networks between hospitals in the treatment of heart diseases.

A patient was admitted to a local hospital severely sick with high fever, shortness of breath and bacteria in the blood. He had previously been operated with implantation of an artificial valve between the left cardiac chamber and the main artery (aorta) due to a large leakage. Ultrasonic examination now showed a leakage in this artificial valve, but because the heart rhythm was very high it was difficult to assess how large the leakage was. A probe was therefore introduced into the throat and far better images of the valve and the heart were obtained. Abnormal structures around the valve were found around the valve and the examiner suspected an infection of the valve, but the images were difficult to interpret. Video recording of the whole examination was therefore sent to Rikshospitalet for review. When we reviewed the video recordings two days later we found the examination not optimal, but some images showed definite infection of the valve and a severe leakage, which explained why the patient was short in breath. The patient was therefore immediately transferred by ambulance plane to Rikshospitalet where a new ultrasonic examination through the throat was performed. This examination showed that the infection had almost loosened the valve from the heart with a severe leakage of blood into the heart chamber. The patient was sent directly to the operating theatre and operated with implantation of a new valve. He recovered completely.

This patient was close to death when the correct diagnosis was made. Ultrasonic images may be very difficult to interpret and may often need expert assessment. The two days time delay before experts evaluated the images was dangerously long. An immediate transfer of digital images to our hospital would have lead to a correct diagnosis two days earlier. We could also have guided the local doctors in how they should obtain additional images to assure the diagnosis even not being on-line. This example is not exceptional. Frequently we are in need of knowing exactly what the admitting hospitals have found. This is particularly important with critically ill patients, but the images can also lead to the conclusion that no severe heart disease is present and transfer of the patient is not necessary. A digital network between hospitals for transfer of ultrasonic images of the heart will be therefore of great clinical importance.

1.3 Project Objectives

The DISSH project deploys a a pilot service for digital ultrasound multimedia exchange based on existing broadband communication links in the health sector in Norway, implemented in the *PACSflow*-application. Other objectives include genericity. *PACSflow* is initially designed for communicating digital ultrasound data. However, the development is sufficiently generic to allow communication of other diagnostic data as well. The added value of *PACSflow* is along these three axes:

- **Technological added value:** The ability to provide and support a complex service for health care workers across hospitals.
- **Organisational added value:** The ability to provide cost-effective services to several organisational units in the face of dispersion of resources.
- **Economic and social added value:** The ability to handle higher volumes of patients or to perform medical treatment and analysis with higher quality.

The *PACSflow*-application implements the necessary user interfaces for the medical personnel, and the interfaces to the technical infrastructure of the hospitals, i.e., the PACS, the HIS and the networking infrastructure. The requirement scopes for *PACSflow* include:

- *PACSflow* implements a user interface for sending and retrieving images and medical data. The user interface is suitable to be used by medical personnel without profound knowledge of ICT-systems.
- *PACSflow* interfaces the PACS of the hospitals for retrieving data, and for initiating DICOM transfer between PACS.
- *PACSflow* interfaces the HIS for retrieveing administrative data. *PACSflow* also ensures the integrity of the patient data with respect of all data elements being correctly associated to the

patient.

- *PACSflow* provides a messaging facility for informing medical personnel on newly arrived data, and for the transfer of descriptions on medical cases.
- *PACSflow* uses current standards and procedures within health care as far as possible. The existing infrastructure of the hospitals must be used without introducing new services that need special attention of the IT departments.
- *PACSflow* obeys the security policies used within health care in Norway. This includes availability in operating hours, confidentiality and integrity of the data.

Since this is the first attempt to achieve this kind of functionality in the hospitals in Norway, and since we have limited resources with regard to the infrastructure, we cannot address every wish from the potential users. We do not address preview facilities of the remote medical images, real-time transfer of the images, video conferencing facilities, and 3D-tracking of the ultrasound probe using a virtual probe at the expert side.

The result of the DISSH project is the implementation the *PACSflow*-application, which provides a service that exploits broadband communication between hospitals for distributing echocardiographic digital ultrasound data. With *PACSflow* it should be possible for a remote hospital to send medical images to Rikshospitalet and within an hour obtain a critical evaluation of the images and advices how to further examine and treat the patient.

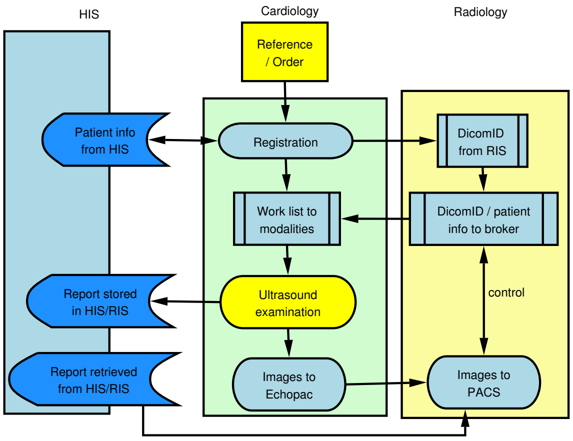

Figure 1. Work flow at cardiology department.

2 Technical Background and Requirements

We investigated a number of issues such as inter- and intra hospital network infrastructure, US scanner export and import functionalities, US data format and transmission, standards and routines at departments and hospitals. Subsequently, in the course of these investigations we noted that routines of handling messages and data from other hospitals lack standardised practise. In the following we outline systems and practise used at the departments of cardiology and radiology.

2.1 Present Solutions

Present solution at the Department of Cardiology The department of cardiology at Rikshospitalet uses US scanners from GE Vingmed Ultrasound AS, Horten, Norway. The scanners are connected in a separate private network called Echo-net. It has options for storage and disk backup facilities. Workstations and PCs, operating on Microsoft Windows XP, are connected in the Echo-net. The EchoPAC software, delivered by GE Vingmed Ultrasound, is used for accessing US data from databases, viewing and analysing images and cine-loops, and creating examination reports. It provides also the possibility to export and import US raw format data (a proprietary format by GE Vingmed Ultrasound) to DICOM[1] in JPEG[2] compressed format. This option makes it possible to export and import US data from DICOM servers, e.g., a PACS. However, in the present configuration this option is not active. Images that are exported to a PACS must have valid DICOM fields for UID (unique ID), name, personnummer, date of birth, gender, etc. preferably obtained from the hospital information system (HIS). In the present configuration of EchoPAC, worklist is not active.

Present solution at the Department of Radiology. The department of radiology at Rikshospitalet implemented PACS in 2002. The PACS is delivered by Sectra AB, Linköping, Sweden, while the radiology information system (RIS) is delivered by Kodak Inc, USA.

The routines at the department of radiology are somewhat different from that in the department of cardiology, since they have different requirements and raw image formats for analysis and viewing purposes. The department of radiology has a streamlined system where PACS, RIS, and

1. Digital Imaging and Communications in Medicine.
2. Joint Picture Expert Group.

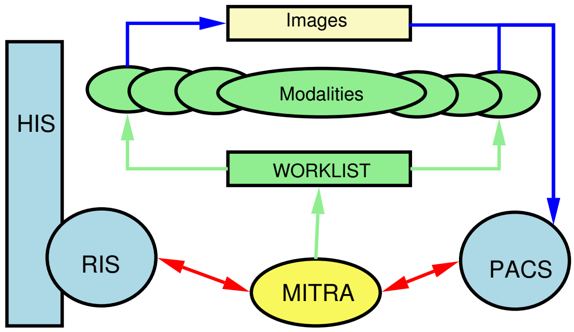

Figure 2. Setup of RIS and PACS at Sørlandet Sykehus i Arendal.

PIMS (patient information management system, aka HIS) are interconnected.

Present solution at Sørlandet Sykehus i Arendal (SSiA). We show the setup at Sørlandet Sykehus i Arendal (SSiA) in Figure 2, where all communication between RIS and PACS is controlled by the MITRA broker. SSiA uses the DIPS as HIS system. Both PACS and HIS are available at the entire hospital, while the RIS parts are only accessible by the departments due to security reasons. This means that each department (radiology, cardiology, etc.) has their own RIS implemented as a closed area of the HIS[3].

