

# PACS - Picture Archiving and Communication System

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Figure 1: PACS Workstation [General Electrics]

## Abstract

Picture archiving and communication systems (PACS) underwent a rapid development for the past 15 years, influenced by new technologies, faster network connections and other technical improvements. PACS handles different tasks, aimed to replace former film based medical images and the according workflows in hospitals and medical practices. In a PACS, images are acquired from medical imaging modalities like Computer Tomography (CT), X-ray or nuclear medicine imaging and digitally stored. It is preprocessing these images and making them easy accessible from different workstations within a medical environment. Therefore, modern PACS consist of image acquisition components, a controller, a database server, an archiving system and an underlying network to connect them. Each of these components needs to fulfill certain hardware and software requirements. PACS can also be interacting with other hospital wide systems, e.g. Radiology Information System (RIS) and Hospital Information System (HIS), to add according patient data or to support an end-to-end workflow. The images are stored in an archive and can be requested from multiple PACS workstations, where physicians and radiologists can examine the images for primary diagnosis, write reports, prepare for medical procedures or compare them with former studies. These workstations are providing complex software to analyze the images, e.g. 3D animation and computer-aided diagnosis (CAD). Furthermore, PACS use industrial standards such as DICOM and HL7 to improve compatibility with new imaging modalities. There exist several different PACS implementations on the market, e.g. actual PACS systems from Siemens, AGFA, and the open source project openSourcePACS. The PACS development process is not going to stop yet, as there exist many trends and possible improvements for PACS in the future, like the improving resolution and data size of medical images, faster networks and mobile solutions for teleradiology, i.e. the cooperation of radiologists over long distances.

**Keywords:** PACS, picture archiving and communication system, medical software, DICOM, RIS, HIS, teleradiology

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## 1 Introduction

The first development of digital radiology and the basics of Picture and Communication Systems (PACS) took place in the 1970s. However, the practical implementation of working systems started in the early 1980s and such concepts became popular [Lemke 2003]. The term "PACS" was coined by Duerinckx (see [Duerinckx 2003]) in 1982 shortly before the First international Conference and Workshop on Picture Archiving and Communications Systems in California. Since then, there were many conferences concerning PACS technology, e.g. the meeting of the Japan Association of Medical Imaging Technology (JAMIT) since 1982 and the EuroPACS since 1984.

With the growing popularity of digital sensors in medical sciences, the amount of digital data produced in hospitals and medical practices increased exponentially. Besides digital technologies, such as Computer Tomography (CT), nuclear medicine imaging or Medical Resonance Imaging (MRI), former analog technologies such as X-ray became able to produce digital images instead of analog films. PACS provided an efficient handling method for medical imaging and later PACS implementations included other forms of media, e.g. audio or film materials. Current PACS are storing, proceeding and converting the medical data in a hospital or a medical practice. As a result they are making it easy accessible from different locations, long-term available and editable. The images can be viewed and compared at special workstations, providing lots of advantages such as simultaneous viewing on different locations and powerful graphics software. This is leading to an acceleration of the related medical processes and saves costs. Figure 1 shows an example of such a workstation. Whereas in former times, PACS only exist

in major hospitals, today the decreasing costs for technical equipments and software are forwarding the installation of PACS in small clinics as well. Faster wide area connections (WAN) and wireless communications are channeling PACS research into the direction of teleradiology, i.e. the cooperation of medical institutes with radiologists over long distance, e.g. through mobile devices and rapid data transfers.

Due to many different PACS products from varied vendors, many PACS projects from the Universities or open source communities and plenty of scientific papers with sometimes diverging opinions, it is not easy to get a quick idea of the subject of PACS. This paper answers to this problem by giving a review on the current state of the art of PACS. Therefore in the following sections, a general description of the typical components, standards and technologies of a PACS are presented. This includes related systems and an introduction of the DICOM and the HL7 industrial standard. To provide a more practical view on PACS systems, the actual PACS systems from Siemens, AGFA and the open source project open-SourcePACS are briefly introduced, outlining some practical possibilities. Furthermore the current advantages and disadvantages of a PACS implementation in a modern hospital are discussed in a conclusion. The scope of this discussion is to outline the existing effects on the radiologic workflow and the cost benefits. Finally trends and possible improvements of PACS in the future are determined in the conclusion, like the improving resolution and data size of medical images and mobile solutions for telemedical access.

## 2 Components and architecture of PACS

Although there are many PACS solutions from different vendors, the basic components, standards and corresponding systems of a PACS are very similar. Hurlen et al. [Hurlen et al. 2008] defined the properties of a PACS, as a system that typically acquire, store, transmit, display, and process digital images.

On the basis of this definition the components can be separated. For acquiring and preprocessing of the images an image acquisition component is needed. To store the image a database component exists, controlled by the PACS controller, which is the central controlling component in a PACS. Finally, to display the digital images, a viewing component is required, referred to as workstation. In the following these components are specified in more details, regarding to the models given in [Huang 1996] and [Heitmann 2006].

