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INTEROPERABILITY IN MEDICAL INFORMATION SYSTEMS STATE OF THE ART

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Interoperability in Medical Information Systems: State of the Art

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Interoperability in Medical Information Systems: State of the Art

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Abstract: The need for interconnecting medical information systems in order to make optimal use of clinical and administrative data raises the problem of interoperability in health-care systems. This problem and its possible solutions according to current practice and theory is surveyed in this paper. Specifically two modes of interoperability, i.e. sharing of data among different databases and teleconferencing, are discussed. Furthermore, ongoing standardization work within the area of interoperability is surveyed and finally some example hospital systems from the west coast region in Sweden are described with an emphasis on interoperability.

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1. Introduction

1.1 Motivation

Data communication, storage and retrieval, mutual understanding despite borders, distances and systems heterogeneity, are all equally essential in health-care information systems. Information technology has reached a point where dramatic improvements to the way such systems work are possible.

In particular, the interconnection of information processing systems in order to make optimal use of medical and administrative data, will be the basis for improved care and higher efficiency in future health-care information systems. The purpose of this paper is to discuss issues and techniques related to computer supported exchange of information in health care activities, with respect to current technology and future trends. This work is performed as a part of the MILORD-project[1].

1.2 Basic Assumptions and Delimitations

There are at least four different reasons for the increased need for interoperability in medical information systems:

- specialization in medicine means that medical data is produced by different sources which then needs to be aggregated and integrated for use in different care activities [Saranummi1991].
- we also see a development (in public health-care) towards decentralization of care providing institutions, which may imply the introduction of organizational boundaries as well as geographical distribution of care units.
- a current trend is that an increasing number of both administrative and clinical activities are supported by computerized information systems. The result is a multitude of different systems which are heterogeneous in hardware, system software as well as in the semantics and syntax of information.

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[1] The MILORD-project is sponsored by the CEC AIM-programme: Project A2024 MILORD, · and by NUTEK - the Swedish Board for Technical Development.

- specifically for public care provision there is a need for global aggregation of information for evaluation, planning and control.

A difficult problem is the complexity of interconnection for information exchange. This exchange is needed in order to provide integrated views of data, e.g., for a medical patient folder where the contents may be retrieved and integrated from several different sources.

In general, *interoperability* is the ability of a set of autonomous information systems to exchange information on the basis of standardized high-level protocols (i.e., OSI(7) or similar). Further, all systems share a common set of rules for interpretation and a common conceptual model, of the information to be exchanged. The autonomy of these systems means that they have a high degree of independence with respect to their administration and implementation.

In the general case, we can distinguish several problem areas that can benefit from improved interoperability of health-care information systems, e.g.,

- aggregations of medical data, including access to geographically distributed data.
- support for remote consultation, real-time (or synchrounous) conferencing and non real-time (or asynchrounous) conferencing.
- interfaces between IS and medical equipment and instrumentation.

Another view of interoperability refers to organizational aspects, e.g., the exchange of information between public and private care providers and betweeen independent private institutions. An issue here is the extent to which medical information can be made available to different institutions. Included in the health care information domain can also be various information sources indirectly part of the care process, such as drug (effect) databases, registers for dicease statistics, as well as population registers. The ability to access these sources and integrate data also fall under the area of general interoperability.

In addition to the general goals of efficiency and quality of care, the increased interoperation will have other effects, e.g., an improved integration of administrative and medical information and promoting the establishment "informal networks" for communication among individuals and groups.

2. Information Systems & Databases

2.1 Information Systems Architecture

The development of integrated information systems for health-care is a complex task due to the heterogeneity of information (the number of different datatypes) and the many kinds of systems in operation today. The need for a better understanding of the information systems architecture in healthcare has been recognized, e.g., by standards bodies [CEN1991].

Some examples of various application domains and the corresponding types of information systems are,

Administration & Resourcce control

- Staff , Materials mgmt , Budget, etc

Patient administration

- Admission/Discharge, Scheduling, etc

Clinical

- Medical folders mgmt, Decision support, etc

Medical Services

- Laboratory systems, medical instruments (e.g. in radiology), etc

General databases

- drug databases, dicease registers, medical and health-care related litterature databases, etc

Clearly, many information systems applications belong to several of these domains. We also see a trend today where information systems to support e.g., a clinic, include both medical and administrative functions, thereby becoming more or less self-contained and reflecting the status of the unit they support.

Several different classifications and abbreviations are currently used to describe information systems in healthcare. A Hospital Information System (HIS) is seen as an overall information processing system for a healthcare (hospital) environment, managing both administrative and patient related information. We also have various systems to support a certain department or clinic e.g., the concept of Radiological

Information System (RIS) denotes the medical and administrative information management facilities needed in a radiological unit, often in connection with PACS technology (see below). Similarly, the concept of Ward Information System (WIS) [Baud1991] has been used to denote the information system support for the actors (patients, nurses, physicians) and the activities (care provision, data aquisition and presentation) on the ward level. On this level we also have bedside systems, e.g., managing kardex data. We use the concept of Healthcare Information Systems (HCIS) to collectively refer to the different applications of information systems in the health-care environment.

