INTELLIGENT MEDICAL NETWORK

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A dissertation submitted to the Graduate Faculty
in Computer Science in partial fulfillment of the
requirements for the degree of Doctor of Philosophy,
The City University of New York.

1996

UMI Number: 9707118

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

This manuscript has been read and accepted for the Graduate Faculty in Computer Science in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

August 5, 1996

Date

Chair of Examining Committee

August 6, 1996

Date

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Abstract

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The content of this dissertation is the research and design of the intelligent network-based systems for a specific class of medical and health care applications. The knowledge module of intelligent systems has been introduced and designed according to the specific needs of medical systems. All basic elements of the knowledge module were divided into two major categories: service functional blocks and application functional blocks. The functions of the existing major components of telecommunication networks: communication, switching and administrative modules have been reviewed in light of the utilization of the knowledge module. Based on a developed scenario of a request resolution by an intelligent network, a general object-oriented model of intelligent telecommunication system has been elaborated. This, in turn, led to building of the detailed architecture of an intelligent network and its knowledge module in particular.

As the result of the analysis and classification of information requests in the telecommunication network for medical services, algorithms for service functional blocks were designed, particularly a recursive algorithm of request processing and information retrieval in the network.

The design of application functional blocks of the knowledge module is based on complete object-oriented analysis of a medical care system. This analysis includes the identification and formal description of all potential members of the medical network and medical knowledge as objects of integrated medical systems. The object model comprises description of an object's hierarchy, attributes, operations, processes and information flows for all defined objects, as well as object, functional, and dynamic models.
Design issues for database and functional modules software have also been analyzed.

Finally, the Data-Mail Electronic Consultation System at the Mount Sinai Medical Center is discussed. This system was developed in accordance with the general architecture of an intelligent medical network and is utilizing the object model of a medical care system. The system software modules and database are presented as an example of a working intelligent medical telecommunication system.

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The papers based on the dissertation research have been accepted for presentations and publications by the following conferences:

M. Krol, S. Ahamed, V. Lawrence. "Tele-Medicine and Medical Networks". *SEACOMM'96*. Kuala-Lumpur, Malaysia, August 96.

J. Kannry, J DuPont, M. Krol. "Data-Mail: A Design for Electronic Consultation.". *AMIA Annual Fall Symposium*. Washington, D.C., October 1996.

INTRODUCTION

FUNCTIONS AND PURPOSES OF AN INTELLIGENT MEDICAL NETWORK

The primary purpose of a medical network is to provide means of communication for members of medical community. The existing Internet services require users to know the exact Internet address of the party they want to address, or force them to use the standard services offered by an Internet access provider. When a customer wants to find an information which is not formally defined (as is often the case in a field of medicine and health care), or when a client does not know the location of the desired information within the Internet, the process of finding a required information becomes a very time consuming and tedious job.

On the other hand, the functions of numerous existing specialized medical networks are to provide limited number of services, mostly financial by nature, to members of a particular managed care organizations. Sponsored, supervised and maintained by insurance companies, this systems allows entrance to network information only to a limited number of network participants, and restricts the access to available information only to certain narrow defined areas of data. And, after all, the information is limited to commercial, i.e. insurance and financial data, and does not contains all medical aspects of these data.

Contrary to the business community where secrecy is the nature of business, the scientific, and particularly medical community always were wishing to share and exchange the results of their research. Over the years, practically all medical institutions have developed their own Information Systems (IS) and accumulated big volumes of various kind of data. Some of these information may be unique and could be object of interest by other members of network. Therefore the majority of members of medical network would be able and willing to exchange these various kinds of information. Medical network is unique in terms of information structure. Many members of network use basically same type of information. On the other hand, since most of medical systems were created independently, they all bear different data structures and formats, architecture, access methods, and so on. Therefore most of the medical network participants' databases and knowledge bases are not able to communicate directly to each others even in the simplest cases of direct information request for a particular formally defined piece of data from another medical institution. Moreover, existing types of medical network do not provide the capabilities to search and find a location of a particular medical clinical and scientific information necessary to answer a request for information which was sent to a network. This can be done by utilizing the capabilities of an intelligent medical network.

Ideally, a participating member of a medical intelligent network will have specialized intelligent peripherals (IP) - workstations with a software designed specifically to communicate with other members of this network, and will have one universal telephone number for a workstation to call to address all medical-related inquiries. This intelligent peripheral will define possible types of services the network may provide and will assist a customer to create an inquiry to be sent to a network in a specific format. The network should be able to accept an inquiry, identify it and locate the best source of knowledge related to a specific inquiry. This may be an internal knowledge base, or a knowledge base of a participating member of a network, or a human expert. Then an inquiry will be transferred to a proper address within the network. In case of an internal knowledge-base the system should be able to find out the correct answer and transfer it back to an inquiring party. If the query could not be answered internally by the network, then it has to be transferred to the most appropriate knowledge based system of other members of a network. After the question is answered, the response should be transferred to the sender of the request. In case of inability of participating knowledge based systems to answer the question, the inquiry will be transferred to a participating human expert. This, in turn, may require teleconferencing or, rather, telecounselling of experts, which is also may be provided by the network.