### 2.1 Image acquisition component

The images of a PACS are produced by several radiologic imaging modalities. While the images of CT, ultrasound, MRI and nuclear medicine imaging (PET/SPECT) are digitally captured, the images of X-ray scanners have to be digitalized first. The images can be transmitted from the modalities using a specified interface. A DICOM interface is the most frequently used standard at this point. [Heitmann 2006]

Due to the fact that many imaging equipments are not supporting industrial standards, like the DICOM standard, acquisition computers (also called acquisition gateways) are needed to enable the digital exchange of the images. Therefore a computer is placed between the modalities and the PACS network. The computer receives the picture from the imaging modality through its specified interface, preprocessing it and converting it to a standard, which is supported by the PACS (i.e. the DICOM standard). For the image exchange between the modality and the acquisition gateway Huang [Huang

1996] distinguishes between two types of interfaces, a peer-to-peer network interface using TCP/IP or a master-slave connection using direct memory access. Figure 2 shows a simple model of the image acquisition process.

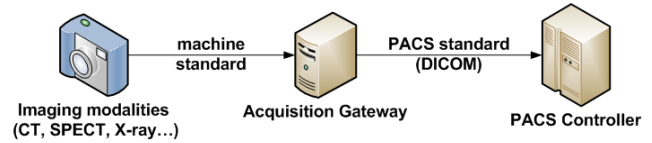


Figure 2: Image acquisition process

In many systems the imaging modalities or the acquisition gateway are also connected to the hospital information system (HIS), as discussed later (Section 2.3.2). Through the HIS interface additional patient information can be added to the images, using the HIS interface and the HL7 protocol (Section 2.2.2) [Huang 1996]. For an facile integration of imaging modalities into a PACS, DICOM conformance should be required from both modality and PACS vendors (see [Dreyer et al. 2002]).

### 2.2 PACS controller

The PACS controller is the main engine of the PACS. It controls all transactions in the system between components and its database server and an archive system. The images and the patient information are transmitted from the imaging modalities or an acquisition computer, the radiology information systems (RIS) and the hospital information system (HIS) to the PACS controller. After receiving the data the controller continuous the processing of the data, consisting of the following tasks [Huang 1996]:

- Extracting text information describing the received studies
- Updating a network-accessible database management system
- Determining the workstations to which the newly generated studies have to be forwarded
- Automatically retrieving necessary comparison images from the archive
- Automatically optimization of the pictures (optimal contrast, brightness and correct orientation)
- Performing image data compression
- Archiving the picture and deleting archived pictures from the acquisition computers
- Serving archive requests from workstation or other controllers

The most important property of the PACS controller in cooperation with its archiving system is to fulfill data integrity and system efficiency. Hence, it must ensure that no data is lost after receiving it from the imaging modalities. As long as an image is not archived in the long-term archive, PACS always keeps two copies of it in different storages. Moreover, the access from the workstations to the archive have to be as fast as possible. [Heitmann 2006]

### 2.3 Database server and archiving system

As announced before the database server and archiving system is part of the PACS controller. There exist different ways to built up the central archiving component of a PACS, but in general the major tasks of it can be outlined with the following statement of Strickland

[Strickland 2000]: "The PACS database ensures that all images are automatically grouped into the correct examination, are chronologically ordered, correctly orientated and labeled, and can be easily retrieved using a variety of criteria (for example, name, hospital number, date, referring clinician, etc). All imaging studies of a patient are immediately available on the PACS which encourages review of examinations with preceding studies and intermodality comparisons".

Therefore a PACS database server should consist of redundant databases with identical reliable commercial database software (e.g. Oracle, MySQL), supporting Structured Query Language (SQL). The systems should mirror the data in two database servers, to ensure a stable data handling even in the case of system failure or disk crashes. The PACS database system should be interfaced to the radiology information system (RIS, Section 2.7.2) and the HIS (see Section 2.7.1), to allow gathering additional patient information. [Huang 1996]

The hardware of the database system should use an fast multiple central processing unit and performant interfaces, like SCSI (Small Computer System Interface), S-ATA (Serial-Advanced Technology Attachments) and a fast network interface. With this configuration the system can support parallel processing and a simultaneous transfer of images to different networks or network devices (see [Huang 1996]).

The storage components are normally separated in a fast short-term archive and a slower, cheaper and bigger long-term archive.

### 2.3.1 Short-term archive

The short-term archive is used as the cache of the system. It is the most expensive storage in a PACS. Images from last recent studies and examination are firstly stored there to provide a fast access from viewing components. As said before the capacity of this cache has been increasing in the last 20 years. For comparison: While Huang recommended at least 13.6 gigabyte RAID as a cache in 1996 [Huang 1996], the PACS of the radiological institute of Munich owns a 880 gigabyte cache pool (see [Wirth et al. 2005]). This is correlating with expanding data size of medical images through higher resolutions.

The short-term archive is realized with S-ATA or SCSI hard disks in a redundant array of inexpensive disks (RAID). Through the use of RAID transfer rates between 150 MB/s to 320 MB/s are possible. The most frequently used RAID levels in a PACS are level 1 and level 5. RAID level 1 mirrors the data on more than one disc, improving fault tolerance, while RAID level 5 is using the concept of stripping and parity, to improve the transfer rates and to balance workload between discs. RAID level 1 and 5 can be combined.

The capacities of the short-term archive should at least be big enough to keep all images produced within two weeks. However, by reason of decreasing costs for hard disks it is nowadays possible to implement short-term archives with a better capacity, big enough to store image data of two years. [Heitmann 2006]

For example: The 880 gigabyte cache pool of the radiological institute of Munich is able to store the images from all examinations within the last 4-5 months (see [Wirth et al. 2005]).