Possibly the first activity seen as amenable-to computerization was the management of medical records or patient folders. The concept of an eletronic medical record [Rector1991] has been studied extensively over the past decades in terms of its role, structure and contents. Increased interoperability of HCIS is a prerequisite for more advanced folder applications. It may allow the data of a forlder to be directly obtained from the source where it originated, and possibly also to be continously updated according to explicit rules in the folder. Available products provide a certain degree of integration, with respect to clinical and administrative data, but are limited in the representation and integration of (multimedia) data. For images, the folder typically contains surrogates for the actual data, e.g., indicating status and location of a set of x-rays. An advanced folder can also support different views of the data available, depending on user category and context , e.g., administrative and clinical views.

2.2 Image Management and Communication

In the area of teleradiology, techniques have been developed for the transfer of digitized radiological images, combining image management and telecommunications techniques. Currently, development of more general systems to store and distribute radiological images in digital form are rapidly progressing. The development of computer-based imaging instruments in radiology fits well into this development. This field is commonly referred to as Picture Archiving and Communication Systems (PACS).

The components of such application systems generally include:

- a computer network
- diagnostics workstations
- image archive and database mgmt

The data volumes in radiological image production are considerable, which places high demands on both storage techniques (space) and transfer techniques (respons time). Current compression techniques provide a compression ratio of 3:1, without loss of data (higher ratios are attainable, but with loss of data). The input devices are any digital image generating instruments (MRT, CT, Ultra sound , etc) including scanners (for photographic media). Protocols for the interface between input media and the communications network exist, e.g., ACR-NEMA (see sec. 4.3), but standardization is needed. Some Teleradiology systems also provide dialogue facilities by which sender and receiver can perform cursor positioning operations on the same image data (which can be used in combination with telephone conversation), in order to provide a basic form of teleconferencing.

Key figures about image communication requirements have been derived from observations and statistical evaluations at several hospitals [Keizers1991]. We report here a summary of these analyses. A modern Hospital with 1500 beds produces about 20,000 Gbit of image data per year (assuming that X-rays are hypothetically converted into the appropriate pixel matrices, e.g 2500X2000 at 10 bit for a chest X-ray). We can assume that every image would have to be transferred from the imaging modality to an archivial station immediately after its acquisition, and that afterwards every image has to be transferred (at least) a second time to one of the reporting places. Also, it results that 50% of old images are additionally acccessed form archive. A profile of the mean image dataflow results in a continuous data stream of about 5Mbits/s during the peak hours of examination work. This does not seem to be extraordinarily high with respect to the transmission frequency of estabilished LANs. However, often the physical bandwidth, i.e. the pulse frequency of the carrier signal on the trasmission line, is mistaken for the average 'data rate' of a message transfer. LANs need sophisticated protocols to solve conflicts in the case of concurrent transmission requests. Protocol execution and network specific data parcelling reduce the total effective data transmission rate to a value which, depending on the number of communicating devices, is some 2..15 % of the carrier frequency.

Because of the significance of an appropriately fast image transmission it seems to be reasonable, if not unavoidable, to develop networks which are specially tailored to the PACS communication profile.

The current level of integration with other information systems (HCIS) is fairly low, due to a lack of standards and a clear understanding of the overall HIS architecture. The PACS products available today are in most cases closed systems, making it difficult to deploy multi-vendor solutions. Users (hospitals) of PACS technology consequently develop their own Radiological Information Systems (RIS) which are connected to PACS services, thereby providing a certain degree of integration with the surrounding patient administrative data management. This strive for a successive integration towards the HIS level, is captured by the more general approach of Image Management and Communication Systems (IMACS), i.e., a generalization of PACS to include other medical image datatypes and patient related data on the HIS level[CEN1991]

2.3 Database Techniques to Support HIS Interoperability

The area of general database technology is important to HCIS since several issues relevant to this environment are addressed, e.g., data models and query languages, techniques for distributed data management and security (authorization & access controls). Lately, an increasing attention has been given to the study of interoperable databases i.e., methods and techniques to allow a set of autonomous, possibly heterogeneous, databases to share and exchange data. In general, DBMS technology can be discussed from several aspects, including the datamodel supported and the architecture for distribution. Both aspects are relevant for interoperability.

A Distributed Database management system provides transparent operations on a physically distributed database, i.e., the database is partitioned and/or replicated over a set of processing elements (or nodes) in a network. Transparency implys that a user (application) perceives the databases as a single logically integrated system, in terms of a global database schema. Among the difficulties in implementing distributed data management is the provision of efficient distributed reliability and concurrency control protocols. Thus many existing products only provide limited support for distributed queries and distributed transaction management [Özsu1991]. Another issue is the maintenance of a strict global schema, which may prove difficult if local changes to database structure are frequent. A distributed DBMS often requires a strong centralized control and administration, with some degree of autonomy for local databases.

