Chapter 4

CARE Cardiology

In this chapter the cardiac imaging workstation developed is presented. The workstation has a computer assisted diagnostic module where the coronary tree model shall play an important role when doing automatic vessel analysis with coronary angiography images. The chapter begins with the analysis of healthcare telematics carried out within the context of the EU project TeleRegions. Then, the adaptation of the former radiology system to cardiology is surveyed with emphasis on the changes regarding the image handling aspects. A careful analysis focused on the intrinsic features of the angiography imaging technology relevant to the workstation is carried out. Special attention is given to standards ought to the their continuous evolution.

4.1 Scope of the application

The CARE system began with a design and implementation of a prototype for multimedia communications and teleworking for radiologists. The system was developed by the author within a project known as "Computer Assisted Radiology Environment" (CARE) [104, 108]. From the medical perspective, radiologists can perform tele-consultations. Also, the addition of telepresence brought new possibilities for them to meet and share expertise without traveling. From the technical perspective, the goal of the prototype was to integrate the various sources of clinical multimedia data into a single record, and to allow that record to be reviewed on a single workstation with sufficient quality for diagnostic purposes. The open architecture of the system would also allow for the future expansion/evolution of the system such as the addition of new software modules. The radiology system was completed and is fully documented in [104].

After the implementation of the workstation, the next objectives were to focus on cardiac imaging and adapt the radiology workstation to such modality. The global goal is to establish an interhospital remote team model of work at a cardiological level between third level health care hospital and a reference centre of second level health care. The model allows to share, through telecommunication, technical and human means of diagnostic as well as sending back, once the patient is submitted to treatment, the report and images of his final outcome. The cardiac imaging system is developed under the umbrella of an European Project named TeleRegions (SU 1002). The project development cycle showed many needs about computer assisted diagnostic tools. Therefore, the development of computer assisted diagnosis tools made necessary the building of a $3D$ computer model of the coronary tree. Both, the evolution of the system from radiology to cardiology and the development of the coronary tree model are the main contributions of this thesis.

4.2 Context

Healthcare telematics is a vast discipline which involves many areas, including teleradiology, teleconferencing, telepresence, remote expert referral, remote diagnosis, Picture Archiving and Communication Systems (PACS), electronic patient record, Hospital and Radiological Information Systems, among others. The health care telematics research presented will be limited to the scenario of diagnostic image referral and computer assisted analysis of X-ray angiographic images. Dealing with such modality (image sequences) is one of the bigger challenges in healthcare telematics. It is believed that the availability of communication facilities in hospitals, which engage in patient referrals of this type, will increase the quality of patient care and decrease the cost of this care. By having access to the diagnostic images, the referral hospital gains insight into the patient's condition in advance, and can advise the referring institution whether transporting the patient is warranted or not. In cases where transport is not necessary, the patient is spared the ordeal of being moved to a new hospital with a new doctor, and the health care system saves money by avoiding the referral. In cases where transport is advised, the cost and inconvenience of repeated diagnostic imaging procedures at the referral hospital is eliminated, thus saving time, money, and minimising radiation dose to the patient.

4.2.1 TeleRegions SUN - TeleApplications for European Regions

TeleRegions is a European Community funded project designed to integrate efforts in telematics of regional administrators, users, research centres and industries in six European regions. The regions of Baden- Württernberg (Germany), Catalunya (Spain), Lombardia (ltaly), North of England (United Kingdom), Oberösterreich (Austria), and Rhóne-Alpes (France) are working together as a collaborative unit. This project comes as a consequence of experience gained from previous framework programmes involving the so-called "Four Motors of Europe," and is strongly supported by their regional administrations. The project comprises the research, development and validation of users oriented telematics tools. The overall objective of the project is to identify and address regional needs by integrating, validating and using telematics applications and services in several sectors.

Naturally, the workstation CARE Cardiology is within the Healh Care sector and provide facilities such as image transmission over a network, case review and remote consultation among cardiologists.

The project uses the following strategy: User-driven definition of needs, project co-ordination using a cross- sector approach, a regional approach toward European benefit, and validation of the project through real-life applications organised into a network of user sites.

The concept of Site User Networks is applied to ensure that the applications and standards defined by the project can reach and be utilised in the workplace of end-users. The function of this network is to validate applications and services developed by the project, distribute knowledge and information among the various levels of users, organisations and regions, and do so in an organised manner between sectors and regions.

4.2.2 Regional Needs in Health Care

The telemedicine framework at the regional level requires the organisation of a consistent network to link the distributed health care centres for remote consultation. This organisation must be established at different levels according to the type of application and communications required. In the health care sector, there are two types of applications that must be supported in the telematics framework:

- generic solutions.
- specific applications.

Generic solutions are those that provide users (in this case medical doctors) with access to basic communication facilities. These facilities are suitable for addressing fundamental needs such as accessing remote databases, retrieving information over the Internet or transferring electronic mail.

Once these basic facilities exist, more complex applications may be introduced. Applied solutions are those, which are developed to solve a specific problem, or to address, sector specific needs. An example of this type of application in the health care sector is remote referral of patient information for medical consultation. In this case, two doctors who are geographically separated may work together in the study of a medical diagnosis. To reinforce the idea of collaboration, telepresence facilities may be added, ranging from file transfer, display synchronisation, voice communication and video conferencing support, culminating with the incorporation of computer assisted diagnostic tools.