### 2.3.2 Long-term archive

One of the most important tasks of a PACS is to ensure a proper long-term archival of image data. This is fulfilled in the long-term archive, a specific archive with a high security level and a high fault

tolerance. A long-term archive need to guarantee a storage of the images between 10-30 years, as regulated by law. By a PACS this archive is digitally realized and it replaces the former big archiving rooms and the human workers to sort it.

The most currently used storage technologies are magnetic tapes, like the Digital Linear Tape (DLT) technology with an average price of 4 Euro per gigabyte. Another technology is the usage of MOD (magneto-optical drive) ordered in MOD Jukeboxes. Wirth et al. [Wirth et al. 2005] say that the application of MOD is with 12 Euro per gigabyte not cost efficient and therefore no longer recommendable. Following decreasing costs for optical disks with about 1 Euro per gigabyte (see [Wirth et al. 2005]), Compact Discs and DVDs have become more popular as a cheap solution for long-term archives. Multiple optical discs or MODs are ordered in optical jukeboxes, which allow a fast loading and unloading of the discs and can be controlled through an SCSI interface. Although the access and transfer time is slower than the other technologies, optical jukeboxes satisfy the requirements for a long-term archive [Heitmann 2006]. Figure 3 shows different optical DVD jukeboxes from the Kintronics NSM series with up to 5.2 terabyte capacity (see [Kintronics 2008]).



Figure 3: Kintronics NSM DVD Jukeboxes

An actually starting trend may be the use of special hard disk systems. These systems are content-addressable storage solutions following the RAIN (redundant-arrays-of-independent-nodes) principal. This newer technologies allow permanent storage of fixed content (WORM, Write Once Read Many), it is scalable up to petabyte ( $1024^5$  bytes) and provides fast disk access time (see [Wirth et al. 2005]).

## 2.4 Workstations

Workstations are the human interfaces of PACS. Kim et al. [kim 1991] wrote that workstations are the point of contact of the radiologist and referring physicians. Therefore, the implementation of the workstation is very important for the success of a PACS. A workstation is a computer with connected monitors to display the informations of the PACS. Figure 4 shows such a workstation solution with multiple monitors. It provides at least a mouse and a keyboard as peripheries to work with the data. The physicians and radiologists are using the workstations instead of the former illumination boxes within medical treatments. The workstation computers are running software for communication, database access, displaying the images, resource management and for processing. With this

software the following fundamental operations are performed on a PACS workstation (see [Huang 1996]):

- Case preparation (Accumulation of all relevant images and information belonging to a patient examination)
- Image arrangement (Selection of cases for a given subpopulation)
- Tools for arranging (Tools for arranging and grouping images for easy review)
- Interpretation (Measurement tools for facilitating the diagnosis)
- Documentation (Tools for image annotation, text, and voice reports)
- Case presentation (Tools for a comprehensive case presentation)

According to new possibilities in computer graphics, current PACS solutions offer advanced software tools, e.g. supporting 3D animations, color highlighting and computer-aided diagnosis (CAD).

Heitmann [Heitmann 2006] distinguishes between four different types of workstation: workstations for primary diagnosis with high resolution monitors (at least 2500x2000 pixel), workstations for writing reports with a lower resolution (at least 1000x1000 pixel), workstations for detailed evaluation with high resolution and faster graphic acceleration and a workstation for digitalizing and printing, including a laser printer and a laser-film scanner. Furthermore, all of the monitors require certain values for contrast and luminance.



Figure 4: Workstation with multiple monitors

An other classification made by Knig and Klose [Knig and Klose 1999] separates between six different workstations. The first workstation in the image process is the quality assurance workstation with grayscale or color monitors and a resolution of 1000x1000 pixels. This workstation is used by radiologists to control the adjustments from the imaging modality and to manage the imaging quality. The second type of workstation is the workstation for diagnosis, with high resolution ( $\geq 2000 \times 2000$  pixel) grayscale monitors for thorax and skeletal diagnosis and lower resolution monitors for other radiological images. Additionally it should provide a monitor with a resolution of at least 1000x1000 pixels, supporting color-encoded images as they are produced in nuclear medicine imaging. The third type is a workstation for demonstration, often placed in consulting rooms, where the images are shown to the patients. Therefore a resolution of 1000x1000 pixels is enough. For viewing and analyzing of color encoded images a color monitor is elemental. The fourth type is the workstation for image reviewing, which is used for communication, for reviewing certain studies, for

preparing a medical procedure and for deciding where the pictures should be sent or stored. The next and fifth type is the workstation for teleradiology, supporting biplane and sectional imaging diagnosis. Biplane and sectional imaging diagnosis are special methods in the teleradiology. The hardware requirements for the image reviewing and the teleradiological workstation are equal to the requirements of the workstation for demonstration. Finally, the sixth type of workstation is the workstation for research, which requirements are depending on the field of study.

In contrast to these two classification stands the recommendation of R. A. Glicksman [gli 1995]: Instead of predefining different types of workstations and their functionalities it is better to support different functionality and privilege based on the user log-in. The advantage of this approach is that no routing to different workstation is necessary, the disadvantage is that every workstation must provide the hardware for every type of work.

In brief there are different classifications of workstations, but they can be combined easily, providing different hardware on the location and different access and methods based on the user level.