General routines. When images of a patient are taken, the medical personnel needs to enter the patient information, including a unique personal ID, e.g., in Norway the person identification number (personnummer). The correct relationship between patient, medical data, reports, and images is achieved using the HIS. The RIS, which is connected to / a part of the HIS generates a DicomID and the data for the work lists. Additionally the technical parameters, e.g., compression methods, must be entered.

When medical images arrive from another hospital by other means than PACS to PACS, the images are not attached to a DicomID. The DicomID must be generated manually. The routines include that a cardiologist writes a referral, the radiology department registers the patient data in the RIS, manually attaches the data to the DicomID, fills out forms[4], and acknowledges the description in the RIS. For each examination, approximately 5-10 minutes are used to perform the procedure.

The routines for teleradiology included several manual steps both on sender and receiver side, as shown in Figure 3. The steps include writing the referral. In some cases anonymizing the referral, answers, journal documents, descriptions, type of examination, number of images, etc. The next steps include calling the recipient by phone, faxing the data, and sending the images PACS to PACS. The recipient must perform a quality check, register the examination in the RIS, attach the DicomID, scan documents, etc. For this procedure each side uses ca. 30 minutes, since most of the steps are performed manually. Note, that this procedure also can result in a possible quality loss, since some documents are sent by fax and scanned afterwards.

The number of manual steps on both sides must be reduced, which includes that the documents are transferred electronically, the quality check must be automated, and smart calling should be introduced. An integration between PACS and RIS must be considered.

3. Note, there are different routines in radiology and in cardiology.
4. At SSiA the form "Underssøkelsen overført Kardiologisk Avdeling 241103" is used.

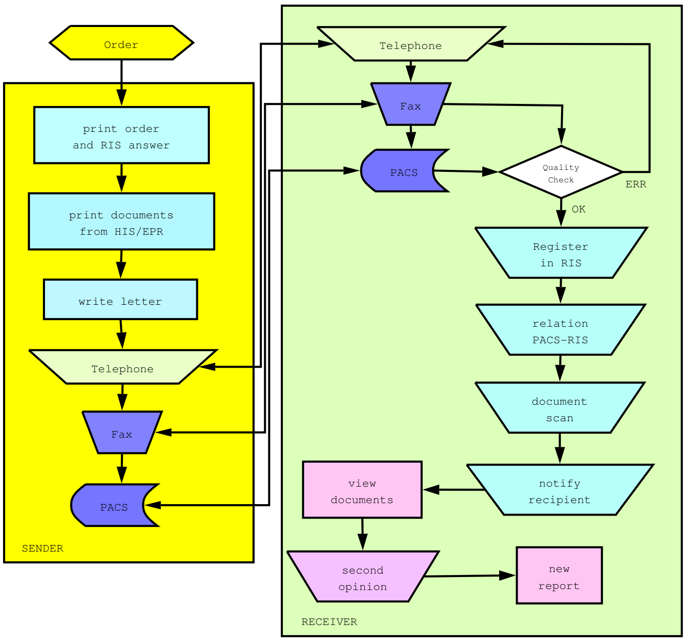

Figure 3. Sketch of cardiology workflow at DISSH project start. Note that PACS and RIS are very recently introduced (independent from the DISSH project), and data transport on CD, and manual routines for retrieving other information were employed just at project start.

2.2 Standards and Formats

2.2.1 Image Data Format

Ultrasound scanners produce different image formats depending of the application requirements, and the underlying system. GE Vingmed Ultrasound scanners produce image data in a proprietary image format, which can be exported to DICOM supporting supporting lossy and lossless image compression.

DICOM [2] is used for exchanging, storing, and retrieving medical images, including imagery within radiology and ultrasound cardiology. DICOM is a standard by the American College of Radiology (ACR), and the National Electrical Manufactures Association (NEMA). The DICOM standardisation documents are available at `http://medical.nema.org/dicom`. The first version of DICOM was released in 1985, the second in 1988, and the third in 1993.

The DICOM standard defines the semantics of commands and associated data, the semantics of file services, file formats, and information directories, and operation in a networked environment. It consists of sixteen parts[5], covering various subjects including information objects, service classes, data structure encoding, data dictionary, message exchange, network communication support, media storage, file formats, and security profiles.

DICOM defines information objects for images, and for administrative data, e.g., patients, studies, reports, and other data groupings. DICOM specifies data formats, a network protocol utilising TCP/IP, defining the operation of service classes beyond the simple transfer of data, and a mechanism for uniquely identifying information objects.

2.2.2 Image Coding

Image coding standards provide solutions to compress, decompress, and error concealment for effective storage and transmission of raw image data. Currently, medical image data can have

5. including two parts which are retired.

resolution up to 16 bits per pixel. Within radiology the only acceptable compression standard has been lossless scheme, with a typical file size reduction by a factor of 2–3. The coding standards supported by DICOM include raw raster image, JPEG[6], JPEG 2000 [3], and JPEG-LS [4, 5]. The following image coding packages were investigated as candidates:

Sharpbyte. The Irish company, Sharpbyte Ltd (`www.sharpbyte.com`) offers a product, which uses a patent claimed technology for medical applications. The Sharpbyte solution was evaluated by Rikshospitalet within the frame of the project (See Appendix C). The product seems suitable for our project with respect to encoding requirements. However, the price tag seems too high. This solution would be non-standard with respect to PACS.

Huffyuv. Huffyuv is an implementation for a lossless video encoder. See Appendix B.1.1.

JPEG 2000. The JPEG 2000 standard (ISO/IEC 15444-1) uses wavelets and arithmetic coding for providing lossy and lossless compression methods for images. The list of implementations of the JPEG 2000 codec includes an implementation by Norsk Regnesentral for JPEG 2000 and MJPEG 2000, J2000, JJ2000, Kakadu, and Jasper. See Appendix B.1.2 for a description of the software packages.

JPEG-LS. Developed originally by HP for lossless compression in medical imaging applications. The codec uses a combination of prediction codes and Huffman entropy coding. The reference implementation is from Hewlett-Packard (see Appendix B.1.3). Other implementations include the codec from the University of British Columbia, and the implementation by D. Clunie (see Appendix B.1.4).

2.2.3 Message and report formats

When investigating a medical case images and associated examination reports containing various information about the patient are required. Presently, DICOM does not support such examination reports to be included. Although using private tags in DICOM might be an option, this has so far not been used, since the use of these features need changes in the setup at every site they are used. Recognising this problem, the DICOM committee has started working on a solution called DICOM structural reporting (DICOM S/R), which still is an ongoing work.

Within one hospital there might be many different electronic patient record (EPR) systems available. The most used major EPR systems in Norway are DIPS, InfoMedix, and DocuLive [6]. The documents and messages created by proprietary systems are difficult to incorporate in applications delivered by other vendors. To address this issue, IHE (Integrating the Health care Enterprise) was established in the US (`http://www.rsna.org/IHE`), and is being considered in other countries, e.g., in Norway.

EDI (Electronic Data Interchange) works by providing a collection of standard message formats and element dictionary in a simple way for businesses to exchange data via any electronic messaging service. XML (extensible markup language) together with EDI provides a standard framework to exchange different types of data – for example, an invoice, health care claim, project status – so that the information be it in a transaction, exchanged via an Application Program Interface (API), web automation, database portal, catalogue, a workflow document or message can be searched,

6. ISO/IEC IS 10918-1, ITU-T Recommendation T.81.

decoded, manipulated, and displayed consistently and correctly. The supporting standards include DICOM [2], HL7 (see `http://www.hl7.org`), and XML. KITH (`http://www.kith.no`) provides reports and recommendations that health care system vendors in Norway use as guidelines for respective systems.

2.2.4 Data Transfer

A typical transfocal echo US examination can produce several hundreds of Mbytes of data. A frame rate of 100–150 fps is common. Taking into account of image resolution, bits per pixel, full colour (RGB), and frame rate, it is evident that images need to be compressed prior to transferring on a bandwidth limited network.