Along with an inquiry recognition and inquiry resolution functions, the network will also provide educational, administrative and financial services., as well as a Bulletin Board for all members. These services are in certain degree interconnected and in general may be referred to as supporting services.

Administrative services include membership, marketing, referrals and some other functions. Since communication is the nature of the business of the medical network, marketing services may be divided into internal marketing within the network and external marketing outside the boundaries of the network. Marketing functions usually are not considered directly related to primary business functions of an enterprise, and in a case of external marketing for the network it is still true. Nevertheless, internal marketing, due to the communication nature of a primary business of the network, may be considered as an integral part of the network functions. Membership services are partially interconnected with marketing and include recruiting new members and accommodating existing members. By joint efforts of marketing and membership services, suggestions for new network functions may be solicited among members of a network, and new services may be tested among certain groups of members of the network.

Educational services may include the organization of tele-conferences, interactive training, access to multimedia encyclopedias, dictionaries, thesauruses and so on. These educational services may be provided by two different ways. First, the network may provide just the telecommunication services between a party providing a training and / or education session and participating "students". Although this kind of service may require introduction of a few additional features of the network, there is nothing specific, which would distinguish these educational functions from other telecommunication services of the network. The other way of providing educational services is by creating a specialized educational modules within the intelligent medical network. It seems that providing educational services by the medical network itself may not be economically feasible unless there will be developed an intelligent educational network. The interaction of two intelligent networks (educational and medical) is a complex and independent problem and an area of a separate research.

Financial services, besides the most primitive billing, accounts receivable and account payable functions may also provide help in assessments of new equipment and plans of modernization, communication with vendors,, management consulting , organizational restructuring and so on.

In addition to aforementioned supporting services, available and visible to users, the network architecture will include a very important maintenance subsystem, with specific functions of basic maintenance and current upgrades of internal knowledge bases, databases and software modules, and also introduction of new services. All these functions should be performed without any interruptions to basic services provided by the network.

METHODOLOGY USED IN THE DISSERTATION

Software Engineering Methodology.

A software engineering methodology is a process for the organized production of software, using a collection of predefined techniques and notation conventions [107]. A methodology is based on a systematic approach, usually presented as series of steps, with techniques and notation associated with each step. The complete life cycle of a software development process is comprised of:

- Initial formulation of the problem;
- Analysis
- Design
- Implementation
- Testing (Unit and system)
- Maintenance
- Enhancement

Among different methods of software engineering two major approaches may be mentioned. One is a Top - down approach, where the development starts with an overview and analysis of the whole system, and is advanced to the actual programming stage by refining the model at progressively more detailed levels.

On the contrary, a bottom - up approach starts with some prototype software programs, which are expanded during an operational phase of a software life cycle. In a real - life environment both approaches may co-exist. Initial design for a new project is usually done utilizing a top - down approach, while enhancement and expansion of existing software are usually done by a gradual incremental additions of new groups of programming modules.

Object-Oriented Methodology

The concept of Object - Oriented Methodology (OMT) originated from the ideas of procedural abstraction and data abstraction. OMT utilizes the advantages of both these approaches. In procedural abstraction the programming module is created to execute a rigidly given algorithm on standard, relatively simple data structures, passed as parameters. The algorithm may be very complex and usually designed specifically for a particular single task or operation. The programming code executing an algorithm is protected from other modules, which have no access to the programming code with the exception of a standard call utilizing standard data parameter interface. Usually the most complex parameter may be presented in the form of array of a structure (in C language), unit (in Pascal) or other similar construct.

In data abstraction the software module (a database) is created to perform few basic functions (Find, Add, Update and Delete) on a complex custom designed data structure. All access to the internal data structure by other modules is restricted to this functional calls. Therefore an interface to an Abstract Data Type (ADT) consists of a list of permitted functions. Object as a programming software module is designed to perform any of the functions, specified explicitly for a given task, which are defined as *methods* or *operations* on this object. As a rule, an interface to an object may include methods, or operations, and data parameters - *attributes* of an object, while implementation of both methods and internal data structures are hidden and protected, and access to them are restricted to only authorized objects.