## 2.5 Network

As on the one hand image transfers are data intensive and cause a high network load, on the other hand a fast access of the image data from different locations is one of the major attributes of a PACS system. Therefore a specified underlying network is necessary. It is recommended that smaller groups of imaging modalities and their acquisition gateways are grouped in local area networks (LAN), many of such network are connected by a wide area network (WAN), provided by an regional Internet service provider. In the future increasing WAN speed will allow hospitals to work together over larger distances sharing one PACS system. [Knig and Klose 1999]

For keeping a network simple and scalable for standard UNIX and Microsoft Windows based computers, the TCP/IP protocol is recommendable. As technologies for the local area network, the Ethernet protocol following the IEEE 802.x standard or asynchronous transfer mode (ATM) can be used. ATM allows prioritisation of certain data, but is harder to implement as the technologies differ from vendor to vendor. Ethernet provides higher network speed with up to 10 Gigabit/s, while ATM runs with up to 2.2 Gigabit/s. In the implementation process of PACS it is important, to determine the most used network connections to prevent bottle-necks (see [Heitmann 2006]).

To illustrate important aspects in a PACS network, Figure 5 shows an example of a possible PACS network in a small hospital. Three imaging modalities are connected through acquisition gateways, which are using a local area network, realized with an Ethernet switch and 100 Megabit/s Ethernet cables. For example these three imaging modalities are placed in the radiological department. Moreover, in this LAN is also one workstation (workstation 4) to check recently taken images. This LAN is connected over a fast 1000 Megabit/s cable through another LAN, maybe in another building of the hospital. In that LAN there is a workstation for printing and scanning films (workstation 3) and two workstations (workstation 1 and 2) with multiple monitors connected with 100 Megabit/s. This two workstations could be the workstations for primary diagnosis, i.e. in examination rooms. The PACS controller with its database and archiving system is connected with a faster 1000 Gigabit/s Ethernet connection. This is necessary to prevent a bottle-neck at the controller's connection, because nearly every request in a PACS is passing the controller (e.g. store image, load image, request comparison images). The presented network would



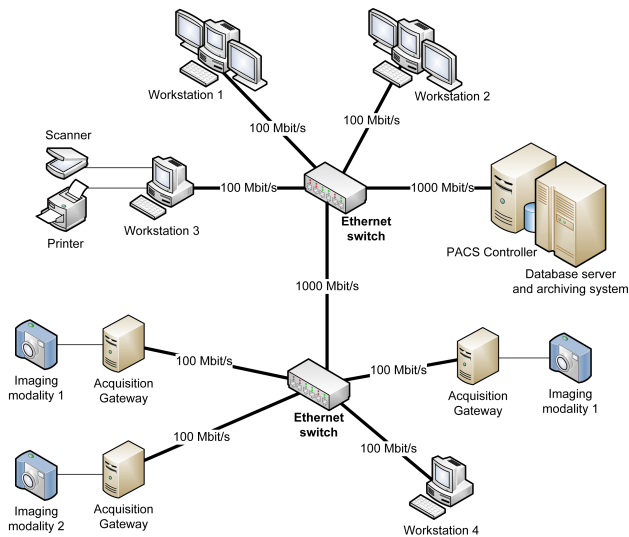


Figure 5: Network model of a PACS

be a small but reliable PACS network. A possible extension of this network is to connect an external radiology or share this PACS controller and archive with another hospital over a fast WAN connection.

## 2.6 Communication protocols

To provide scalability of a PACS, defined industrial standards are needed. In the last twenty years DICOM and HL7 became the enforced standards in medical IT. The DICOM standard specifies the handling of imaging data, while HL7 cares patients and examination processes. These two standards will be briefly introduced in this section.

### 2.6.1 DICOM standard

As in the 1970's digital medical imaging modalities and the use of computers to save and process the digital images became popular, the American College of Radiology (ACR) and the National Electrical Manufacturers Association started to cooperate on the definition of an industrial standard in 1983. In 1985 this incorporation published the ACR-NEMA Standards Publication. It defined the terminology, the information structure and the encoding of digital images. However, the communication of the images was not specified in these early years. In 1993 the version 3.0 of the standard was released, now renamed into Digital Imaging and Communications in Medicine (DICOM). As the name suggests, the communication and exchange of images was now included. It now created a standardized network protocol utilizing TCP/IP, introduced the operations of *Service Classes* and the handling of uniquely identifying *Information Objects*, which ensure that DICOM is independent from the underlying physical network. Since these extensions of DICOM (version 3) the realization of PACS. [NEMA 2008]

The standard is structured in parts, which are still advanced by ACR-NEMA's *Working Groups* to keep up with the rapid progress in medical information technology. Since the release of DICOM (Version 3) many more services and classes were added to the standard, offering a lot of operations and possibilities which are improving the workflow of digital medical images. DICOM defines

data structures, network oriented services, media formats for data exchange, work-flow management, specified presentation and the requirements of conformance of devices and programs. [Mildenberger et al. 2002]

The data structures for medical images and additional data are defined with so called *Information Object Definitions* (IODs). These definitions are describing a set of attributes, which an information object can or has to contain. Each attribute has a well-defined meaning and is identified with a pair of 4-character hexadecimal value. The first four hexadecimals are defining the group of the attribute (i.e. 0010 is the group containing patient data), the second four values are identifying the attribute within the group (e.g. 0010/0010 is the attribute containing the patients name). For every attribute there exist a defined *Value Representation* (VR) (e.g. IntegerString), defining the data type of the attribute's information. Moreover, for every attribute exists a defined *Value Multiplicity*, defining how often this attribute can be used in an object, and an *Element Type* which defines if the attribute may exist or has to exist in the object. Very important are the attributes 0020/000D and 0020/000E, which contain the Unique Identifiers (UID) of the object. Every UID is identifying exactly one study and is a worldwide unique number. Furthermore, it is possible for DICOM users to define so-called private attributes, which are then of course not readable by every DICOM supporting device. These attributes are often used by vendors to save hidden additional data from their machines, which is not displayed at the workstations. However, it may be used for support reasons or by additional tools. With the IODs different data structures are defined for variant radiological technologies and machines (e.g. CT, MRI or SPECT). [Mildenberger et al. 2002]