Multidatabases and Federated Databases [Sheth1990] represent an approach to decentralized data management, which differs from a distributed database in that the independence (or autonomy) of constituent databases are emphasized. Specifically, multi DBMSs have been proposed as a means of integrating a set of existing (possibly hetergeneous) databases. In some models, a global schema is then mapped to the schemata of local databases, which may imply datamodel translations. A federated database system does not maintain a global schema, rather, a federated schema is contructed by selective integration of subsets of the databae scehmata of other (remote) databases. Interoperability in federated databases and federated information systems in general [Ahlsen1991] also includes issues in semantic heterogeneity, and the techniques the cope with this such as schema integration.

A Federated architecture is appealing for the healthcare environment, since it emphasizes controlled data sharing thru well-defined interfaces and autonomy of individual databases. Autonomy means that changes can be made to local database schemata as long as the interfaces are left intact (c.f., encapsulation in object-oriented models). This independence also implys that the owners (administrators) of a database are in full control of the locally stored information, which is important for authorization and access controls of external users and systems.

Catalogues are important for the definition of interfaces between communicating databases, e.g., for federated databases. Catalogues (or data dictionaries) are used in DBMS to manage meta data, and can also contain descriptions of the intended semantics of data. There is a need for common conceptual models of medical information, as a basis for the design of common datamodels, which then can be used for interface definitions. To this end, the development of medical term catalogues play an important role in database design for interoperability in medical information systems.

Finally, we note that computer supported teleconferencing and consultation is one medical application area where database techniques can bring added value. Primarily by providing access to local as well as remote databases (e.g., in another clinic) during a consultation session.

3. Teleconferencing

Two forms of teleconferencing can generally be classsified: interactive real-time and non interactive non real time conferences. Non real time conferencing software are common text line based systems like the News system which support non interactive computer conferences. Real time teleconferencing includes online audio and/or video communication [Gerfen1986].

3.1 Non Real-time Teleconferencing

In the mid 1970s the DARPA (Defense Advanced Project Research Agency) began working towards an internet. The internet architecture and protocols took their current form in 1978-79. The transition to this new technology was completed in 1983 when all computers connected to the ARPANET were demanded to use TCP/IP, [Comer1988]. The interconnection of various networks is not possible without technologies like the TCP/IP suite.

With the development of standards for protocols and interconnecting networks communication applications like mailing and conferencing systems became feasible. While mailing is similar to normal post services - writing a letter and sending it to one or more receivers; - conferencing gives the possibility for group talks - everyone can talk to anyone else in a group and the whole group can participate.

A basic technical difference distinguishing conferencing systems from mail systems is that the former need multicast or broadcast transport mechanisms to support them, while the latter can get along with unicast mechanisms. There are few standards for conferencing, but a useful classification for common text line based conferencing software is by the structureit imposes on conferences [Quarterman1990].

Three kinds of conferencing software structures can be classified [Cook1987]:

- Line structure

  Messages are simply stored and displayed according to their chronological order.

- Tree (branching) structure

At every point of the conversation branches to subtopics can be specified. Thus messages within a group can be selected according to specified subtopics.

- Star (item and response) structure

  This is a compromise between the former structures: branches are only permitted from the basic conversation line; branches from branches are not allowed.

Not only the internal communications of a conference can be structured in different ways, but also the conferences themselfes may have a structure among them. The News system (B news 2.11) is an example for a conferencing software with structured conferences. It is one of the most widely used systems in the world according to the number of users and machines it runs on [Quarterman1990].

On the basis of the internet protocols the News system was developed as one of the first conferencing systems in the mid 1980s. Various long term conferences on scientific and technical subjects are part of the news system. The basic element of information distributed in the news system is called an article. Articles are grouped according to topics in newsgroups [Kantor1986, Spafford1988]. Users who want to participate in a conference can read and post articles to these newsgroups. It is not possible to define 'closed' groups, i.e. groups which can be referered to only by authorized persons. The news service provides functions for asynchronous conferences. It can take up to 7 days until an article reaches all connected sites.

The News system is an example of a common conference system which is based on text oriented messages without online facilities. There are a number of other systems for asynchronous conferencing which are less comon than the News system like PARTI [Cook1987], CoSy [Meeks1985] etc. The above listed conferencing systems are non interactive text line based. Thus they do not have online characteristics which are necessary to give the impression of a realistic conferencing situation.

Interactive systems like TALK and PHONE on UNIX systems allow online communications between connected users. The former is a One-to-One interactive CMC (Computer Mediated Communication) system, the latter has One-To-Many communication capabilities. Both of which are text line based, i.e. audio and video equipment or multimedia documents are not supported.

3.2 Real-time Teleconferencing:

Nowadays highspeed fibre networks like FDDI and B-ISDN make it feasible to integrate real time conferencing soft- and hardware in a workstation environment. In 1985 the DBP presented the first video conferencing system to the public [Gerfen1986]. It was not integrated in a computational environment but it allowed real time audio- and video communication.

Four kinds of real time teleconferencing can be distinguished:

- Telephone conferencing using standard telephones,
- Audio conferencing with full duplex audio equipment including the capability of data transmission (e.g. images, facsimilies etc.),
- Video conferencing with full duplex audio equipment, video communication and optional data transmission
- Integrated video conferencing within a workstation environment.