4.2.3 Health Care Cluster

The project TeleRegions uses the cluster concept to have a better management of the different sectors. The health care cluster handles the co-operation between regions within the health care sector. The cluster is defined as an inter-regional process unifying a collection of similar applications. These applications have unique identities according to their distinct objectives and local requirements within the region. The cluster serves to facilitate the sharing of objects, methodologies, technology, and experience, and to disseminate these results according to the actual objectives in each region.

4.2.4 Healthcare telematics goals

In the context of the Health Care Cluster, the goals for the use of telematics are to establish communications between health care centres in order to facilitate the transmission of clinical data and images, and to use these communication links to help reduce the cost and increase the effectiveness of health care delivery. Two types of communication links are used according to the user needs of each application scenario. Inexpensive ISDN links are used for applications requiring low bandwidth communication for the transmission of still images, while high speed Internet network connections are required for the high bandwidth requirements when transferring sequences of images.

4.3 Telemedicine at Regional Level

In Catalonia, our region within the project, the Catalan Health Service maintains a network of regional hospitals. Due to the population distribution, this network has a heterogeneous nature in several factors:

- Hospitals vary in size between 50 and 850 beds, although most are small.
- The economic resources and medical expertise vary between hospitals.
- The availability of Hospital Information Systems is sparse and access to clinical databases varies.

This situation has resulted in a disparity in the availability of healthcare services within the region, with the largest concentration of specialised services located in the capital city of Barcelona. Due to this concentration of services, many patients from outside the metropolitan area of Barcelona are forced to travel to the capital to receive specialised health care. As a result, these patients are inconvenienced by the need to travel while ill (often requiring a specially equipped ambulance for transportation), and the health care system is burdened with this added expense. Given that a percentage of all interventional procedures are considered to have been performed unnecessarily, and that there is a certain risk factor involved with performing these procedures, clearly, if telematics can be applied to identify the dubious or unnecessary cases before referral, then the quality of patient care will improve. In [85] Rahms et. al. estimate that the application of telecardiology could result in the saving of around 200 lives and 5000 million pesetas each year in Spain. There are many potential applications of telemedicine, but for the purpose of the TeleRegions project a limited selection of clinical scenarios have been defined.

4.3.1 Clinical Scenarios

Within our region in the health care sector, two separate clinical scenarios were proposed: a mammography screening program where images acquired at primary care centers are transferred via ISDN links to a secondary care hospital for expert screening and a coronary heart disease program where patients are referred by a secondary care hospital to a tertiary care hospital for interventional catheterisation. The mammography screening scenario was separately developed and is out of the scope of this thesis. The chapter focuses in the latter case, where diagnostic images acquired at the secondary care hospital may be sent via a Metropolitan Area Network to the tertiary care hospital to avoid repeated diagnostic procedures, and the post-interventional images and results may be returned to the referring physician for follow-up and treatment. The scenarios are depicted in Figure 4.1

4.4 Telematics Cardiology Demonstrator

Given the need for digital image exchange in the health care sector within our region to support cardiac patient referrals, and the unique requirements inherent in the exchange of digital cardiac angiographic image data, a system has been designed to manage this data exchange.

The Telecardiology Demonstrator is a system, which is intended to apply existing telematics technology to demonstrate its potential usefulness to the communication needs of health care applications. Specifically, a prototype implementation is planned to support communication between cardiac care centres where a need exists to transmit medical images between co-operating centres. Since the end-users of the Telecardiology system are meant to be medical professionals who do not necessarily have any computer experience, great attention is given to the design of the user interface and the identification of the user's requirements.

The demonstrator is built based on the evolution of the existing system Care Radiology.

4.4.1 Application Area

The application shall be targeted on the network of regional hospitals of Catalonia that:

- takes care of Coronary Heart Disease (CHD) and
- needs to exchange medical information and coronary imaging for common diagnostic procedures and further communication of results after treatment be it surgical or interventional.

From section 4.3 (the hospital network working in the Service of Public Health has several heterogeneity factors) one can conclude that the levels of opinion and interest of the professionals are also different on the telecommunication possibilities and on a multi-center model.

Finally, but technically the most conditioning, telecommunication networks are available at different levels of bandwith. There is a metropolitan area network (MAN) covering Barcelona and its arounds at 34 Mbps (can be upgraded up to 600 Mbps) and ISDN is available all over the region. Inside the framework of the remote consultation it is necessary a consistent network to link the distributed health care centres. These links are at different levels: the communication within a hospital is performed over existing local area networks, the communication in a hospital area over the MAN.