The DICOM network oriented services are realized with Service Classes, which provide operations on an Information Object to make the exchange of the data possible. A Service-Object Pair Class (SOP Class) is a combination of a Storage Class User, the user of a function, and a Service Class Provider (SCP), the provider of the requested service. These roles can change, depending on the operation. For example: If a CT is sending information to the PACS Controller, the PACS controller is the SCP and the CT modality (or acquisition computer) is the SCU. If the Controller now request the archive to store the data object, the Controller became the SCU and the archiving system is the SCP. [Mildenberger et al. 2002]

Beneath the specification of the data structure and the network services, DICOM is standardizing the conformance: Every vendor who wants to use DICOM on an imaging modality, has to publish a list of services the machine can provide and may use. This ensures an easy integration of DICOM conform devices (see [Heitmann 2006]). Although DICOM provides some security guidelines, a support for workflow which can communicate with a RIS, well-defined media formats and the possibility to save special clips which were made at an image review, without saving another duplicate of the image (see [Mildenberger et al. 2002]).

In conclusion DICOM ensures certain accordance between DICOM conform device, but it is important to know, that not every DICOM device is automatically compatible with every other DICOM device. The compatibility depends on the requested and provided services. Nevertheless DICOM is very important for the development of PACS because it is the only frequently used standard in medical imaging.

### 2.6.2 HL7 standard

The Health Level 7 (HL7) standard is an industrial standard for the exchange of medical data, developed and distributed by the Health Level 7 Inc. [HL7 2008], an US company. Although the standard is

in commercial hands of a company, it can be used for free. In this paper HL7 is always used for the standards not for the company. The latest version approved as an ANSI standard is HL7 version 2.6, but a draft of version 3 is available on their website (see [HL7 2008]).

The HL7 standard is build on top of the application layer, the seventh layer of the ISO/OSI reference model. It is defining the data structure of textual messages to communicate between applications in a medical environment. This could be the exchange of data between multiple departments in hospitals or between different hospitals and medical practices. Thereby the scope of the standard is to facilitate the interface implementation in computer applications from varied vendors. Most of the RIS and HIS implementations are supporting the data exchange through HL7. Hence, a PACS should provide an HL7 interface to communicate with these systems. [Huang 1996]

Different to DICOM, HL7 is textual orientated and it is defining the transfer of data through event based text messages. A typical situation for an HL7 message would be a new patient in a hospital, who needs to be examined in the radiology department. This event would trigger the sending of an HL7 message to the radiology department, including the necessary patient data. In this case, HL7 defines the data structure of the message and the meaning of the different data parts. After a successful sending of this HL7 message, the radiological department has all the data needed to add the upcoming examination into the workflow of the radiology department. [Heitmann 2006]

The HL7 standard defines multiple events, message types and segments. These events control when a message has to be broadcasted, for example when an ADT event ("Admission, Discharge, Transfer") is raising, the connected HL7 messages with the updated patient and study data will be sent. There exist several types of messages depending on the triggered event. The type of a message is specified through the segments the message is including. A segment is the smallest data element in the HL7 standard. For example, a PID segment contains the patient identifying data. Every message got to include a message header segment in which certain constants are defined, like the encoding of the separator and the type of the message (see [HL7 1998]).

## 2.7 Related systems

This section is introducing two other computerized systems appearing in the context of medical information technology, the Hospital Information System and the Radiology Information System.

### 2.7.1 HIS - Hospital information system

A Hospital Information System (HIS) is a computerized management system in a hospital to manage administrative, financial and clinical tasks within a hospital. It is supporting the organization of patients, workflows and employees. Huang [Huang 1996] wrote, that there are three major categories to be handled by the HIS: the support of clinical and medical patient care activities, the administration of the hospital (financial, personnel, payroll, bed census, etc.), and the management and control operations to provide long-range planning and evaluation of hospital performances. It is controlling financial tasks, like an automatic printing of bills and calculating costs. Since the early sixties there have been a lot of different HIS systems, changing with IT development and newer programming languages. HIS systems are not very portable, as they are

strongly linked to national rules and culture of medical treatment. [rie 1993]

To provide a paperless integration in the workflow of the hospital, the PACS need to be connected to the HIS. Through this interface it is possible to combine images, patient data and examination information in the treatment processes.

### 2.7.2 RIS - Radiology information system

Radiology Information Systems (RIS) became popular, when radiological scanners like CT or MRI were turning the radiology department to a key diagnostic department in the seventies. Accordingly, to manage this huge and expensive imaging departments RIS were implemented all over the world [rie 1993]. Depending on the situation of the hospitals, RIS systems were either realized as stand-alone systems or as an extension of their HIS. Parallel to a HIS, the RIS is coordinating the workflow in a radiologic department, like setting examination dates and examination structure, forwarding results and the scheduling of radiologists, assistants, rooms and the utilization of imaging modalities.