In 1988/89 the BERKAPS project realized a concept for teleconferencing workstations. The project was founded within the scope of the BERKOM projects and allows real time conferencing including audio and video communication and distributed group working on multimedia documents [Gehring1989, Schindler1988]. The BERKAPS system was a descendant of the TELES.VISION system which can be connected to ISDN or telephone and X.25. It is a PC integrated video conferencing system which allows group working on standard PC applications [GmbH1991].

Another project in the scope of the BERKOM projects is the MEDAP project which deals with the development of medical workstations with integrated teleconferencing facilities. It started in 1990 with the implementation of basic medical and conferencing functions. Real time video communication was not included in order to meet the concept of a lowcost medical workstation. Only distributed group working on medical images and audio transmission is supported during a conference by using the standard SUN audio equipment of the workstations. In order to have an impression of the conference participants photos are displayed in the window related to the conference [Lemke1990a, Lemke1990b, Lemke1991]. In 1992 the development of the MEDAP workstations will be continued. In addition to the basic medical functions, complex 3D applications will be realized. Real time video will be integrated in the conferencing system. Thus it will be possible to configure low cost and high end teleconference workstations. The former without video equipment, the latter including special frame grabbers and video cameras.

4. Standards for information exchange

One of the most important means to realize interoperability is the use of standards. There exists world-wide a large number of standardization bodies in health care, which often address overlapping areas and produce conflicting standards. It therefore becomes important to coordinate the activities of different standardization bodies. The standardization efforts in the health care area are in Europe coordinated by the Technical Committee TC 251 of CEN (Comité Européen de Normalisation), [CEN1991].

There are seven working groups under TC 251 addressing different subfields within the health care area:

1. *Health Care Information Modelling and Medical Records*. This working group addresses modelling methodology and conventions, high level frameworks and architectures for health care information systems.
2. *Health Care Terminology, Semantics, and Knowledge Bases*. This working group studies terminologies and coding systems in health care. Translation between natural languages is also investigated.
3. *Health Care Communications and Messages*. This working group investigates interprocess communication, interchange formats, character repertoires, communication profiles etc.
4. *Medical Imaging and Multimedia*. This working group addresses techniques for medical image interchange, including applications such as radiology, nuclear medicine, and pathology.
5. *Medical Devices*. This working group investigates standard formats for the representation of biosignals and other output from various medical equipment.
6. *Health Care Security and Privacy, Quality and Safety*. This working group addresses issues such as authentication, access rights, audit requirements, error recovery, continuity of service, and data communication security.
7. *Intermittently Connected Devices*. This working group studies the special problems caused by off-line devices, such

as patient held cards, portable computers, and magnetic disks.

The connections between CEN TC251 and other standardization organizations are depicted in figure 1.

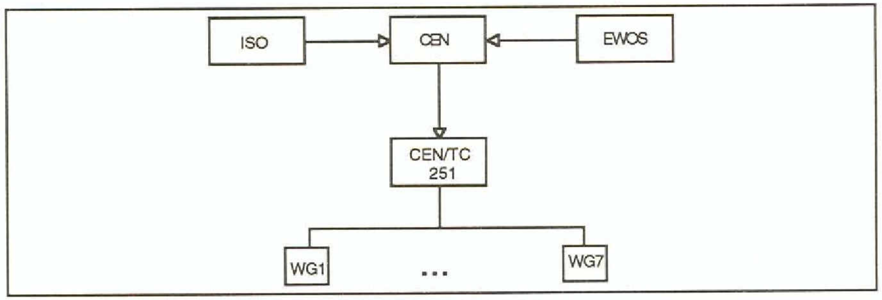

FIGURE 1. CONECTIONS BETWEEN STANDARDIZATION ORGANIZATIONS.

The arrow from ISO to CEN indicates that when an ISO standard is available, it will be put to the formal vote for adoption by CEN as an EN (European Standard). The arrow from EWOS (European Workshop on Open Systems) to CEN means that proposals from EWOS will undergo a voting procedure by CEN to be approved as an EN or ENV (European Prestandard).

In the following subsections, we describe some of the more important standardization efforts in health care terminology, health care communications, and medical imaging.

4.1 Standards in Health Care Terminology

There are many different terminologies and coding systems for the various subfields of the health care area, e.g. for diseases, drugs, medical procedures, therapies, and health care articles.

The most important classification systems for diseases are WHO's ICD-9 and ICD-10 (International Classification of Diseases) standards, [WHO1978]. The patient classification system ICD-9-CM DRG (Diagnosis Related Groups), [Fetter1983], is based on ICD-9 and includes also patient attributes, such as age, sex, and length of stay.

Two well known terminology systems are SNOMED (Systematized Nomenclature of Medicine), [Cote1980], and MeSH (Medical Subject Headings), [MeSH1985], which are used mainly for indexing medical articles. SNOMED is a medical terminology system which maps medical concepts into points in a multidimensional space. MeSH points medical and some non-medical concepts into a hierarchical classification.

There exist several projects, whose aim is to obtain a unified medical language. The most important is UMLS (Unified Medical Language System), which is coordinated by NLM (the United States National Library of Medicine), [Walker1988]. The goal of UMLS is to form linkages between existing terminology systems (e.g. MeSH, SNOMED, ICD, DRG), and to derive theoretical principles of linguistics, which can be used to express relationships among medical concepts.