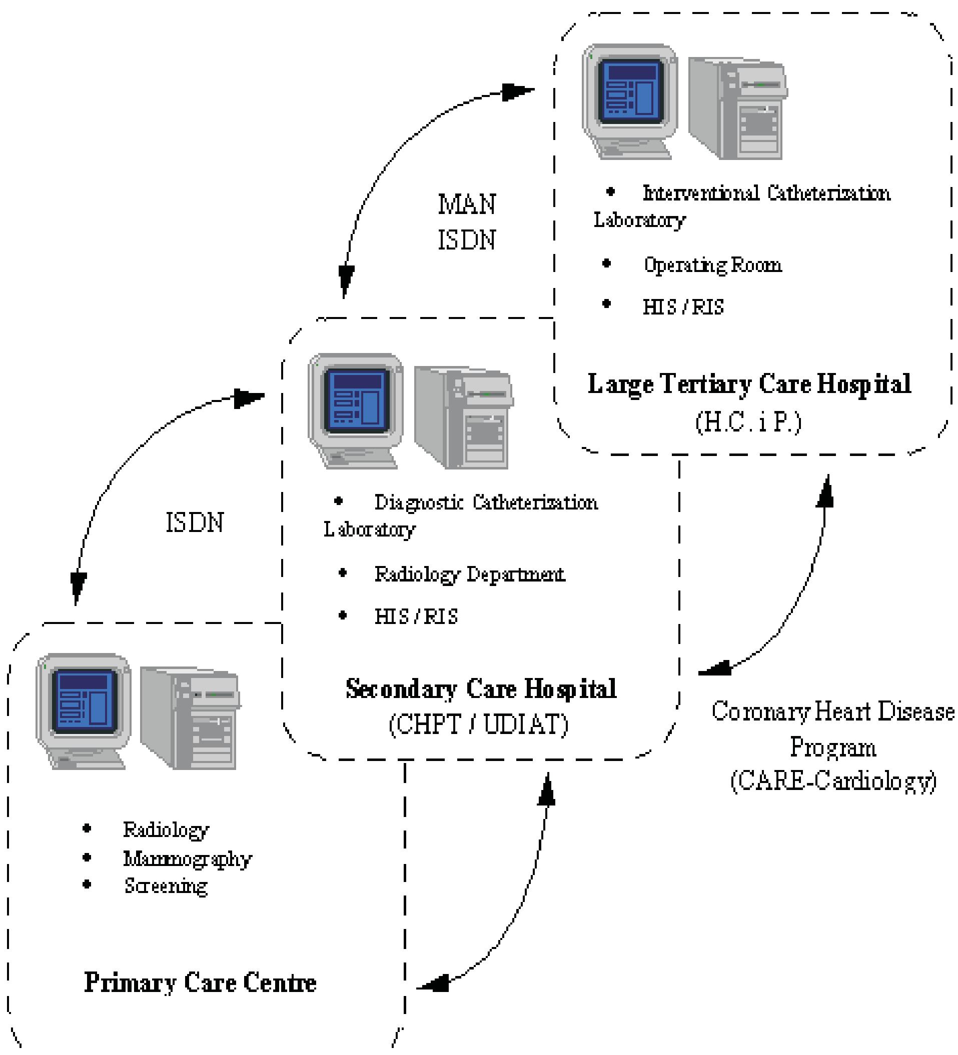


Figure 4.1: Clinical scenario of the telematics healthcare programme addressed by the TeleRegions project in Catalonia.

The following hop to link several hospitals or several health care centers in a regional area or in a country area can be done through wide area data networks and over the ISDN services, both offered by national PTT.

4.5 From Care Radiology to the Telecardiology Prototype

4.5.1 Adaptation to the needs of cardiac imaging

Since the CARE implementation was early designed based on the needs of radiological imaging, it had to be adapted to take into account the special requirements of cardiac imaging practices.

Cardiology imaging is, generally, considered separately to radiology due to the unique imaging requirements of cardiovascular imaging, even though many of the same fundamental principles are used. The requirements of cardiovascular imaging, the background of this field, and the underlying mechanisms used in the formation of X-ray cardiac images were introduced in chapter 2 and shall be further developed in this chapter.

Starting from a workstation capable to transfer diagnostic images and related identifying and administrative data like CARE Radiology, it was adapted to the typical cardiac scenario depicted in figure 4.1: patients referred from one hospital where diagnostic images have been obtained to a second institution where therapeutic intervention or surgery are to be performed. Post-interventional images can, also, be transferred back to the referring physician. The scenario comes from a careful analysis of the telematics needs in clinical angiographic imaging applications.

4.5.2 General requirements already met in Care radiology

- The multimedia workstation design, including the telepresence and the communications software copes with the heterogeneity mentioned above.
- Connects a diversity of technologies for acquiring and transmitting digital medical images. Currently, Siemens CT and MRI are connected. A Laser film digitizer interface is ready. An interface to an ImageComm System can aquire sequences of angiographic images.
- Ability to access and transmit data files and images of different HIS (Hospital Information System)/RIS (Radiological Information System).
- The possibility to work at real or deferred time or a combination of both (i.e. previous high resolution image transmission for further interactive communication), according to the economical resources and existing telecommunication networks. Support for communication through coventional modems, ISDN and broadband networks.

Software requirements included:

- A standard communication protocol between the equipment providing medical images and the workstation (DICOM).
- Facilities for voice and data integration.
- Set of image processing facilities.
- Data, voice and image real-time communication between doctors and radiologists.
- Shared bitmap and text editor (terminal synchronization).
- Full LAN/WAN support.
- A friendly user interface, taking into account the opinion of radiologist for its design.
- The data is organized as stated in the DICOM model (see 4.5.5).
- Extensibility: the project was developed considering a future expansion of the system, so that the incorporation of the multimedia database management as well as the computer assisted diagnosis is feasible. Therefore, flexibility and easy evolution are also fulfilled requirements.

4.5.3 Design of the workstation

The first step in any software design process is to determine what is to be done. There are many methodologies, which specify in detail the various steps, which may be followed in the process of defining what a software system should do [19, 78, 96]. Invariably, these methodologies define a manner in which the software requirements can be specified, and how this information is recorded so that it may be shared among designers and implementers of the software, as well as with potential buyers or users of the final system. One of the best approaches to deal with system complexity is the object model. The radiology workstation was developed under this paradigm and the cardiology one shall follow the same strategy.

4.5.4 Object Oriented Design Techniques

The software design and implementation of the Telecardiology Demonstrator, was to be carried out according to object-oriented techniques.