While a PACS is managing the imaging data, the RIS is managing administrative tasks. To get reliable patient data and to integrate the radiological department into the workflows of the hospital, an interface to the HIS is needed and nowadays implemented. Hence, a modern PACS is trying to combine images and the associated workflows and documents, RIS and PACS are deeply connected. That is the reason, why many vendors are selling their PACS as an integrated RIS/PACS product, because most of the modern PACS solutions are containing solution for administrative and management tasks of the radiology department.

## 3 Current PACS products and software

After describing the abstract components, protocols and architecture of PACS, the following section is concentrating on current PACS software available on the market, to outline the possibilities of actual PACS systems. Therefore, some PACS examples are shortly presented. Naturally, there are a lot of PACS solutions available on the market. Hence, it was necessary to confine oneself on a few examples. The PACS AGFA IMPAX, Siemens syngo Suite, and the open source project openPACS were just randomly picked without any intention in advertising them.

### 3.1 Agfa: IMPAX 6®

Agfa *IMPAX 6* is the PACS system of the *IMPAX Enterprise* solution, an integrated RIS/PACS and reporting system. *Impax Enterprise* is build up on *IMPAX 6*, adding reporting tools, web-based services, system monitoring and 24x7 support [Agfa HealthCare 2008b]. *IMPAX 6* and *IMPAX Enterprise* are developed and distributed by Agfa HealthCare, a global vendor in the market of integrated IT and imaging systems. Agfa HealthCare is developing PACS system since 1991 and has installed more than 1,200 PACS systems worldwide [Agfa Group 2006].

*IMPAX 6* offers a role-based access based on IT standards, fitting to the users workflow. Furthermore, the interface can be adjusted by the user. *IMPAX 6* distinguishes between six different user types: radiologists, technologists, hospital administrators, PACS administrators, clinicians and IT managers. Login is provided at installed

workstation and office desktops. In addition *IMPAX 6* allows remote access over HTTPS. Thus, *IMPAX 6* is supporting teleradiology and a secure access to patient information from locations outside the clinic, e.g. the radiologists home (see [Agfa HealthCare 2008a]).

Furthermore, the Agfa PACS contains applications for processing, storing and consulting complex image data files. This includes 3D images, images obtained through combining data from MRI, PET and/or CT devices and images used for virtual colonoscopy, computer assisted detection (CAD) and nuclear medicine [Agfa Group 2006]. The processing of complex images is done within the *IMPAX 6* workflow. As a result the productivity of users is improved, as the processing is already done when receiving the images.

The communication of *IMPAX 6* is based on client-server technology, using Web services for a communication between the clients and the core. Therefore, Agfa implemented a so-called *Websurge* technology to reduce problems with low-bandwidth networks. This technology is sending only the pixel data for the actual required resolution of the image. Moreover, a PACS is designed in a 3-layer architecture, consisting of a business logic layer (application server), a data layer (*IMPAX core*) and a presentation layer (*IMPAX client*). [Agfa HealthCare 2008b]

Overall, Agfa provides with *IMPAX 6* a suitable PACS solution, fulfilling the requirements for the imaging workflow and teleradiology, e.g. speech reporting and Web access. Agfa offers besides *IMPAX* and *IMPAX Enterprise*, a solution for small clinics and medical practices called *IMPAX EL*, archiving solutions, e.g. *IMPAX Data Center*, and workstation devices such as *IMPAX EL DS1000* and *IMPAX MA3000*. Agfa is also selling an IT system for hospital administration (Agfa *ORBIS*) and imaging modalities. Hence, an integration of *IMPAX 6* with these modalities or system is facile.

### 3.2 Siemens: syngo<sup>®</sup> Suite

Siemens *syngo Suite* is the name for an integrated RIS/PACS solution from the Healthcare Sector of the Siemens AG. *syngo Suite* can be partitioned in four different groups, *syngo Portals*, *syngo Applications*, *syngo Enablers* and *syngo Special Topics* (see [Siemens Healthcare 2008]).

With *syngo Portals*, Siemens coined the portal software running on the workstations, which enables a role-based login such as described in section 2.4. Siemens [Siemens Healthcare 2008] is providing four different user interfaces, depending on the login: Firstly the *syngo Portal Radiologist* offers access to relevant information and tools. It is structured according to radiological workflow to improve task organization when checking requests, reading images, and signing reports. Secondly the *syngo Portal Referring Physician*, offers workflow support and allows a secure interaction with the radiology department. The next workstation environment is the *syngo Portal Executive*, providing tools for quality metrics and other key performance indicators. Finally, the *syngo Portal Transcriptionist*, offers access to relevant information and tools for the transcriptionist.

The second part of the suite is called *syngo Applications*. It is including different software applications, each of them developed for specific tasks. The packages of *syngo Applications* can again be distinguished in workflow applications, imaging applications and so-called knowledge applications. The workflow applications are including tools to organize the imaging workflows. Secondly the imaging applications are including image processing and editing tools, i.e. 2D applications, 3D applications, 4D applications, intelligent post processing applications, dynamics applications and

multimodality applications. All of them aim to help physicians and radiologists in imaging diagnosis. Most of the applications are supporting the physicians with computer-aided diagnosis (CAD). Figure 6 is presenting a screenshot of a Siemens 4D application. Finally, the group of knowledge applications is containing the tool *Soarian Quality Measures*, which is providing the creation of charts and statistics about the imaging work. It measures changes of efficiency and enables a faster quality control.