DICOM [2] is used to transfer the images between PACS. DICOM uses TCP/IP as the underlying networking protocol. The IT departments of the hospitals provide secure data transport between the PACS. Whether security is achieved by using secure lines (e.g., ssh-tunnels, VPN), or by using DICOM Part 15 [7] is beyond the scope of our project. In the DISSH-Project a VPN-solution is used.

Besides the medical images, administrative data and notifications must be transferred. These data contain information on the patient, and descriptions of the medical case including diagnosis information. This type of information is confidential and sensitive, and security policies apply for the transfer between hospitals. The policies of the hospitals require that sensitive medical data cannot be sent by email.

The networks of the hospitals in Norway where the clinical data can be accessed are separated from publicly accessible networks. Clinical and sensitive data cannot be accessed from the outside of these networks. Strict policies, controlled by the Norwegian Data Inspectorate (Datatilsynet), apply to data exchange between hospitals. The closed networks of the hospitals are interconnected by the national health care network (nasjonalt helsenett).

The hospitals of Norway are using the AMTrix message broker system for communication both inside the hospitals and between each other[7]. The AMTrix installation defines policies and rules approved by the Norwegian health authorities for different types of information.

2.3 Security and Integrity Requirements

The standard ISO/IEC 17799 [8] is relevant for security and integrity requirements. The key aspects of Information Security are to preserve the **confidentiality**, **integrity** and **availability** of an organisation's information. All three properties are relevant for the DISSH-project, since loss of one or more of these attributes can endanger the performance of a hospital.

Within the DISSH-project most of the security issues are covered by the infrastructure of the hospitals. Within the hospitals the security requirements are moderate, while the security requirements between hospitals are very strong. Confidentiality and integrity are achieved by using secure lines, VPN, and other suitable middleware, which are beyond the scope of our project.

Patient data and medical data are considered confidential. Since the SMTP protocol is considered non-secure by the health authorities, these data are not allowed to be sent over email. For transfer of confidential messages the AMTrix message broker must be used, which is part of the infrastructure of/between the hospitals.

7. See the entry on AMTrix in the glossary in Section A

2.4 System Integration and Tool Selection

The DISSH project to used standards, tools and routines acknowledged for the use in health care in Norway. The introduction of new routines must be done carefully, and in full accordance with the policies of the involved personnel and the health care authorities. Wherever possible existing infrastructure with a perspective in the future was used. We also intended to use technologies which will be mostly compatible with future standards in health care, where they are not yet decided (e.g., HL7, XML-based patient records, DICOM S/R). The following policies are used:

- The DISSH project uses DICOM for storing images, and transfer of medical images between PACS of the involved hospitals. Where implemented, PACS of the hospital installation will be used; For hospitals without a PACS implementation a PACS must be chosen.[8]
- The DISSH project builds on hardware and operating system policies of the hospitals. This includes that *PACSflow* is implemented as independent from these issues as possible. We provide both a solution for both Linux and a Windows environments.
- For messaging the use of the networking infrastructure is done according to the policies of the hospital. This includes the use of the AMTrix message broker.
- Since the capacity of the interconnection between the hospitals is large enough, there is no need for using other coding than the PACS and the DICOM standard offer.
- Upon arrival of medical data the medical personnel must be notified. Since security policies in hospitals do not allow for sending email containing patient data, we considered (a) to use DICOM structured reporting, which contains the messages in the receiver headers[9], or (b) to use the message broker middleware when sending the messages from the sender-side.

8. The choice of a PACS is beyond the scope of this project. However, for open source alternatives we provide a short overview in Section B. The DICOM Toolkit (see Section B.2.1) seems to be a suitable alternative, possibly in connection with the CDmedic distribution (see Section B.2.4).
9. DICOM gives the possibility to define new tags, which could be used in our case. However, this would result in a non-standard implementation, resulting in potential compatibility problems.

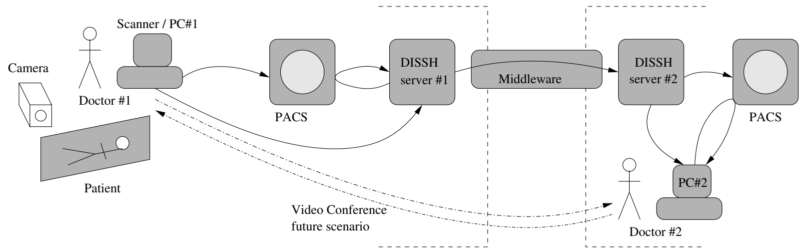

Figure 4. Illustration of the DISSH use scenario.

3 The *PACSflow* Application

3.1 The Use-Scenario

The scenario illustrated in Figure 4 is basis for our decisions on system architecture. The actors and facilities at the sending hospital are marked with #1, while the actors and facilities at the receiving hospital are marked with #2. The scenario in more detail is as follows:

1. The medical image data are taken from a scanner and stored in the PACS database in DICOM format at Hospital #1.
2. Doctor #1 of Hospital #1 requests medical image data to be sent to Doctor #2 / Department at Hospital #2 for medical analysis. Doctor #1 fills out a form on PC #1, and the form is sent to DISSH server #1.
3. DISSH server #1 retrieves medical image data from PACS database, transfers it to DISSH server #2, which stores the data in the PACS of Hospital #2.
4. The DISSH software creates a notification message, containing the medical case, that is sent to the mailbox of Doctor #2.
5. Upon receipt of the message Doctor #2 can access the medical image data from the local network of Hospital #2.

3.2 System Architecture

The DISSH-software consists of the distinct parts which are explained in the following. Additionally, the infrastructure of the hospitals, and between the hospitals are used, which include the PACS, the message broker middleware, and the communication infrastructure.

- The *PACSflow*-web application is used to provide a user interface to the medical personnel, using a standard web browser for interaction. The doctor at Hospital #1 enters the patient and study, including medical information on the case.
- The web application interfaces the PACS by using commands of a toolkit accessing DICOM.
- The DISSH application generates messages for the medical personnel, containing the ID for the study, and medical information on the case.
- The doctors at the receiving hospital access the data by using a browser. The application is controlled by the web application. The viewing functionality of the images itself is provided by software of the PACS.

3.3 Platform Choices

Since the hospitals in Norway use some flavour of the Windows operating system as the default platform, it is essential that the *PACSflow*-application runs on a Windows platform. However,

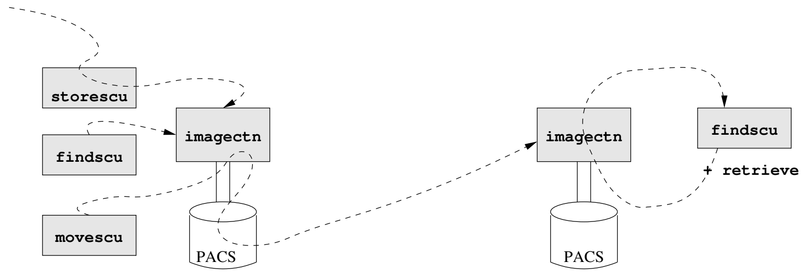

Figure 5. Illustration of DCMTK used in DISSH.

since Linux is used to an increasing extent, we implemented the application to be interoperable with Linux as far as possible. Most parts of the development were performed on a Linux platform, before they were implemented in the real environment at the hospitals.

It was decided to implement a web application, which implies that most parts of the user interface are handled in a web browser, while a web-server handles the requests, and interfaces the PACS and the other infrastructure. The web-application can later be integrated in a portal solution.

For the implementation of a web application several possible technologies can be used. We considered using technologies based on CGI-scripts using programming languages like Perl and PHP, which are platform-independent, and relatively simple to implement. We also considered using frameworks like .NET and J2EE, which use web-services. These already contain support for XML, which would simplify the implementation of messaging over XML, as suggested by some of the initiatives for information exchange in health services. However these frameworks require the setup of a special application server, and the implementation would be platform-dependent.

We decided to base the implementation of *PACSflow* on PHP, whose run-time environment can be easily installed on both Windows and Linux platforms. PHP applications can be run on both Apache and MS IIS web servers.

3.4 PACS Functionality

The medical images are stored in a PACS, and the transfer of images is implemented as a transfer of data between PACS. Rikshospitalet and SSiA both use the Sectra PACS within radiology, which supports transfer and decoding of JPEG-encoded DICOM files according to their conformance statement.