4.2 Standards in Health Care Communications

An essential role in the definition of communication networks protocols is represented by the "Information Processing Systems - Open Systems Interconnection" Basic Reference model (ISO 7498/1983). The OSI model describes how machines can communicate with one another in a standardized and highly flexible way by defining the functional layers that should be incorporated in each communicating machine. Each hierarchical layer in the model (the layers are 7) provides a different set of functions, and the intent is to make each layer as independent as possible from all others. Each layer has a defined interface with the layers above and below. This interface is flexible so that designers can implement various communication protocols and still follow the standard.

The IEEE 802 committee has undertaken some major activities in the field of Local Area Network (LAN) and Metropolitan Area Network (MAN) definition, and a series of documents describing specific architectures and implementation at the different layers of the ISO/OSI Reference model have been produced:

- IEEE 802.1 deals with networks architectures, involving the higher layers in OSI model (from layer 3 and up)
- IEEE 802.2 deals with the logical link layer, a sublayer of the Data link layer in the OSI model
- IEEE 802.3 LAN standard, known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD) bus, is closely associated with Ethernet and involves contention access on a bus topology.
- IEEE 802.4 LAN standard deals with all elements of the token-passing bus access method and its associated physical signalling and media technologies.

- IEEE 802.5 LAN standard deals with all elements of the token-passing ring access method and its associated physical signalling and media technologies.
- IEEE 802.6 LAN standard defines a Metropolitan Area Network using broadband transmission technologies.

A more recent standard for a fiber optic based LAN (known as the Fiber Distributed Data Interface- FDDI) has been defined in the ANSI ASC X3T9.5 document. It employs a ring topology with a token-passing access method and a baseband modulation. Due to its high performances (100Mbits/s), it is intended for the connection of high performance mainframes, workstations and peripheral equipments and to provide a backbone connection for lower speed LANs. An enhanced version of the network, called FDDI-II, handles voice traffic as well as data, so that interfacing to video and sound network is simplified.

The International Consultative Committee for Telegraphy and Telephony (CCITT) has developed the world-wide public network standard: the Integrated Service Digital Network (ISDN and B-ISDN). It is intended to provide end-to-end digital communication of voice, and all types of packet switched and circuit switched data over the public switched network.

All the standards described above involve the two lower layers of the OSI reference model, that is the physical layer and the data link layer. The first provides mechanical and electrical specifications and procedures to establish and maintain an end physical connection. The second ensures that the data passes without error from one machine to another, specifying the rules to access to the transfer medium and the format for data transmission. A large number of different communication protocols (developed by different computer vendors) perform the functions described in the higher layers in the OSI model and allow machines of the same type (vendor) to be completely interconnected.

Another well-known set of communication standards is represented by the TCP/IP (Transmission Control Protocol/Internet Protocol) suite. The development of these protocols were sponsored by the US Department of Defense, and they been adopted by a large number of computer industries. The Internet Protocol (IP) corresponds to the OSI layer 3 and provides the software for routing data to the various nodes (machines) in an interconnected networks environment. The Transmission Control Protocol corresponds to to the OSI layer 4 (transport layer). It provides for reliable inter-process communication between a pair of processes in host computers attached to distinct but interconnected networks. The TCP/IP standards are independent from the lower layers, that is on how the functions of layers 1 and 2 in the OSI model are implemented. The set of TCP/IP Application or User Level Protocols which operate at levels higher than 4 are not OSI-compatible. These protocols define some useful standard utility for file transfer (FTP), mailing service (SMTP), remote access (TELNET) and distributed file system service (NFS).

4.3 Standards for Medical Information Systems and Image Management

The American College of Radiology and the National Electrical Manufactures Association have defined a standard for communications in digital radiology (ACR-NEMA 300-1985). The standard is intended to allow communications between interfaces from different manufacturers within a networked environment. It specifies the hardware interface, a minimum set of software commands, and a consistent set of data formats for communications across an interface between an imaging equipment (device) and a network interface unit or another imaging device. The ACR-NEMA standard has six layers patterned after the OSI model, it does not includes the network layer (level 3), in fact it defines a point-to-point interface, therefore does not require the routing functions of the network layer.

It is important to note that the ACR-NEMA standard is not intended to be a communication network standard, a PACS standard, or a data base standard. The version 3.0 of the ACR-NEMA Digital Imaging and Communication standard will provide capabilities for transmission of 2D images (as well as multiple images in a single message), graphics, text and commands.

A partially extended (modified) version of the ACR-NEMA standard, the Standard Product Interconnect (SPI), has been jointly worked out by the European Philips and Siemens. Also, there exists a Japanese version known as Medical Image Procurring Standards (MIPS). The Papyrus standard extends the ACR-NEMA standard capabilities by defining a file format for storage and exchange of image files from different modalities and diagnostic informations in a PACS. The Papyrus standard was developed at the University of Geneva, and it has been extensively modified after it was evaluated by a technical working group of the European TELEMED project (see sec. 5.2.3), that required several functionalities to be added to the original Papyrus format, in order to be as compatible as possible with the SPI standard.