The third group of *syngo* is *Enablers*, covering back-end components, hardware, technology concepts and interfaces. This includes data management (scaling, availability, image and application distribution, and multi-site), operations management (user management, access rights, security, support applications), and interfaces to other systems (HIS, Billing, Lab, etc.) [Siemens Healthcare 2008].

Lastly *syngo Suite* contains the group of *syngo Special Topics*. Referring to the website of Siemens Healthcare [Siemens Healthcare 2008] *syngo Special Topics* denotes a software solution called *Magic2syngo*. *Magic2syngo* is a concept to connect the Siemens HIS solution *Magic* with the Siemens RIS/PACS *syngo*.

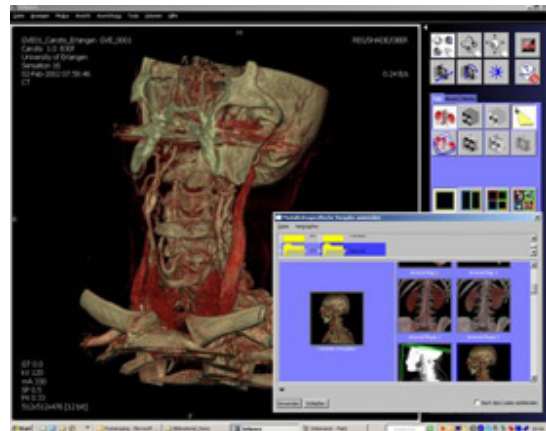


Figure 6: syngo 4D Application

Siemens *syngo* already appropriates recent trends like web portals and web spaces for the *syngo Suite*. However, the website does not specify complete product packages to buy. Furthermore, there are dependencies between the products, e.g. the *Soarian Quality Measures* tool can just be used with another tool, called *REMIND*. This has to be considered by planning a *syngo Suite* based PACS. Moreover, Siemens is not offering technical details and information about hardware requests on the website, consequently a good consulting with Siemens specialists is required. In a nutshell, Siemens Healthcare provides a modern PACS environment with *syngo Suite*, that is prepared for the current needs in handling medical images and satisfies teleradiology requirements.

### 3.3 openSourcePACS

*OpenSourcePACS* is a free, open source PACS developed by a team of the Medical Imaging Informatics group of the University of California, Los Angeles (UCLA). The first release was published under the open source lesser GNU public license (LGPL) in 2005. *OpenSourcePACS* delivers a basic PACS system, providing the communication and storing of medical images. Moreover, it is enabling an imaging clinic or hospital to offer its services over the web to physicians within or outside the institution (see [UCLA 2008]). However, *openSourcePACS* is just handling the image flow and not

yet supporting all RIS tasks like dictation, transcription and reporting. That means, that *openSourcePACS* is, in contrast to the two commercial PACS introduced before, not yet a fully integrated RIS/PACS solution (see [Bui et al. 2007]).

As it is published under LGPL there are more specific details about the architecture of *openSourcePACS* available: It is programmed in Java and web-based technologies to ensure a cross-platform deployment and development. *openSourcePACS* is providing standard compliance using DICOM based protocols and aiming to be extensible. The *openSourcePACS* is build upon six different components: Referral Order System (ROS), Image Server, Image File System (IFS), Reconciler, Station and the Admin Client. Figure 7 shows the architecture diagram of *openSourcePACS* [UCLA 2008].

ROS is the application server of the system, based on the open-Source application server JBoss. ROS is providing the user authentication service, and is controlling the business logic to keep the system connected. It also provides the web interface to the system. Secondly the *openSourcePACS* Image Server (OPIS) component is a medical imaging server, receiving images through DICOM push operation from DICOM devices and saves the images and the IFS. Consequently, the IFS describes the underlying file system, e.g. a RAID system. The reconciler is a client application to match studies with orders, querying the ROS about open studies and open orders. After matching the server is adding the corresponding studies/orders to a work list, which can be viewed at workstations running the station application. The station component is using a DICOM viewer and allows adding data to a DICOM structured report. Finally, there exists an Admin Client, an application for PACS administrators to configure a running *openSourcePACS*, i.e. user setup, procedure setup, and site setup. [UCLA 2008]

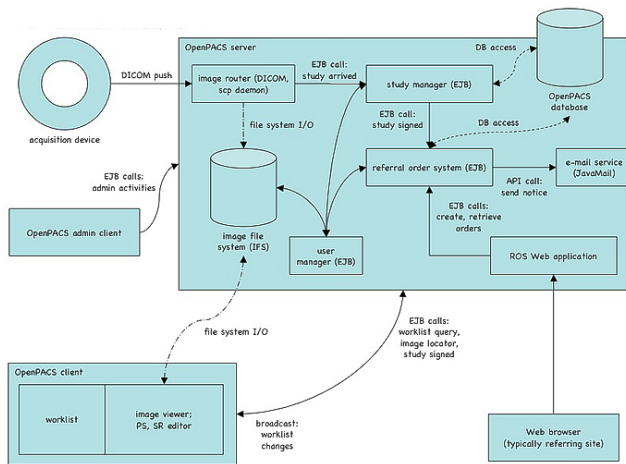


Figure 7: *openSourcePACS* architecture diagram

A basic workflow supported by the *openSourcePACS* would be the following scenario, lean to [UCLA 2008]: A physician in a medical practice examines a patient and comes to a conclusion, that an MRI is needed. Therefore, he is logging on to the website of a closed imaging center running *openSourcePACS*. On the website he fills out a form with the image request and the needed patient data. The study is scheduled with the used RIS and does not involve *openSourcePACS*. After the patient has been scanned, the study data is pushed to the *openSourcePACS* Image Server, storing the image in a local cache and additionally in a long-term archive if connected. With the *openSourcePACS* Reconciler the study can be matched by a radiologist with the corresponding order. In the

meantime, the study can be viewed with the Station component at multiple workstations in the department. Here the radiologist may reply with comments and suggestions to the physician. When the study is completed at the imaging center, a radiologist signs the study. Thus the *openSourcePACS* notifies the physician by email. Now the physician can view the completed study through the *openSourcePACS* web application.