Partner hospitals which do not already have a PACS in use, can implement this functionality using open source software. Suitable choices are: the MIR CTN, (see Section B.2.2), the imageCTN of DCMTK (see Section B.2.1), and the PACS of the Java DICOM Tools (see Section B.2.7). MIR CTN implements most functionality; while imageCTN and DCMTK already contain JPEG-related code.

Since the involved hospitals are using the GE VingMed ultrasound scanner *PACSflow* must be able to store and process files generated by this equipment, which produces compressed images using the the JPEG baseline transfer syntax. The Sectra PACS is capable of storing, sending and receiving this type of images. However, the *imageCTN* does not support the JPEG Baseline transfer syntax for the compressed images. The *MIR CTN* does not accept data via the JPEG baseline transfer syntax. The Java DICOM Tools support the JPEG baseline transfer syntax.

Interaction with the PACS involves DICOM commands, e.g., C-FIND, C-MOVE, or C-STORE.[10]

10. In the software DCMTK the programs findscu, storescu, and movescu can be used to call these functions from a shell

In order to demonstrate the transfer functionality outside the protected areas of a hospital, we used the DICOM toolkit (DCMTK), which runs on Linux and Windows platforms, as follows (see also Figure 5):

- On two machines each we set up an image base (CTN) with the application *imagectn*, which implements the C-FIND, C-MOVE, C-GET and C-STORE service classes.
- We implemented a program to list all available DICOM files in a image base, using the application *findscu*. The resulting list of files can be used to select files for transfer later.
- We implemented a program to initiate transfer of a given DICOM file to a remote CTN.

3.5 Notification and Messaging Functionality

Medical personnel are notified by *PACSflow* upon arrival of a new medical case, i.e. the ultrasound images have been transferred. The doctors at the receiving hospital can access the description of the medical case, and diagnostic data attached. Due to security reasons we cannot use email for transport of these messages, but make use of other message handlers supported in the infrastructure of the hospitals.

The implementation of messaging within the health-care domain is subject to several national [9] and international projects, e.g., HL7 and IHE. Since these efforts have not yet concluded, we implement our own scheme.

3.5.1 Messaging using DICOM headers

A solution using solely DICOM mechanisms would include: The (email) address of the receiver must be included into the DICOM file. This solution includes to add information to the DICOM files, extracting this information, and use this information in order to notify the receipt of a file.

One way to accomplish notification is to use tags in the DICOM header for addressing. For this purpose private tags and existing tags could be used. Several fields in DICOM refer to physicians. The most relevant is the field "Referring Physician", which is the physician asked for a second opinion. Other relevant fields include "Physician approving interpretation", "Physician(s) of record", and "Name of Physician(s) reading study".

This approach is non-standard causing possible problems, since the receiving physician will not always have the same role, and methods for notification based on the fields in the DICOM-header must be built into the receiving PACS. The use of DICOM S/R (which uses standardised DICOM headers) has been considered. However, since the working groups have not concluded their work yet, we did not implement this approach.

3.5.2 Messaging outside DICOM

As an alternative to the above, we use a separate communication protocol, where the message is put together, either as an XML message, or as a pure text message. The message must be assembled on the sender side, since the message content is not available on the receiver side.

Since the DICOM protocol ensures that the status of the transfer of the images is returned to the sender when the transfer is completed, it is not necessary to synchronise with the reception of the images. Therefore, the notification can be issued either on the sender side when the message is sent, or on the receiver side when the message is received.

---

command interface.

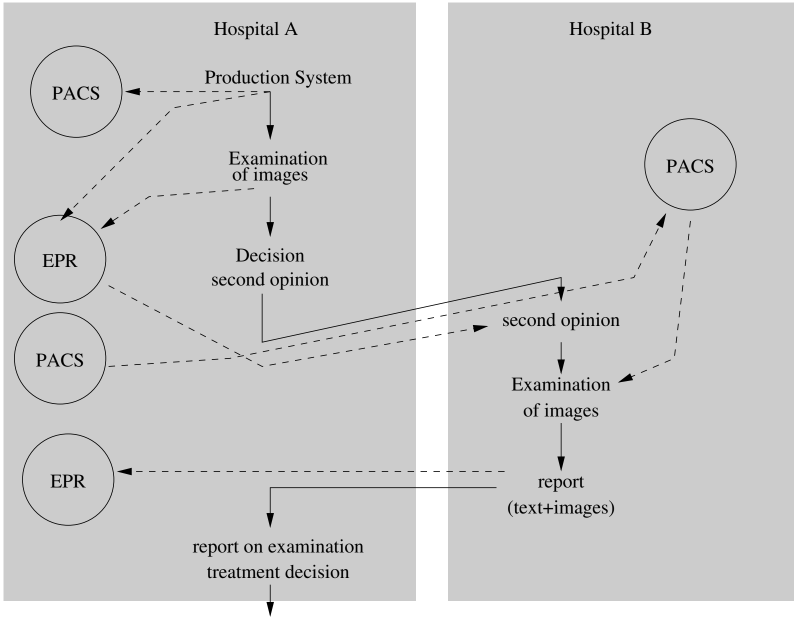

Figure 6. Components and control flow (straight lines) and data flow (dashed lines) in *PACSflow*.

3.5.3 Implementation of Messaging

The messages transfered to the receiving department use the AMTrix message broker system. Its use is approved with regard to the security requirements for sending sensitive patient information.

After the transfer of the image series has succeeded the web-application stores a message in a dedicated folder on the web server. This folder is checked regularly by AMTrix whether a new file has arrived. If so AMTrix fetches this message using FTP. AMTrix then forwards this message according to header informations to the installation that serves the recipient. The receiving AMTrix installation then uploads the message to the receiving web-server, again using FTP. The receiving AMTrix also sends an email notification locally to the email addresses specified in the headers.

Several formats for the message are possible, including several XML formats. For the sake of simplicity we use an ASCII text representation for the message, since the XML formats have not yet been standardised. Defining XML formats for messaging is implemented elsewhere [9].

Each message contains a header formatted in ASCII text, the message, and optionally an attachment. The ^-character is used as a separator between the different fields, which are interpreted by AMTrix. A message has the following fields, which are explained in Table 1:

```
SENDER^RECEIVER^RECV_EMAIL^EXTRA_RECV_EMAIL^TIMESTAMP^ID^TITLE^MESSAGE[^ATTACHMENT]
```

3.5.4 Notification

On basis of the contents of the message a notification is assembled by the receiving AMTrix. Currently in *PACSflow* this notification is sent through e-mail, and therefore may not contain sensitive information. The notification contains the timestamp, sender department, message title, and message ID. Using the message ID it is easy to retrieve the correct message in the web-application.

Field	Description
SENDER	AMTrix-code denoting the sending department.
RECEIVER	AMTrix-code for the receiving department.
RECV_EMAIL	Email-adress for notification.
EXTRA_RECV_EMAIL	Extra email-address for notification. This field can be blank.
TIMESTAMP	UNIX timestamp of time when the message was sent.
ID	Message ID. Format: DATE-TIME-PATIENT INITIALS. Example: `100504-101133-TH`.
TITLE	Message Title.
MESSAGE	The main message.
ATTACHMENT	Attachment encoded in BASE64.

Table 1. Description of message fields

3.6 Web Application

The Web Application implements the user interface, and the control of the commands to the PACS, e.g., initiation of data transfer, and messaging. The Web Application also contains functionality for lookup-tables, in order to hide unnecessary technical details from the medical personnel. These lookup-tables implement user data, departments, location of data, CTN name, ports, etc.

3.6.1 Implementation

The PHP scripts of the web-application generate the HTML code that is viewed in the browser. Functionality that makes the application behave more dynamically, is implemented using JavaScript. The application contains of three modules, one module for sending image series and messages, one module for viewing received messages, and one module for the administration of user data.

The most important windows of the user interface are shown on the front page (login window), and in Figures 8–12. The main window for sending medical images is shown in Figure 11 Information about sender and receiver is retrieved from the user database. From this window it is possible to open a dialogue for searching and retrieving image data from PACS. The sender fills out the form, which is converted into the message sent to the recipients. Additional documents can be attached to the message, e.g., a report exported from EchoPAC or data exported from a patient information system.