Advantages of the object model

In object-oriented design, the principles of abstraction, encapsulation, modularity, and hierarchy are applied to create designs which are superior to those produced by previous methodologies. This approach also offers practical benefits such as encouraging the reuse of software and design, producing stable implementations which are resilient to change both during the development phase and throughout the useful life cycle of the implementation, and by organizing the design in an intuitive manner which is easily understood.

4.5.5 Standards

Despite the conformance of Care Radiology to the standards, the evolving stage of them and the unique features of cardiac imaging modality make necessary a careful review of the current state in the standardization effort.

Overview

A key concept in PACS development is the standardization, both in information technologies and in medical imaging. There are sound standards in hardware and communication aspects meanwhile in software an increasing effort in standardization is currently being done. Digital Imaging and Communication in Medicine (DICOM) is the result of a standardization effort carried out in medical imaging. It covers many useful scenarios for a PACS implementation.

In 1982, the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) started a committee for the development of a standard to set up a definition for a connection between medical imaging devices.

The purpose of the ACR-NEMA committee was to:

1. Promote communication of digital image information, regardless of source format or device manufacturer,

2. Facilitate the development and expansion of picture archiving and communication systems that can also interface with other hospital information systems, and

3. Allow the creation of diagnostic information data bases that can be interrogated by a wide variety of devices distributed geographically.

Version 1.0 of the standard [1] was published in 1985. It covers the specification of a hardware interface supporting point to point image communication (nothing about networking), a set of codes and commands to enable transactions. Version 2.0 [2], published in 1988 added semantic rules to build and transmit point to point messages.

As can be expected from a developing standard, the first versions contained a number of problems which prevented its wide spread implementation. Since the standard encompasses a very broad range of medical imaging equipment and data types, it was decided to begin with a limited solution to the image communication needs. The first standard was limited to point-to-point connections between two medical imaging devices only. The hardware implementation of this connection was specified by a new $50-pin$ connector defined for the standard. Since this connector was not an existing standard, it was difficult for software developers to implement communication routines since the hardware was not yet available. In an attempt to bypass this problem, implementations evolved which used several different types of network protocols to replace the hardware layer of the standard [51, 55, 62, 89]. Implementers of the standard [13, 62, 65] have also reported difficulties with ambiguities which can result in incompatibilities between independent implementations due to differences in interpretation. Also the freedom that the standard offers to implementers to introduce new data elements into their data dictionary has resulted in a proliferation of dialects such as SPI [3], PAPYRUS [86], and others [110]. Other criticisms of the ACR-NEMA standard include some of the limitations imposed on the initial versions. These limitations include the restriction of the standard to two dimensional images only, and the requirement that each message contain only one image. This can cause additional overhead when communicating multi-dimensional image data since each two dimensional image slice or cine-frame must contain complete header information. The amount of redundant data in these headers becomes especially significant with small images such as those used in Nuclear Medicine.

After reviewing the problems encountered during attempts to implement this standard, and better defining the needs of the users of the standard, a third version was planned. The overall goals of this version, entitled DICOM 3.0, were to:

1. Provide increased capability to encourage wider implementation,
2. Seek help from users and implementers around the world,
3. Use existing ISO and other standards,
4. Move toward an object-oriented description of the standard,
5. Incorporate features from Standard Product Interconnect, which is an extension of the ACR-NEMA standard developed by Siemens and Philips [3],
6. Provide a standard in ISO format that is worthy of world-wide implementation,
7. Maintain compatibility with version 2.0 where possible,
8. Complete the first draft in early 1992.

From comments made by the first users of the standard [48, 62], several areas were identified where the standard could be improved.

These points included the following:

1. Addition of a flexible network layer so that imaging devices and workstations could be connected in a network without the overhead of additional hardware (Network Interface Units),
2. Definition of a folder structure such as that used by PAPYRUS [86] to contain multiple images in a single message,
3. Development of an interface to HIS/RIS systems to avoid the unnecessary duplication of data on these systems and on the hospital's PACS, and
4. Definition of more precise methods of conformance validation to ensure connectivity between devices from different manufacturers.

These issues were then addressed by the DICOM committee, and solutions incorporated into the new version.

The Dicom Standard

DICOM Version 3.0 [26] has been completed at the end of 1993. DICOM has received the approval by the International Standard Organization, after an agreement between the ACR-NEMA and the European Standardization Committee, Technical Committee 251 Medical Informatics (TC251)

Currently, medical imaging companies are incorporating the standard at different levels in their equipment. DICOM is based on the Reference Model of the International Standard Organization (ISORM), promoting the Open System Interconnection (OSI) for image devices over standard communication networks (keeping the compatibility with the old point to point ACR-NEMA first versions). This standard has recently become available as a multi-part document [26], and to encourage broader use of the standard, a number of source code implementations have been made publicly available.

DICOM Version 3.0 defines several major enhancements to the previous version:

1. It uses a structured data design, and specifies explicit "Information Objects" not only for images and graphics but also for studies, reports, etc.
2. It defines how devices should react to commands and data being exchanged through the concept of Service Classes.
3. It is applicable to a networked environment.
4. It defines a structure for file exchange.
5. It specifies levels of conformance using a structured Conformance Claim

Structured design

In information systems, careful data modeling can reveal essential units of information and classify these into a precise structure. When this structure corresponds closely to the real world, it helps to harmonize the operation of the system to the tasks that it is representing. Achieving this harmonization can strongly enhance the availability of data records since the information is organized in the same way as it is used in the real world. DICOM provides such a data model for a radiology department, as shown in figure 4.2. Designing the data required by the system in the same way as it is used in the real world provides fast access and in a manner which seems logical to the user. Information systems which operate in a logical manner are much more likely to be well received and used than those which operate in a less consequent manner. This is especially true with medical information systems since these are generally judged very strictly.