Although *openSourcePACS* is offering basic tools and functionalities of a PACS, it does not claim to be an out-of-the-box PACS. For example, quality of service (QoS) and true fault tolerance are not available yet. Moreover, the utilization of *openSourcePACS* in clinical environments needs proper certifications, such as the certification of the Federal Drug Administration (FDA) in the USA and similar institutions in Europe (see [Bui et al. 2007]). Nevertheless, *openSourcePACS* and similar projects are leading the way to cheaper PACS solutions besides commercial products, encouraging the development of own extensions and making source adjustments possible. Besides this, referring to Nagy [Nagy 2007] openSource projects, errors and related updates are in most of the cases rapidly provided, due to the fact that they are backed by a large community.

## 4 Conclusion

After presenting the basic PACS technology and current PACS solutions, there are two questions remaining to complete this state of the art report: What are the benefits of PACS? Why are there still film-based hospitals and medical practices existing? In this conclusion, these questions are answered and a prospect in future PACS developments is given.

### 4.1 Discussing advantages and disadvantages of a PACS

Some benefits of a PACS are directly derivable, such as the reduction of costs. PACS eliminates the cost for the film roles, big rooms and administrative employees needed for the administration of film-based archives. Moreover, the usage of PACS is increasing the productivity of an imaging department in a hospital or a medical practice, through acceleration of the image workflow. In film-based hospitals the images have to be distributed to the various stations after the acquisition process. In contrast, PACS make it possible to access the studies immediately after acquisition. Consequently the report turnaround time is reduced. However, there also exist plenty of benefits that might be overlooked at the first time: Owing to ordered data and search functions in a PACS, the physicians do not longer have to search for images. As a consequence, the waiting time of patients can be reduced which entails a higher customer satisfaction. Finally, PACS are providing better tools and functionalities at the workstation, improving the job satisfaction of radiologists. As a result fault diagnosis can be reduced.

Despite these advantages, there still exist plenty of film-based imaging centers and radiological practices. The obvious question is why these managers did not decide to implement a PACS yet. Firstly, implementing a PACS is an expensive project, even though the prices for hardware and technical instruments are decreasing. Consequently, PACS systems become profitable not until after a few years, what may be a reason why some radiologists still are viewing with skepticism at PACS topics. Another reason might be the change in workflow that could be frightening for conservative radiologists and physicians. Most of the staff will need an introduction and additional trainings to work with the PACS software. Moreover, by replacing the analog films and reducing images to ones and



zeros, with a PACS implementation medical images are not longer substantial objects. As a result they can be lost or deleted, as still no archive can guarantee a total fault-tolerance. The imaging service is essential for current medical environment, so there should always be a computer engineer available, to serve daily faults and problems.

To put things in a nutshell, the benefits of PACS are clearly visible, but there are some reasonable doubts left. To improve the number of PACS installations, the vendors and developers of PACS systems should, besides the technical advancement, focus in helping the end users to remove the last doubts. This could be reached with easier introductions into the topic, even better adjustable systems to the clinical workflows and reliable archiving and backup solutions.

## 4.2 Future trends and developments

After this paper presented the current state and basics of PACS, followed by a short discussion of advantages, disadvantages and problems of PACS, there remains the question about the future trends and happenings in the domain of PACS. Firstly, digital imaging and computer graphics is still a field with rapid progress, developing higher resolution images, saved in better data formats with higher compression rates. Furthermore, PACS are going to provide further technologies for teleradiology, due to the fact that health systems and health institutions are becoming closer connected and cooperating. Besides already realized technologies, such as web access and web viewers, newer technologies for low-bandwidth data transfer are currently enabling to view image streams on mobile devices supporting volume rendering and 3D animations, e.g. on a smart phone or PDA. As a result, radiologists may work from all over the world on a certain study. Consequently, experts do not have to travel to the patients, neither does the patient has to travel to the expert. After successful PACS implementations in several hospitals on the world, the connection between the different PACS got to be faced. A secure way for communication between the hospitals and medical practices would support a total paperless radiology work. As a result, a physician would be able to receive former digital images over a large distance from a hospital, where his patient got an examination a few years before. This would support the idea of the Electronic Health Record (EHR), which is currently discussed in many countries. One concept regarding the EHR, is a patient card equipped with a microchip, which is storing necessary patient data for following examinations or emergencies. In the future it might be possible to store image materials on this microchip, acting like a mobile device of the PACS. Another concept is to connect every medical institution in a country or nation with a centralized server. This solution would enable the exchange of images over the central sever through PACS-to-PACS interfaces. To conclude, PACS have become an essential part in modern medical environments and are facing plenty of different trends in the future.

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