A long list of international association and committees are today involved in activities addressing the development of medical information systems and image management standards, among which can be mentioned:

- the American Society for Testing and Material (ASTM) that set up a number of working groups with the aim of developing standards in the fields of clinical data exchange (E31.11 "Computerization" sub-committe), electronic medical record (E31.12 "Medical Informatics" sub-committee), interfacing clinical laboratory instruments to computers (E31.14 sub-committee), specification of a standard syntax for transferring modular medical knowledge bases (E31.15 "Health Knowledge Representation" sub-committee)
- the Medical Data Interchange Committee (MEDIX), sponsored by the Institution for Electrical and Electronics Engineers, started in 1987 with the project, known as IEEE P1157, for the development of a standard for communication of medical information between heterogeneous healthcare information systems. The P1157 standard conforms to layer 7 (the application layer) of the OSI reference model. Also, the Institution for Electrical and Electronics Engineers sponsored the "Medical Information Bus" committee (IEEE P1073 MIB), whose aim is to define an ISO compliant standard for communication between patient care information systems and bedside medical devices, such as physiological monitors, ventilators, infusion pumps and fluid drainage measurement devices.
- the Health Level 7 (HL-7) is an open consortium of user and vendors involved in developing a specification for use in the integration of heterogeneous healthcare systems. The goal of HL-7 standard is to provide interoperability as soon as possible using industry standard protocols (non OSI compliant) to support transaction oriented messages and batch data interchange. Its main functionalities include patient administrative informations, general querying and display type queries and ancillary data reporting, that is transmission of clinical data between an observing service and a requesting service. The HL-7 standard covers only ASCII encoded messages and has no provision for binary data for raster images.

5. Related Research and Development

In this section, we give a brief survey of a number of on-going and future projects that address interoperability issues in health care information systems. Several projects investigate problems of storing, integrating and incorporating data of different types (text, voice, bio signals, images) and from different imaging modalities. Some projects also study the use of tele-communication in distributing medical information, including tele-conferences. Other projects investigate standards and links between standards for health care terminologies and coding systems.

5.1 Ongoing Projecs within the AIM Program

The following recently started AIM projects are of particular interest as regards interoperability in medical information systems.

5.1.1 Euripacs (AIM)

This project aims at integrating a PACS system, supported by a multi-media medical image database with all other components of a Hospital Information System (HIS), resulting in a second generation distributed PACS architecture test bed. HIS integration will be achieved at a conceptual, technical and functional level. The availability of broadband local area networks, mass storage devices, high definition display systems and multi-media handling offers the opportunity to define, to develop and to assess the concept. Computer networks will provide links to other hospital departments to achieve integration of multimodality image information and expert medical knowledge.

The problems of integrating and incorporating data from different modalities will be studied and techniques will be developed focusing on conferencing over a wide geographical area and between countries. Development of a distributed multimedia database, dealing with information storage and retrieval and intelligent management of information including compression, are topics which will also be examined in the project.

5.1.2 Sammie (AIM)

The objective of this project is the development, testing and validation of software for a workstation for radiology and neuromedicine studies of the brain. The workstations will be of use for diagnosis and for teaching and will merge image information from different imaging modalities. The incorporation of localised biosignal information will also be developed.

5.2 Other Related Projects

There are many other projects that investigate interoperability in health care, and some of the more important are described below.

5.2.1 HELIOS-2 (AIM)

The objective of HELIOS-2 is to develop a fully integrated medical software engineering environment supporting analysis, design, and implementation of medical applications, and to use the platform for building significant parts of a Ward Information System. The project will give special attention to both object-oriented approaches and software re-usability that are considered crucial steps towards the development of more reliable and coherent medical applications. It is envisaged that the project will directly contribute to the development of standards of communication and cooperation between medical software components.

5.2.2 MultiMed (RACE)

The aim of MultiMed [MultiMed1991] is the development of multi-media communication tools for health care professionals. The need for communication in the health care sector, for example in oncology, corresponds well with the services expected to be offered by ISDN.

MultiMed will be a prototype application of such networks, dealing with communication of e.g.

- Text, such as exchanges of patient records, reports of examinations and messages between experts.
- Voice and sound, such as interactive tuition.
- Data and signals, such as results of analyses, files containing images and signals.
- Image, such as digital radiography scanners, angiography and very high definition images.

An example of results produced within this project is a teleradiological link established between the Turku University Hospital and the local hospital of Paimio some 30 km outside Turku [Viitanen1992]. By means of this link Paimio hospital can send x-ray images for consultation to the university hospital. The transfer of films is thus replaced by an advanced teleradiological system able of transferring digitized images as well as textual data between the two sites.

5.2.3 Telemed (RACE)

Telemed is a RACE project whose aim is to investigate the use of the future European broadband net IBCN (Integrated Broadband Communication Network) in the context of medical applications. The main areas of Telemed are the connection of networks for transfer of radiological information, the construction of reference databases of X-ray images, the use of tele conferences, distance education, and expert consultation at a distance. The common characteristic of all these application areas is that they require that medical images with a large information content can be efficiently transferred over the telecommunication network. The Telemed project has constructed prototypes of radiological workstations, and one investigates how these workstations can be used in combination with tele conferences. The idea is that physicians at different sites should be able to view and manipulate the same radiological image during a tele conference session. An important part of the project is to evaluate different PACSs, which are used for communication and storage of digitalized radiological images and other types of medical information.