Care Radiology adheres to this real world model. Regarding differences with cardiology, the global model in Care Radiology is still valid with minor changes at the study, series and image level.

The DICOM Standard also specifies the services which can be applied to the data structures defined by the standard. These service classes describe how devices claiming conformance to DICOM should react to commands and data being exchanged.

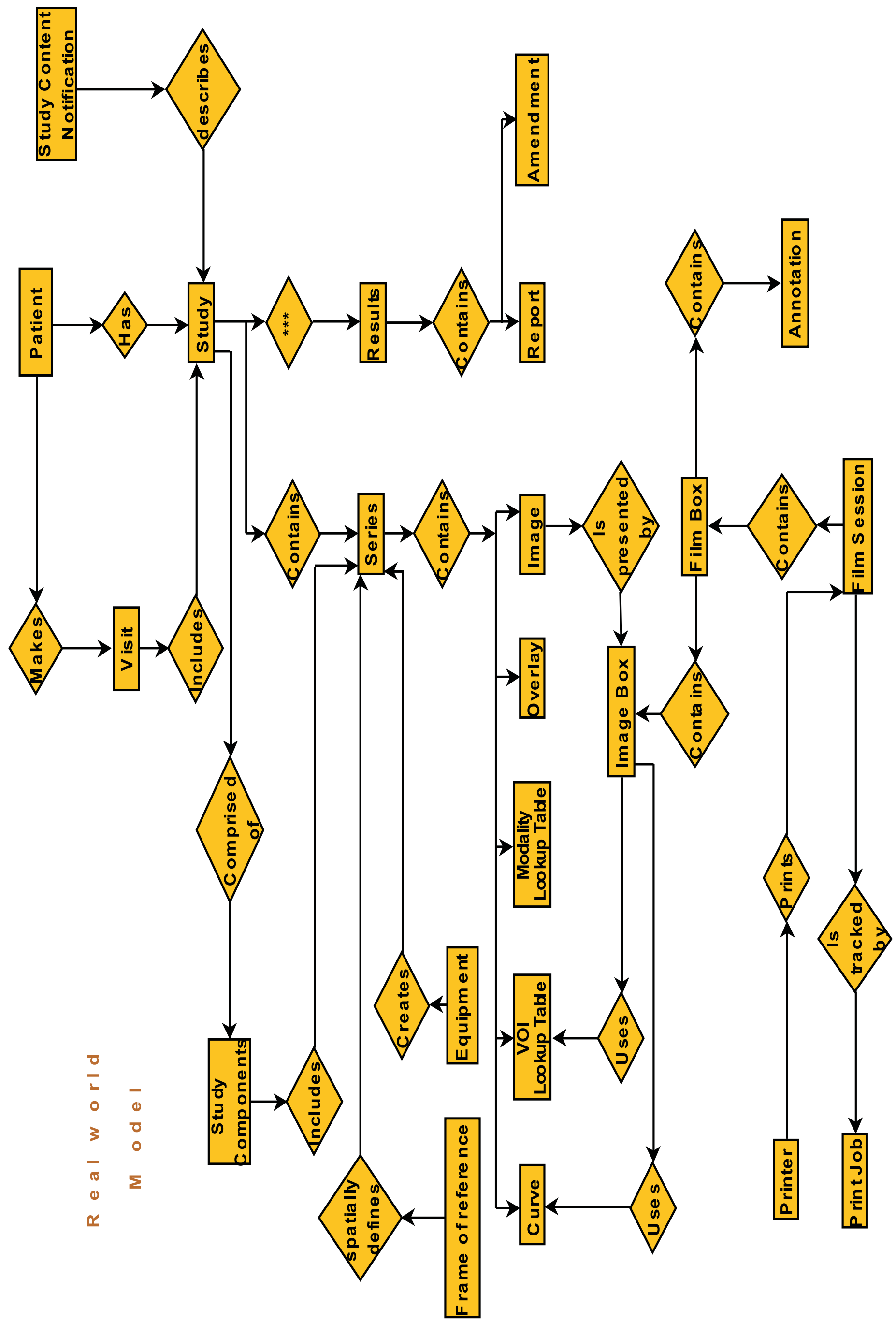


Figure 4.2: Entity relationship diagram modeling the association among information entities in radiology.