The details of the message transfer are described in Section 3.5.3. After the message has arrived at the receiving department, the web-application offers an interface for reading the received messages, and viewing the attached files.

3.6.2 Security

The web-application is secured by that the user has to log in using a username and password. This is handled in PHP, and it makes sure that no non-authenticated user can access any part of the web-application. Further security issues can easily be added, since standard software and standard protocols are employed.

3.6.3 Work flow and Information flow in *PACSflow*

In Figure 6 we show the overall data flow and control flow for the *PACSflow* application. Note that the production system (e.g., ultrasound scanner) is beyond the scope of the DISSH project. However, it is required that *PACSflow* can use the images produced by the production system, which are inserted into a PACS using DICOM. When a doctor uses the *PACSflow* an electronic form will be filled out including diagnosis data. After the doctor at the receiving hospital is no-

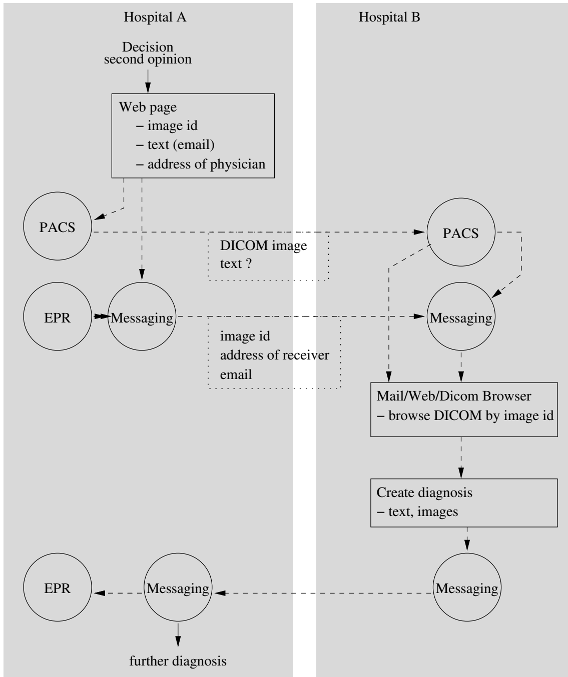

Figure 7. Detailed flow graph for *PACSflow*.

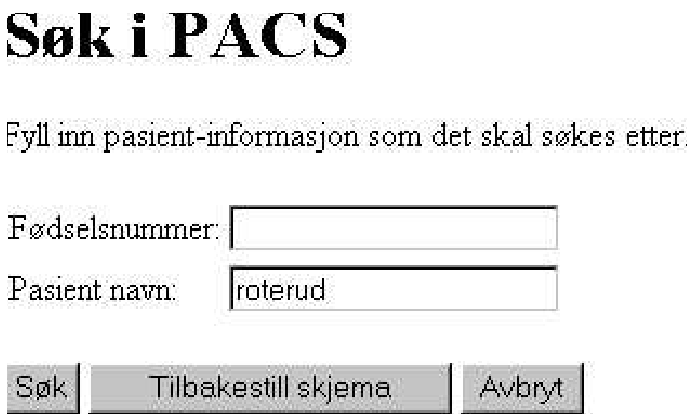

Figure 8. User interface for searching after patients in *PACSflow*.

tified, he can access the images and perform a second opinion, which is sent to the requesting hospital.

Figure 7 shows in more detail how the information flows are designed. PACS, EPR, and messaging modules in both hospitals are important parts in this diagram.

After the decision of requesting a second opinion is taken, an electronic form completed and the information is sent to the *PACSflow* web application. The electronic form contains the following information, which partially are collected from the HIS/EPR:

- study ID of the DICOM images;
- sender (including phone numbers, department, etc.);
- address of receiver or receiving department;
- details about the case, and what the receiving physician is requested to do.

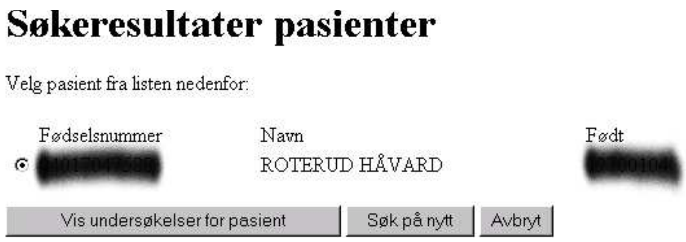

Figure 9. Results from the search after patients are presented. When several candidates are available the right patient can be selected.

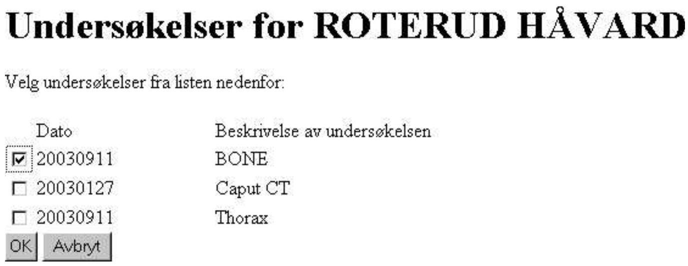

Figure 10. Show the medical images available in the PACS for a patient. The Case(s) to be transferred can be selected.

After the data are transferred to the Hospital #2, the doctor #2 will receive the following data in order to perform the second opinion:

- a notification about a new case arriving;
- the DICOM object(s) transferred to PACS at Hospital #2;
- a message containing ID of the DICOM object, together with with patient information, and information about the case #1.

After the second opinion is performed the result of the examination is sent back as a message to Hospital #1, where the information is added to the HIS/EPR of Hospital #1.

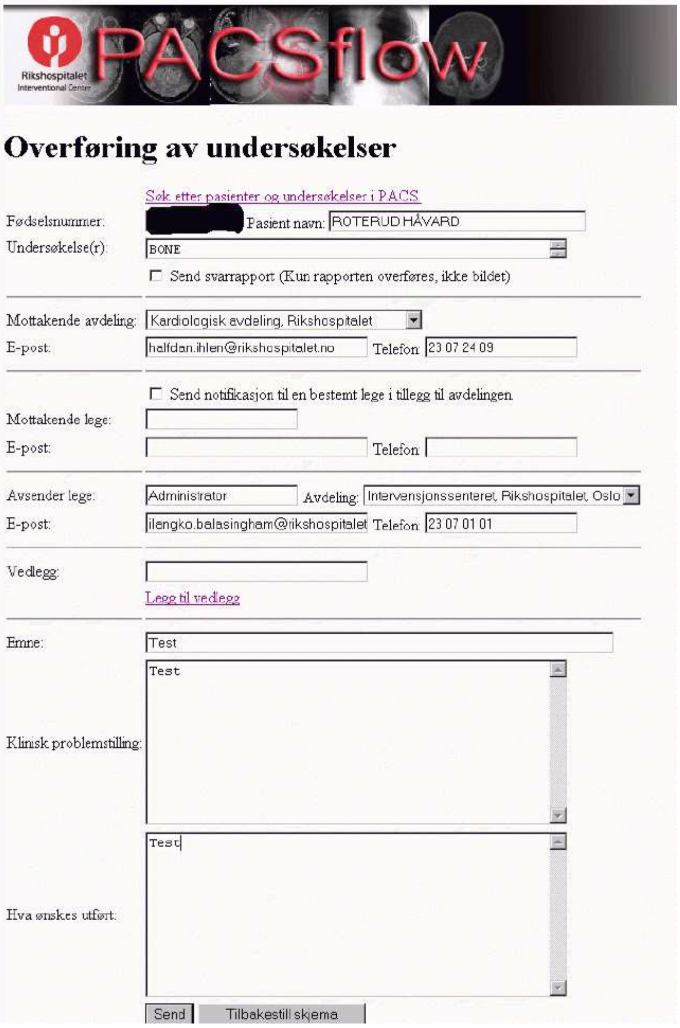

Figure 11. User interface of *PACSflow* for sending medical images. For some fields sub-windows pop up.

Figure 12. User interface for chosing departments that can receive medical images.