5.2.4 GALEN (AIM)

GALEN is an AIM project with participants from Great Britain, the Netherlands, Italy, Germany, Switzerland, Finland, and Sweden. The purpose of GALEN is to construct a foundation for multi-lingual coding systems in the health care area. The kernel of the project is SET (Semantic Encyclopedia of Terminology), which consists of a language independent representation of medical terms and a model for medical coding systems and medical terminology. SET also contains modules with multi-lingual dictionaries and translations to and from existing coding systems. The GALEN project will develop editors and and other interfaces to SET. GALEN will be a complement to on-going standardization work in CEN/TC251, and it will make it possible to realize some of the recommendations of the technical committee.

6. Interoperability Practice: some Examples

In the following, we will look at some example hospital systems from the west coast region in Sweden. The health care in Sweden is organized at several levels. At the regional level there are large hospitals serving the whole region in some speciality. Further, there are province hospitals and province part hospitals, and finally there are care centers at the district level.

6.1 New Demands on Costing

The importance of clinic and ward based systems is increasing, as the demands for cost monitoring and the trading of services between hospitals are emphasized. There is an increasing need to follow the costs and the activities that generate incomes at this level, since the clinic will be responsible for its own budget. The view of the clinic as an economically responsible unit increases requirements on the precision of the administrative systems. The clinical staff has to monitor their own budget, since this is not performed by any central administrators at the hospital level.

As a result of these demands, one hospital in the region (Mölndal) is going to introduce DRG (Diagnosis Related Groups) as a basis for for the budget. DRG is a system for point calculation of diagnoses, 8.000 diagnoses is ordered in 500 groups. Every diagnosis will be registered in a database. It will be important to keep track of the cost per patient (CPP) in terms of the DRG point system, since the hospital will get paid for the activities and services it actually performs. The cost per patient will be handled by a special system running on a mainframe computer.

6.2 Administrative Systems

As an example of the degree of interoperability in a specific hospital, we will briefly describe the situation at the largest hospital in Gothenburg, Sahlgrenska Sjukhuset, which is a hospital at the regional level. A lot of different systems are interconnected in different ways at Sahlgrenska, most systems are connected to the hospital's network (ethernet, TCP-IP). The strategy of the hospital is that every kind of equipment should, if possible, be connected to the net. One of the systems is a patient administrative system (called PAKS) which is used at the clinical level. PAKS is used to keep track of patients, bookings and also patient data. Every clinic runs a local PAKS and "owns" the patient and his data as long as he resides at the clinic. Also physicians and their working schedules are handled by the system. One clinic cannot access another clinic's administrative system. At some hospitals there is an exception to this rule: some clinics can actually access other clinics' booking systems, as for example the orthopedics clinic can make bookings in the radiology administrative system (Borås hospital).

When a patient is entered into the PAKS system, it will fetch some of his personal data from a copy of a central populations register. On a periodic basis, a copy of a register where every Swedish citizen is represented is transferred to the hospital (though only the part concerning the west coast population). The typical user of PAKS is a cashier, a secretary or a nurse, but it might also be a physician who directly could book his patient for the next visit. A library part of PAKS is keeping track of the location of a patient's folder. An estimation is that before this system was introduced, about 20 % of the medical records could not be found when they were needed.

An computerized medical records managemet system is also being built at Sahlgrenska, where the medical information will be kept in the computer as well, possibly in text format with references to files with other kinds of data such as ECG and EEG as well as laboratory data. An advantage of this system is the possibility to transfer laboratory data directly into the patient folder which will reduce the risk of mistakes as well as increase the efficiency. Another possibility considered was to store the patient folder on the patient's own patient card.

An economy system (HORISONT) is used for budget and economical follow up, however there are problems with this system because of its low granularity. It is also used at too high a level in the hospital hierarchy. Data capture for the systems should be done where the data belongs, otherwise people will not understand what they are inserting in the system. As already mentioned, this means that data for economical follow up and administration must be handled at a lower level in the organization. The consequences today are that several clinics will not be paid for about 40 % of the work done.

The invoicing system (DORIS) also resides at a higher level and suffers from similar problems as HORISONT. Concerning administrative systems and clinical systems, it is interesting to note that the decisions of which administrative systems should be used is taken at a rather high level in the health care hierarchy (just below the regional level for example), while decisions on which medical systems should be used is a decision made at the clinical level. Note that the administrative systems also are used at the clinical level.

6.3 Clinical Systems

The clinical-chemical laboratory handles 5.000 test tubes and performs 15.000 analyses a day. The analysis equipment transfers the results directly into an information system which also has an administrative part with patient data (these data are manually entered). The laboratory data are mainly alphanumeric but might be presented in graphical form. The equipment is connected to the net, but the data have to be transformed by an intermediate computer so as to conform to the TCP-IP protocol. The laboratory results are sent to printers at several locations in the hospital. The laboratory data are stored in a database where approximately 400,000 individuals reside.