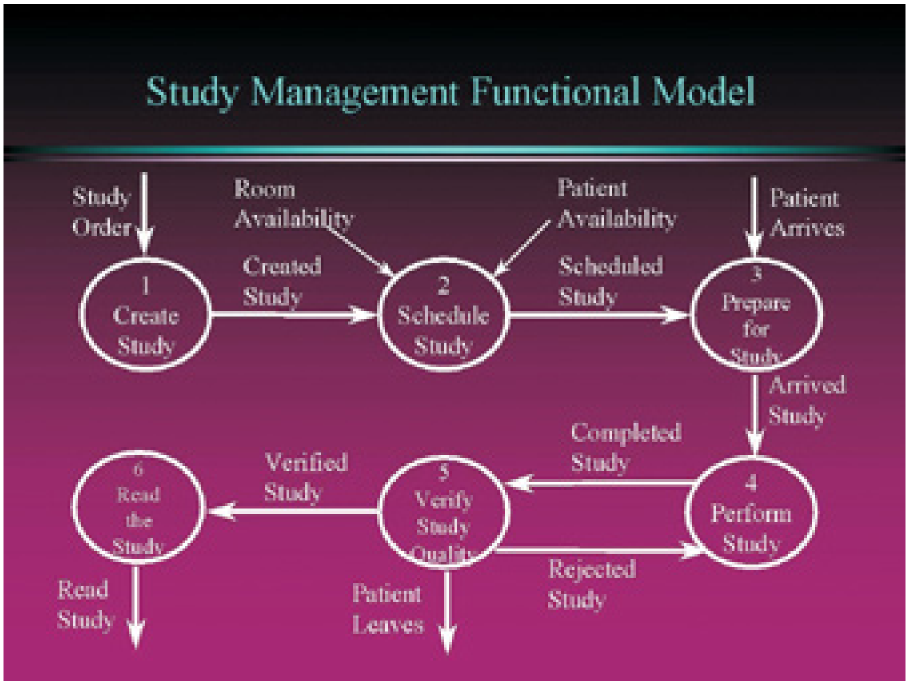


Figure 4.3: Study Functional Model.

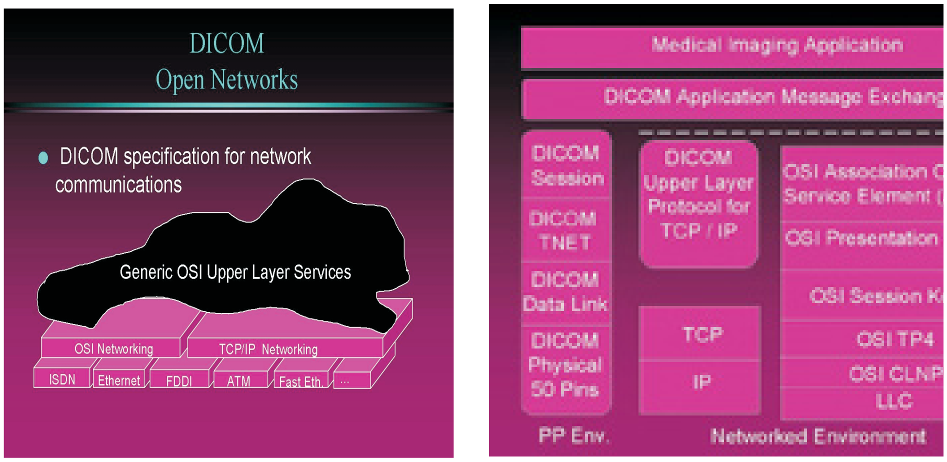
These definitions help to eliminate the ambiguities which were present in earlier versions of the standard.

HIS/RIS connectivity

In the previous versions of the standard, a limited command set existed to transfer data from one imaging device to another. With the in troduction of structured data design and the addition of service classes to the standard, many more services became av ailable. These services provide for more than simply moving data from one device to another, but also for storing and retrieving images, performing queries for patient information, printing, etc. Information objects hav e been added for communication with HIS/RIS systems as well as to communicate images and graphics. The new service classes can be used to operate on any of the information objects such as patient data, study data and results, and thus allow the access to information systems. These services classes also facilitate the connection of DICOM devices to image processing workstations such as the proposed by the Telecardiology Demonstrator for the TeleRegions project. Figure 4.3 depict the supported scenario.

Networking

One of the most serious limitations of the A CR-NEMAstandard was the difficulty inv olv ed in connecting devices to a netw ork. Although it was possible to connect an



(a) (b)

Figure 4.4: (a) Network Support. (b) Protocol Architecture.

A CR-NEMA device via a Network Interface Unit (NIU) to existing standard networks, the additional cost and overhead made most implementations impractical [51, 89] The DICOM 3.0 standard works directly with standard network environments without the need for additional hardware, and still remains compatible with the previous point-to-point interface. The standard supports communication using TCP/IP, as well as the ISO reference model to control theprocess of information exchange among dissimilar computer systems (see Figure 4.4). These interfaces will help to facilitate the widespread implementation of the standard since it uses readily available and inexpensive network interface cards, which are supported by a large number of different computer architectures.

Care Radiology supports TCP-IP and ISDN, hence there are not changes needed for Care Cardiology.

Folders andfile linking

To resolve the problem of passing redundant data when communicating multidimensional images, DICOM has adopted the folder concept of the PAPYRUS file format. This format permits the communication of multiple images in a single message, either by passing all of the data by value, or by linking references to related images in a single identification header. This type of referencing can be achieved by creating references to DICOM data sets containing single images in a so-called DICOMDIR file, although in practice it is much more common to encapsulate multiple image frames into a single message. Figure 4.5 shows the concept. At this point a new development was done to support this concept. The prototype for cardiology uses this specification as an image exchange mean.