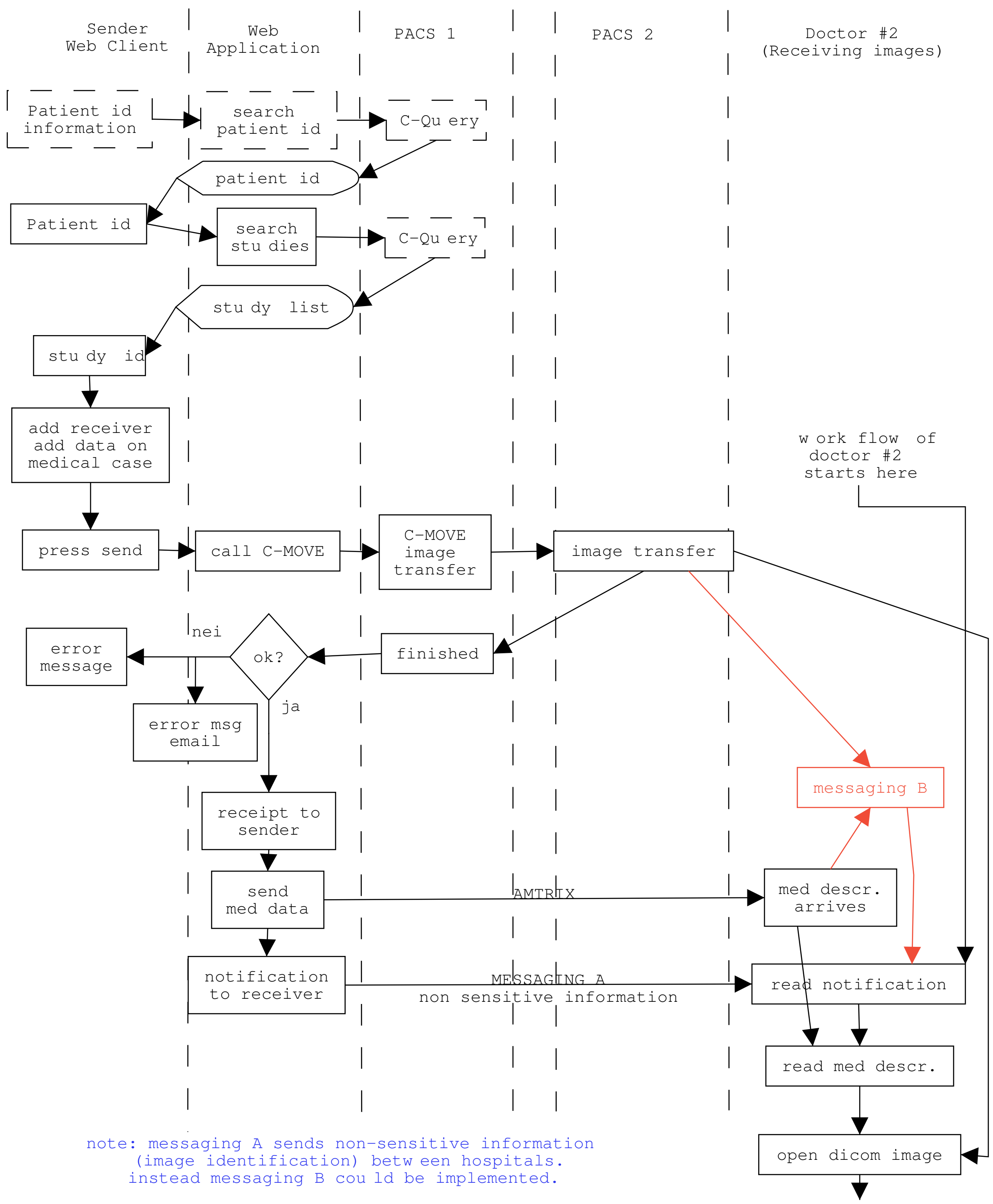

Figure 13. Work flow for implementation of *PACSflow*.

4 Medical Tryout and Conclusions

The *PACSflow*-application is now implemented at Rikshospitalet and SSiA. Since the medical tryout phase only has been started recently, we cannot give yet comments on the effectivity of our solution.

The work in the DISSH-project resulted in the implementation of the *PACSflow*-application, which provides a user interface for doctors at hospitals to transfer medical images to another hospital using a web browser. The application has the potential to simplify the image transfer, shorten down response time for medical answers, and to reduce treatment costs in general.

While working with the project we recognised that the manifold of standards, applications, systems, providers, and routines in all domains of health care was much more complex than first assumed. Many of the systems in health care are not compatible with each other. This observation includes image formats, messaging, modalities, information systems, etc. The application *PACSflow* provides a simple interface that hides this type of complexity from the user in the domain for medical second opinions within ultrasound cardiology and radiology in general.

4.1 Experiences

A cardiac US scanner (Vivid 7, GE Vingmed Ultrasound AS, Horten, Norway), which produces digitally encoded images and image sequences, was used to acquire US images. The images were compatible with the digital image communication in medicine (DICOM) format. A visualization software, EchoPAC (GE Vingmed Ultrasound AS, Horten, Norway), was used to push US images to patient archive communication system (PACS) (Sectra AB, Linkøping, Sweden) using DICOM classes.

The prototype system has been tested from a technical perspective. The department of cardiology at Rikshospitalet and the department of internal medicine at Sørlandet sykehus in Arendal, Norway are performing clinical use of the system. Cardiac US image sequences were compressed using lossy JPEG standard. This reduced the file size by a factor of 3. Initial test indicates that an examination containing image sequences of 184 MB data required 8.3 minutes to transfer from Arendal to Oslo using PACS to PACS communication on an effective 3 Mbits/s channel.

A clinical evaluation study of the system will be presented in a paper shortly. After the clinical evaluation phase the *PACSflow*-application will be offered to other hospitals, and undergo a commercialisation.

A Glossary

We present a list of relevant terms, acronyms, systems, standards and procedures employed in hospitals in Norway. Reports on some of the subject are available from KITH (`http://www.kith.no`).

HIS: Hospital Information System; information system used in hospitals for administrative patient-data and/or EPR. At Rikshospitalet the system *DocuLive EPR* (Siemens) is used, while Sørlandet Sykehus i Arendal uses DIPS. In the hospital-sector in Norway the systems Doculive EPR, DIPS, InfoMedix are used; see `http://kvalis.ntnu.no/index.htm` for an overview.

EPR: Acronym for Electronic Patient Record; identical to the term EPJ used in Norway.

EPJ: Acronym for Elektronisk Pasient Journal; norwegian word of EPR.

DIPS: An implementation of RIS/EPJ; used at Sørlandet Sykehus i Arendal.

PAS: Acronym for Patient Administrative System.

PACS: Acronym for Picture Archiving and Communication System.

DICOM: Digital Image Communication in Medicine; standard for exchange of image information between modalities[11] and systems from different producers. A European branch called MEDICOM exists as a pre-standard.

HL7: Health Level 7, american initiative; see `www.hl7.org`. HL7 is a medical information systems standard.

IHE: Acronym for Integrating the Healthcare Enterprise, an initiative by the Radiological Society of North America (RSNA) and the Healthcare Information and Management Systems Society (HIMSS) (see `http://www.rsna.com/practice/dicom/index.html`). The IHE technical framework defines a common information model and a common vocabulary for systems to use in communicating medical information. Ith specifies how DICOM and HL7 are to be used by information systems to complete a set of well-defined transactions that accomplish a particular task. See also the articles series by Siegel, Channin et.al. [10].

RIS: Acronym for Radiology Information System which is used to support information handling in a radiology department.

EDI: Acronym for Electronic Data Interchange.; uses EDIFACT standard.

AMTrix: Communication middleware and integration broker for business transactions; used in Norwegian hospitals for messaging, etc. AMTrix is produced by Axway (`www.axway.com`) maintained by Communicate AS (`www.communicate.no`) in Norway.

Helsenett: Norway is divided into five health regions (Helse Nord RHF, Helse Midt-Norge RHF, Helse Vest RHF, Helse Sør RHF, Helse Øst RHF), which form together Norsk Helsenett (see `www.norsk-helsenett.no`). The network ties together hospitals, doctors and other enterprises in the health sector.