The clinical-physiological laboratory uses equipment handling biosignals as ECG and EEG which mainly are in binary form, possibly with some alphanumeric information connected to it. A number of ECG PC workstations are sending the signals to a Micro-Vax computer. Because of legal reasons these data are kept for a certain time at a volume of 10 to 20 megabytes for one patient and examination. The data could then be sent to printers at different clinics or to a physician's personal computer where she could use a graphics program to view it. Concerning ultra sound, a big problem is that vendors generally keep the digital signal inside the ultra sound equipment; the signal can be presented on the equipment monitor, but the external interface is only a video signal.

At the radiological clinic there are a number of examination rooms with different kinds of digital medical equipment, CTs, MRs etc. All storage is handled locally in the specific equipment. These equipments are not connected to the network because of similar problems as with the ultra sound equipment, i.e. they are not open systems and are not following any standard. However there is a lung examination room with a tv-camera and digitizer where the digitized images are manipulated on a VAX-station which is connected to the network. There is thus some experimentation with open systems, but no PACS has been introduced.

A problem when introducing digital techniques in this environment is that everything is set up to suit film management. Film display panels are used for presentation and viewing of images, and it will be hard to replace this technique with a presentation medium for digital images. The requirements on the presentation equipment are extreme in terms of high resolution and the possibility to view several images at the same time by several people.

There are no interoperations between the clinical systems and the administrative systems today, but there is a need for such an integration. At the radiological clinic at another hospital (Borås), the diagnosis (text) is stored in the radiological administrative system. The diagnosis is based on radiological images and a higher degree of interoperability would have made it possible to link these images to the diagnosis data.

6.4 Networks and Interoperability

There is a network to which most of Gothenburg health care units are connected. However, not all hospitals in the region are connected, although they easily could be. The network is an ethernet and the TCP-IP protocol is used. A microwave link is connected from Sahlgrenska to the second largest hospital (Östra sjukhuset) and to the data administrative service office of Gothenburg. Other smaller hospitals are connected through 64 kbit lines and the care centers of Gothenburg will also soon be connected. The care centers will then eventually be able to send referrals and medical records to a hospital via the network.

Another example of a hospital network environment is the neighbour community of Mölndal, where the hospital has one basic network (ethernet, TCP-IP) with four nodes, one for each clinic. To each of these nodes, a local clinic based network is connected.

Other kinds of communications for consultation support are made for some islands in the archipelago, where for example biosignals could be sent to the hospital through telecommunication. There also exists a number of specially equipped ambulances where the biosignals could be sent to the hospital. With a system called Mobimed [Mobimed1990], the ambulance crew can send data,e.g., ECG, pulse, and blood pressure, to the hospital for consultation. If a patient in the ambulance shows signs of an acute heart disease, the medical equipment is connected to the computer net, and on the hospital a phycisian receives the information on his computer display and gives the ambulance crew advice through the computer. All information is sent through Mobitex which is a digital network for mobile data communication, covering all of Sweden. Speech contact could also take place at the same time. Mobimed is a kind of telemedicine system without images. Mobimed might also be used through NMT - the national mobile telephone network (and soon by satellite).

An example of a higher degree of interoperability is the radiological clinic in Borås which has four types of image producing equipment and two cameras connected through a laser cable (token ring ethernet). There is a digital angiographic laboratory, an operation video, ultrasound equipment, and a computer tomograph. The system is today only used due to the benefit of needing just two cameras which could be used by any of the image generating equipments, which send digital data to the film producing camera. The network could however be used to adopt a more interoperable connection between the systems. To introduce a real PACS-environment, transmission media of higher capacity must be installed.

However, there is a link between the computer tomograph and a dosage planning system at the oncology laboratory. The tomograph (Siemens) could send images to the dosage planning system (Helax) which calculates the dosage on the basis of the image. The only information today that is saved for a reasonable amount of time in digital format are the images from the tomograph, which has its own laser disc storage. The other images are saved as film.

7. Concluding Remarks

Interconnecting information processing systems is a prerequisite for a more optimal use of medical and administrative data in health care, and will pave the way for higher efficiency in future health-care information systems.

This problem and its possible solutions according to current practice and theory has been surveyed in this paper. Specifically, the two modes of interoperability that are included in the MILORD project, i.e. sharing of data among different databases and teleconferencing, have been discussed. Ongoing standardization work within the area of interoperability has also been surveyed. We note that there is a wide spectrum of different standardization subject areas ranging from general medical terminology to low level data & tele communications protocols.

Concearning the underlying communications there are several possibly solutions for HCIS where image data is important. Technical options range from standard LAN solutions (e.g. Ethernet) possibly in combination with CATV-transmission techniques, to more advanced network technology such as Transputer networks and FDDI.

Finally we have given a brief overview of some example hospital systems from the west coast region in Sweden. The users (medical staff and administrators) are well aware of the need for improved interoperability. Many projects are under way and several systems are in operation, but the situation is still characterized by local solutions. This is mainly due to the lack of an overall framework (or model) for HCIS interoperability, which takes into account the varying requirements of the health care environment.

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