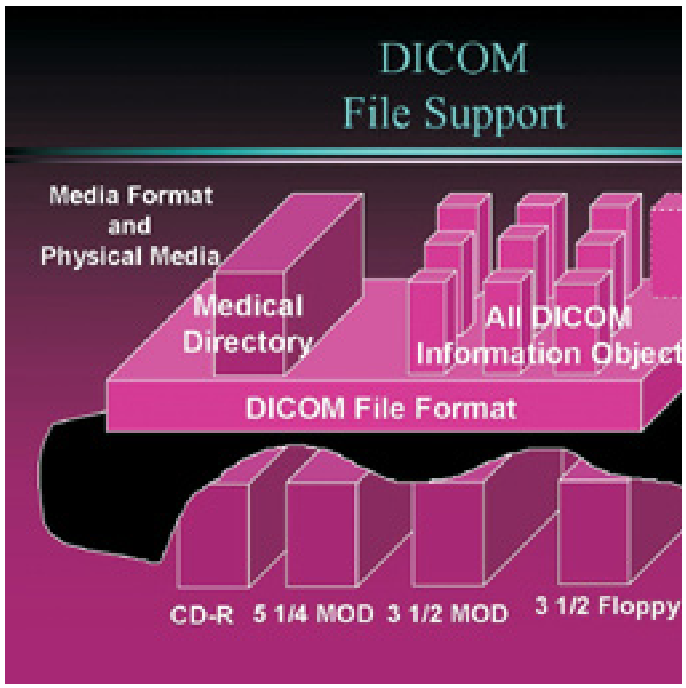
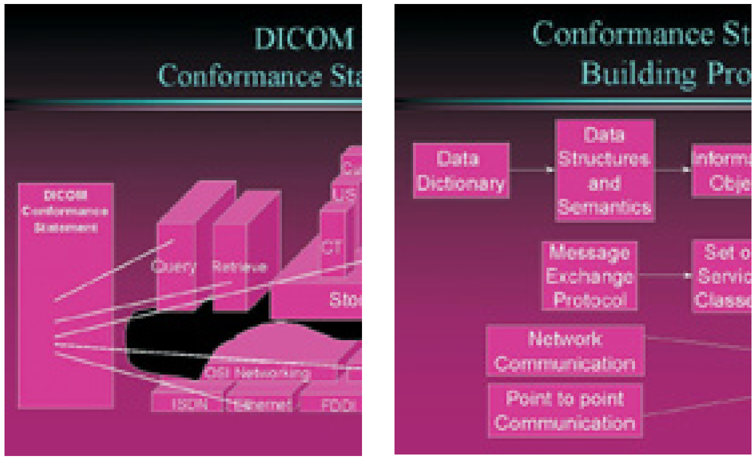


Figure 4.5: File System Model.



(a) (b)

Figure 4.6: (a) Conformance Statement related objects. (b) Construction of a Conformance Statement.

Conformance statements

The DICOM Standard is a very rich and complex set of protocols, definitions of command syntax and semantics, and definitions of data objects. Each implementation of the standard need not support the entire standard though. Any particular application must only implement those parts of the standard which are related to the needs of the application. In order to ensure connectivity of devices claiming DICOM conformance, it is necessary to specify exactly which features of the standard have been implemented. This is accomplished through a Conformance Statement. The Conformance Statement allows a potential purchaser of a system to see which optional components of the standard are supported by a system, and what additional extensions or specialisations the implementation adds. To determine if two systems can be connected, an end-user can compare the Conformance Statements from each system and see to what extent communications might be supported between the two implementations. Each implementation must meet the minimum general requirements to claim DICOM conformance, and may then utilise any additional classes, protocols, data attribute, etc., which are required by the implementation.

It is also possible for a potential purchaser of medical imaging equipment to specify the subset of DICOM functionality to be provided by an equipment vendor by drafting a User Conformance Profile (UCP). This provides a mean for the user to precisely define the requirements of a system, and to avoid confusion and ambiguities when the system is being implemented. There is one drawback of this approach however. Since a UCP specifies a subset of DICOM functionality, it is possible for other choices to be made, and for several different incompatible profiles to be defined to address the same problem [79]. Figures 4.6 summarize the objects involved in a conformance statement and the building process.

4.5.6 Standardisation Efforts in Cardiology

Following the lead of the American College of Radiology (ACR) and the National Electrical Manufacturers' Association (NEMA), the Cardiac Catheterisation Committee of the American College of Cardiology (ACC) formed a subcommittee to facilitate efforts to standardise digital image archiving in the cardiac catheterisation laboratory. At that time, in 1992, the ACR-NEMA Committee was working on the DICOM standard to promote the exchange of radiological images. In parallel, the Task Force on Digital Imaging in Cardiology of the European Society of Cardiology (ESC) began work on the definition of requirements for a digital archival and exchange medium. The efforts of these groups resulted in the adoption of the DICOM standard as the means by which digital angiographic images would be interchanged, and the selection of the CD-Recordable as the exchange medium. A DICOM implementation entitled DISC ′95 was developed for demonstration purposes, and was shown at the 1995 meeting of the American College of Cardiology in New Orleans. This demonstration was successfully repeated at the conference of the ESC in Amsterdam that same year. Since that time, all major manufacturers of digital angiographic imaging systems have begun to support the DICOM CD-R for the exchange of image data [27, 22, 52, 68, 111].

Based on these standardisation efforts and industry support, it would seem logical for any emerging application dealing with the exchange of digital angiographic image data to support the DICOM standard.

4.5.7 Conceptual model for cardiology image communication

The conceptual model of the process of interchanging medical images between two cardiovascular imaging systems can be regarded as a special case of the general radiology imaging model. Figures 4.7 and 4.8 show the model supported and in care radiology and figure 4.9 shows the model planned for cardiology. These figures show two important aspects: the model is the same and the big specialization lies on the connection of cardiovascular image acquisition systems to the telecardiology workstation. Given the diversity of manufacturers and configurations of angiographic acquisition systems, the topic of interfacing to these systems is complex, and is detailed in section 4.5.8. The communication requirements between two implementations of the telecardiology demonstrator defined below are already covered in Care radiology.