SECTRA PACS: PACS system delivered from the swedish company Sectra AB (See `www.sectra.se`). used at both Rikshospitalet and Sørlandet Sykehus i Arendal.

EchoPAC: System from the company GE Medical Systems (see `www.gehealthcare.com`) to store

11. A modality is defined as a group or type of imaging units, e.g., CT or MR.

medical images, especially in echocardiographic applications. The system is used at Rikshospitalet.

DicomID: Identificator to join patient identity, images and reports. Other names used are: DicomNR, Accessesionsnr, Tilgangsnr, and HenvisningsID.

MITRA: Broker system; data base program which facilitates communication between RIS, PACS and modalities.

B Resources – Software and Links

B.1 Software for Image Coding

B.1.1 Huffyuv

Huffyuv is an open source project by Ben Rudiak-Gould for implementing a lossless video encoder. After having vanished for a while, the source code of Huffyuv is now available again at `neuron2.net/www.math.berkeley.edu/benrg/huffyuv.html`.

B.1.2 JPEG 2000

The JPEG 2000 standard (ISO/IEC 15444-1) uses wavelets and arithmetic coding for providing lossy and lossless compression methods for images. The list of implementations of the JPEG 2000 codec includes:

- Norsk Regnesentral have implemented an encoder for JPEG 2000 and MJPEG 2000.
- The J2000 codec (`http://www.j2000.org/`) is an open source codec for JPEG 2000, written in C and running on several platforms (Windows, Linux, Unix, Plan9).
- JJ2000 (`http://jj2000.epfl.ch/`) is the official reference implementation, written in Java. It supports features that did not become a part of the standard, and is suitable for small devices and small pictures.
- Kakadu (`http://www.kakadusoftware.com/`) is a complete implementation of the JPEG2000 standard with good performance. Licenses are available for ca. US$150 (single user non-commercial), ca. US$ 700 (multi-user non commercial), and US$ 7000-14000 (commercial license).
- JasPer (`http://www.ece.uvic.ca/~mdadams/jasper/`) is an open source implementation in C.

B.1.3 HP LOCO-I/JPEG-LS

LOCO-I, available at `http://www.hpl.hp.com/loco/`, is a reference implementation of JPEG-LS standard by HP for lossless compression in medical imaging applications. Only binaries available. However, source code for JPEG-LS is available from `http://www.ece.ubc.ca/spmg/research/jpeg/jpeg_ls/jpegls.html`.

B.1.4 JPEG-LS by D. Clunie

JPEG-LS, available from `http://www.dclunie.com/jpegls.html`, is an open source implementation of the proposed JPEG-LS standard, DIS 14495; see `http://www.jpeg.org/public/jpegnew.htm`. The implementation is part of the `dicom3tools` package for medical images. The implementation handles one component (i.e., grayscale images) in the current version (dated 2002).

B.2 Open Source Software for DICOM handling

Since open source software (OSS) [11] is available in source code which can be altered, this type of software is suitable for experimenting without causing great costs for licenses and purchase. We give an overview of some relevant packages, most of them implementing some aspects of DICOM.

B.2.1 Dicom toolkit (DCMTK)

DCMTK, available from Offis at `http://dicom.offis.de`, is a collection of libraries that implement large parts of the DICOM standard, written in a mixture of ANSI C and C++. DCMTK is released under a BSD-style license by Offis (a German research institute), and is used often for research, and as a basis for commercial software. DCMTK works on Windows, Linux, Solaris, OSF/1, IRIX, FreeBSD and MacOS X. DCMTK includes also an implementation of lossless JPEG, and a module for transfer of DICOM data via TLS using OpenSSL.

B.2.2 MIR CTN (Central Test Node)

The MIR DICOM Central Test Node Software (CTN) from ERL at Washington University available at `http://www.erl.wustl.edu/`, implements aspects of DICOM for cooperative demonstrations at RSNA annual meetings. The goal was to provide an implementation that facilitated vendor participation based on the evolving DICOM standard. CTN is implemented in C, and works on Windows, and (possibly) Linux.

B.2.3 David Clunie's dicom3tools

The dicom3tools, available from `http://www.dclunie.com/dicom3tools.html` implement tools and libraries for handling offline files of DICOM 3 attributes, and conversion of proprietary formats to DICOM 3. Can handle older ACR/NEMA format data, and some proprietary versions of that such as SPI. Works on Mac, and Linux. (And maybe windows.)

B.2.4 CDmedic

CDmedic, available from `http://cdmedicpacsweb.sourceforge.net`, implements a full featured free PACS based on MIR CTN, DCMTK and mysql, with remote administration using apache mod perl and imaging processing capabilities using ImageMagick, Grevera's dcm2pgm DICOM converter and AFNI. CDmedic is based on the Linux-distribution Knoppix. Released with the GPL license.

B.2.5 OpenEMR

OpenEMR, available from `http://stack.onlyic.org/openemr/`, is a modular, HIPAA compliant, Open Source, cross-platform Electronic Medical Records system (EMRS). It facilitates efficient office management through automated patient record journaling and billing integration, and has been integrated with third-party technologies including speech recognition, secure wireless access, touch screen portables, and biometric authentication. Interface screens are customizable and optimized for consistency, simplicity, speed of access to patient information, and minimum eye strain. OpenEMR works on Linux and Windows platforms, and is released under an OSI-approved license.

B.2.6 Conquest DICOM software

Within the EC Conquest project, (see `http://www.xs4all.nl/~ingenium/dicom.html`) a full featured DICOM server has been developed based on the public domain UCDMC DICOM code developed by Mark Oskin at the Medical Center of the University of California at Davis. Released under a BSD-style license. Works on Windows platforms.

B.2.7 Java DICOM Tools

The Java DICOM Tools, available at `http://www.tiani.com/JDicom/` implement a collection of tools for DICOM in Java. Built partially on Softlink's javadicomtoolkit. The use is free of charge, but only for special use. Source-code is not available. The PACS of the Java DICOM tools supports the transfer of images using the JPEG baseline transfer syntax.

B.2.8 dcm4che

dcm4che, available at `http://dcm4che.sourceforge.net/`, is an implementation of DICOM in Java. The sample applications may be useful on its own. It also includes an IHE compliant Image Archive application, based on J2EE.[12] Released under the LGPL.

B.2.9 MRIConvert

MRIConvert, available at `http://lcni.uoregon.edu/~jolinda/MRIConvert.html`, is a medical image file conversion utility that converts DICOM files to SPM99/Analyze, BrainVoyager, and MetaImage volume formats. It runs on newer Windows platforms. MRIConvert was written using wxWindows, an open-source library for cross-platform GUI development. Free use, but source-code not available. Binary for windows available.

B.3 Dicom viewers

We present DICOM viewers in a separate section. In the DISSH project it was considered to use DICOM viewers that can be started directly from the web application.

B.3.1 Dicomviewer

DICOM Viewer, available at `http://mars.elcom.nitech.ac.jp/dicom/index-e.html`, is used to access DICOM data that are stored on a server. It is written in Java, by Nagoya Institute of Technology, Iwata laboratory and Takahiro Katoji. The software is under the GPL; however there is an additional claim that the URL of the web page, or the reference to the article [12] are included. *Dicomviewer* does not seem to be capable of showing the images from VingMed, neither in compressed nor uncompressed format.

B.3.2 Dicomworks

Dicomworks is a DICOM viewer for Windows, available at `http://dicom.online.fr/`, developed by radiologists. Can open most kinds of DICOM-images, also compressed images, and series of images. The program is rather slow, and uses much of system resources. The software can be downloaded for free. A registration is required to get full functionality. Support for DICOM query/retrieve is planned.

B.3.3 Medview

Medview for Windows, available at `http://www.viewtec.ch/meddiv/medview_e.html`, was not tested by us, but it seems to offer much functionality, and support for most DICOM files. License costs ca. 300 Euro.

B.3.4 Tomovision

Tomovision for Windows, available at `http://www.tomovision.com/download/tomovision.htm`, offers a simple user interface with not so much functionality. Can open all sorts of DICOM images. Freeware.

12. Software is of alpha quality.

B.3.5 ezDicom

exDicom for Windows, available at http://www.psychology.nottingham.ac.uk/staff/cr1/ezdicom.html has quite good functionality. Can open all sorts of images, but gives wrong colours on some images. Open source software.

B.3.6 Rubo Medical Imaging Dicomviewer

RuboMed for Windows, available at http://www.rubomed.com, offers not so much functionality. Can open all sorts of files. Costs ca. 1000 Euro per license.

B.3.7 AccuLite

AccuLite for Windows, available from Accuimage at http://www.accuimage.com/ can open most sorts of images, but has troubles with some. Freely downloadable.

B.3.8 Dicomviewer (Nagoya Institute of Technology)

The Dicomviewer by Nagoya Institute of Technology (http://mars.elcom.nitech.ac.jp/dicom/index-e.html) is Java-based, which can be used on all platforms. It is specially designed for use in a web-server with a suitable user interface, and can open all kinds of DICOM files. However, it is rather slow. GPL license.

B.3.9 Imread Dicom viewer

The Imread DICOM viewer (http://www.uchsc.edu/sm/neuroimaging/download/imread/imread1.htm) is Java-based. Works with simple DICOM images, but does not support compressed images, or series of images. Freely downloadable.

B.3.10 DicomScope

DicomScope for Windows from Offis, availabe at http://dicom.offis.de/dscope.php.en, offers a messy user interface. Does not support compressed DICOM images. Freeware.

B.3.11 Osiris

Osiris, available at http://www.expasy.org/www/UIN/html1/projects/osiris/osiris.html, is a DICOM-viewer for Windows and UNIX. Does not support compressed images. Freeware.

B.3.12 Dicom Image Viewing Software

The DICOM Image Viewing Software (http://www.ee.bilkent.edu.tr/~cetin/dvs.html) is a DICOM-viewer for Windows. The software did not work in our environment.

B.4 Commercial Software

The following enterprises deliver commercial software for image handling, including commercial PACS implementations, etc.:

- Sectra PACS (http://www.sectra.se).
- InfoMediQ (http://www.infomediq.com)
- Medview http://www.viewtec.ch/meddiv/medview_e.html
- Digit Médic http://users.skynet.be/digitmedic/
- http://www.siliconmindset.com
- http://www.tomovision.com
- http://www.mallinckrodt.com/
- http://www.medicalconnections.co.uk/
- http://www.softlink.be/javadicomtoolkit.htm

- http://www.thecriswells.net/YourDICOM/
- http://www.leadtools.com
- http://www.accusoft.com
- http://www.intelerad.com/
- http://www.alitech.com/

B.5 Sites for DICOM Example Images

- http://www.excel-medical.com/Waveform.htm
- ftp://medical.nema.org/medical/dicom/MRMultiframe/20030404

B.6 Web Pages of General Interest

- http://www.pixelmed.com/ – General site, that contains software samples, and a book by David A. Clunie.
- http://medical.nema.org/ – The DICOM homepage.
- http://www.erl.wustl.edu – Homepage of ERL-MIR-WUSTL.
- http://rsna.org/ihe – The IHE homepage.
- http://www.rsna.org/practice/dicom/ – Survey of software for DICOM.
- http://www.idoimaging.com/index.shtml – A database of open-source medical software, test images, etc.

C Comparison of Compression Methods

Ultrasound images are used for many different diagnostic purposes. One area of interest is diagnosis of heart diseases. Rikshospitalet has an expert team under Prof. Ihlen and serves as a national center for diagnosis of difficult heart cases. The patients are often from remote regions, and most of them are small children. Most of the local hospitals have ultrasound scanners and can produce digitally encoded ultrasound images. On-line transfer of high quality ultrasound images from the local hospitals to Rikshospitalet will provide quick and better diagnosis and will be a great help for very sick patients.

Sharpbyte Ltd (`www.sharpbyte.com`) is an Irish company that claims to have a patent, proprietary image compression solution. Their image compression software can operate in lossy as well as lossless modes.

Comparison of lossless image compression algorithms. File sizes of images compressed using Sharpbyte solution are compared with the recent image compression standard, JPEG 2000. The results are shown in Table C.1. We did not focus on how the files transferred from one computer to another. In JPEG 2000, VM 7.2 is used. We used ISO standard images having 8-bit resolutions. In Sharpbyte upload client, we chose lossless only/lossless.

The following commands were used for the series of test images:

JPEG 2000 script:	`./vm7_compress_32 -i inimage.pgm -o outinmage.cmp -Frev`
JPEG-LS script:	`./locoe -i inimage.pgm -ooutimage.cmp`

In another test with the results in Table C.2 we used ultrasound images from a GE VingMed scanner, which have a resolution of 8 bits.

Conclusions.

- The Sharpbyte software looks easy to use and runs reasonably fast on standard personal computers.
- Ultrasound images have high correlation among frames. Such temporal correlation can best be exploited using a video compression algorithm than a still image compression scheme. This may provide smaller file sizes and may lead to faster transmission on bandwidth limited networks.

Image	Image dim.	Orig. file size	Sharpbyte 1[a]	Sharpbyte 2[b]	JPEG-LS	JPEG 2000
Aerial2	2048 × 2048	4.194.321	3.156.978	2.771.594	2.772.925	2.889.770
Barbara	512 × 512	262.159	235.207	157.584	159.561	162.825
Beach	512 × 512	262.159	197.213	157.145	156.775	168.394
Bike	2048 × 2560	5.242.89	3.766.631	2.812.403	2.856.623	3.039.775
Cafe	2048 × 2560	5.242.897	4.421.226	3.302.204	3.337.277	3.556.043
Goldhill	512 × 512	262.159	216.400	154.967	154.389	161.257
Lena	512 × 512	262.159	222.409	138.743	138.809	145.900
Tools	1524 × 1200	1.828.817	1.570.106	1.203.964	1.213.616	1.257.340
Texture_1	1024 × 1024	1.048.593	612.991	844.425	845.207	896.401
Texture_2	1024 × 1024	1.048.593	899.601	701.897	702.557	740.953
Woman	2048 × 2560	5.242.897	4.024.109	2.899.303	2.917.089	3.012.130
Total size		24.897.651	19.322.871	15.144.229	15.254.828	16.030.788
% of comp.		100 %	77.6 %	60,8 %	61.3 %	64.4 %

a. Sharpbyte1 = Conventional lossless compression.
b. Sharpbyte2 = Sharpbyte Medical lossless compression.

Table C.1. Comparison of file size after compression for a series of test images.

Image	Image dim	File size	Sharpbyte	JPEG-LS	JPEG 2000
Im1	416 × 332	414387		103567	129946
Im2	416 × 332	414387		101837	127816
Im3	416 × 332	414387		98844	125946
Im4	416 × 332	414387		97212	125457
Im5	416 × 332	414387		97743	125670
Im6	416 × 332	414387		99761	128392
Im7	416 × 332	414387		99133	126319
Im8	416 × 332	414387		98955	126230
Im9	416 × 332	414387		99063	126237
Im10	416 × 332	414387		97830	125473
Im11	416 × 332	414387		97052	124056
Im12	416 × 332	414387		98864	125538
Im13	416 × 332	414387		98210	127017
Im14	416 × 332	414387		96269	122420
Im15	416 × 332	414387		103027	129201
Im16	416 × 332	414387		105195	130811
Im17	416 × 332	414387		102042	128003
Im18	416 × 332	414387		102690	128864
Im19	416 × 332	414387		103202	129117
Im20	416 × 332	414387		102259	129159
Im21	416 × 332	414387		101510	128638
Im22	416 × 332	414387		103909	130412
Im23	416 × 332	414387		105167	130522
Im24	416 × 332	414387		105671	130507
Im25	416 × 332	414387		105412	130542
Im26	416 × 332	414387		105523	130084
Im27	416 × 332	414387		105979	130528
Im28	416 × 332	414387		106474	130787
Im29	416 × 332	414387		106811	131143
Total size		12017223		2949211	3714835
% of comp		100 %		24.5 %	31.0 %

Table C.2. File size of a series of ultrasound images from GE VingMed scanner with a resolution of 8 bits.

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