The block diagram of the Care radiology workstation can be appreciated in figure 4.10. Some of the blocks were adapted to the cardiology requirements. As stated above, the acquisition subsystem has been changed. Being Care radiology based on DICOM, the main data structures remain unchanged and only the DICOM module specification for X-ray angiography had to be incorporated together with the DICOM folder. Other modules subject to changes were the display and image processing ones. Both modules have incorporated facilities for dealing with the specifics requirements of angiographic image sequences. The chapter continues with a careful study of the special requirements and features needed to evolve the radiology workstation towards cardiac imaging.

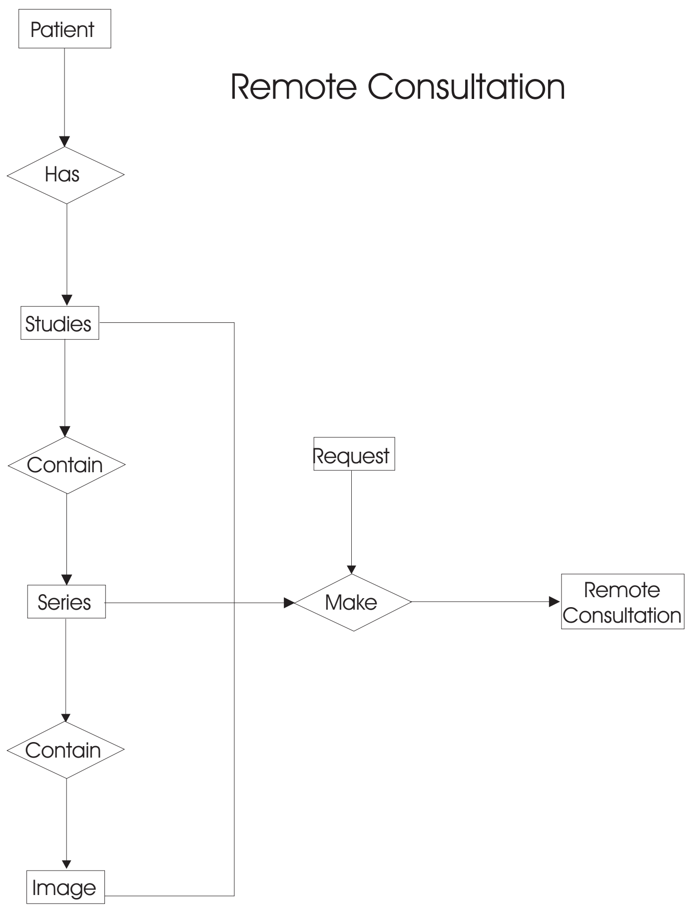


Figure 4.7: Conceptual Model of a remote consultation.

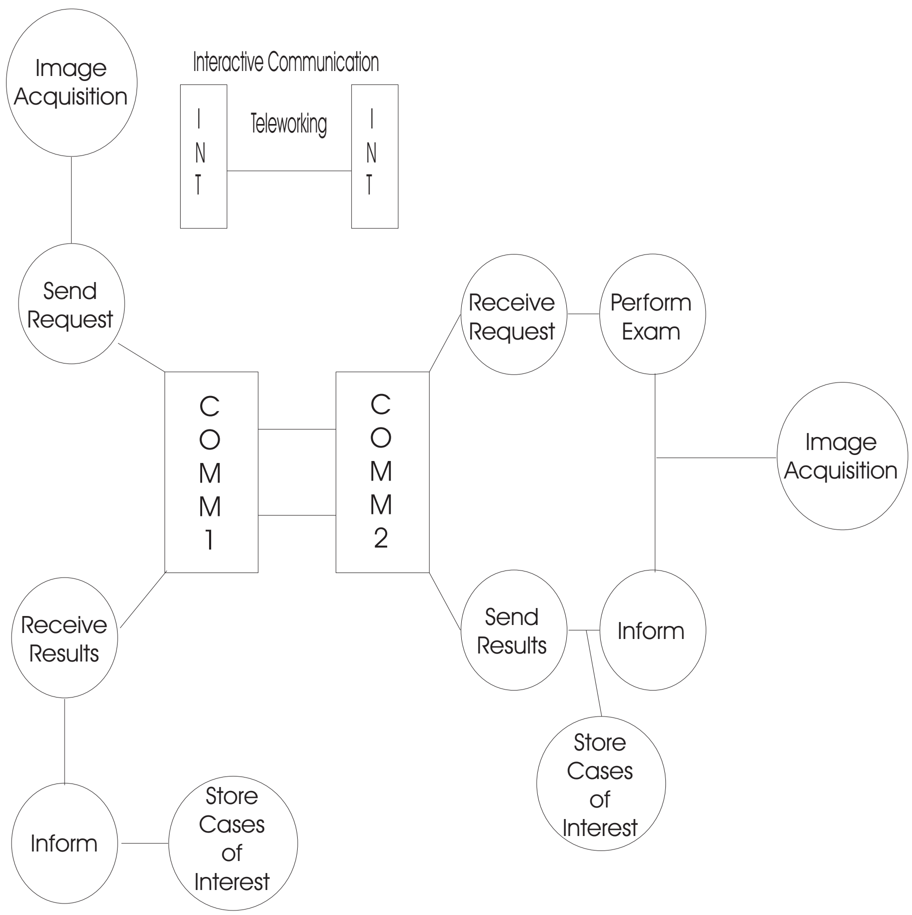


Figure 4.8: Conceptual Model of Care radiology.