The three fundamental principles of Object Oriented Methodology are [107]:

- - *Encapsulation* (also information hiding) : a separation of the external interface of an object, which is accessible to other objects, from the internal implementation details of the object, which are hidden from other objects. Encapsulation prevents a program from becoming so interdependent than even a small change in a requires massive re-developing efforts on the whole project. The implementation of an object can be changed without affecting the applications that use it.
- - *Inheritance* is an abstraction for sharing similarities among classes while preserving their differences. Individual objects, which can be defined using the same characteristics, belong to the same class. The superclass has all common

characteristics of it subclasses, while each subclass inherits the features of its superclass and may also add its own methods and attributes. The inheritance is also called the "is -a" relationship because each instance of a subclass is an instance of the superclass as well. Inheritance is transitive across an arbitrary number of levels. The terms ancestor and descendent refer to hierarchy of classes across multiple levels. Inheritance allows the conceptual simplification of a system that comes from reducing the number of independent features in a system. It has become synonymous with code reuse, since already developed classes are often organized into libraries and the modifications of objects to new projects can be done by deriving new subclasses from existing ones.

- \- *Polymorphism* is the ability of operation to be applied to many different classes. The particular implementation of a method may be determined by an object at execution time. Therefore the object - oriented methodology allows for an implementation of truly dynamic features of a system.

The OMT methodology supports the entire software life cycle and consists of several phases:

- The phase of System Analysis is associated with understanding and modeling the application and the domain within which it operates. The initial input to the analysis phase is a problem statement which describes the problem to be solved and provides a conceptual overview of the proposed system. The output from analysis is a formal model that captures the three essential aspects of the system: the objects and their relationships, the dynamic flow of control, and the functional transformation of data.

- The System Design phase deals with the overall architecture of the system. Using the object model as a guide, the system is organized into subsystems. Concurrence is organized by grouping objects into concurrent tasks. Overall decisions are made about processes communication, data storage, and implementation of the dynamic model.
- The Object Design phase produces a practical design of a system, based on the elaborated, refined and optimized analysis models. During object design there is a shift in emphasis from application concepts towards computer concepts. The basic algorithms are chosen to implement each major function of the system. Based on these algorithms, the structure of the object model is then optimized for efficient implementation. The design must also account for concurrence and dynamic control flow as determined during system design. The implementation of each association and attribute is determined. Finally, the subsystems are packaged into modules.

By utilizing OMT a seamless development process can be achieved, because the object model developed during analysis is used for design and implementation, and work is advanced by refining the model at progressively more detailed levels rather than converting from one representation into another. There are no discontinuities in which a notation in one phase is replaced by a different notation in another phase. The development process using the Object Modeling Technique is iterative. Each iteration adds or clarifies features rather than modifies work that has already been done, so there is less chance of introducing inconsistencies and errors.

Structured Analysis / Structured Design

Structured Analysis / Structured Design (SA/SD) software engineering methodology is based on data flow diagrams [107, 146]. During the analysis phase, data flow diagrams, process specifications a data dictionary, state transition diagrams, and entity-relationship diagrams are used to logically describe a system. In the design phase, details are added to the analysis models and the data flow diagrams are converted into structure chart descriptions of programming language code.

Data Flow Diagrams model the transformations of data as it flows through a system and are the focus of SA/SD. A data flow diagram consists of processes, data flows, actors, and data stores. Starting from the top level data flow diagram, SA/SD recursively divides complex processes into subdiagrams, until many small processes are left that are easy to implement. When the resulting processes are simple enough, the decomposition stops, and a process specification is written for each lowest - level process. Process specifications may be expressed with decision tables, pseudocode, or other techniques.

The data dictionary contains details missing from data flow diagrams. The data dictionary defines data flows and data stores and the meaning of various names. State transition diagrams model time dependent behavior and are similar to the dynamic model of the OMT. Most state transition diagrams describe control processes or timing of function execution and data access triggered by events. Entity - relationship diagrams highlight relationships between data stores that otherwise would only be seen in the process specifications. Each ER data element corresponds to one data flow diagram data store.

The above tools are used during the process of structured analysis. Structured design follows structured analysis and addresses low - level details. Data flow diagram processes are converted into programming language functions, and a structure chart is created showing the procedure call tree. SA/SD organized a system around procedures, and in the SA/SD approach the functional model dominates, the dynamic model is less important, and the object model is the least important of all three

SA/SD and OMT modeling have much in common. Both methodologies use similar modeling constructs and support the three orthogonal views of the system. Object - Oriented Methodology organizes a system around real - world objects, or conceptual objects that exist in the user's view of the world. It does not disintegrate data and functions, but rather consider them as two characteristics of an object. That's why an object - oriented approach better integrates databases with programming code. SA/SD is useful for problems where functions are more important and complex than data.

Rapid Prototyping

In a rapid prototyping approach a small portion of the software is initially developed and evaluated through use. The software is gradually made robust through incremental improvements to the specification, design and implementation. This approach is useful for a development of software in a highly dynamic environment, where systems requirements cannot be fully identified prior to the development and utilization of the software.

A prototype version of an interactive procedure-unit actually displays screens and accepts input , so that users can get direct experience of what it will be like to work with the system, when it is eventually delivered [54]. We can distinguish "Discovery prototyping" from "refinement prototyping".

In discovery prototyping, only the most informal analysis of requirements is done before the developer produces a prototype to reflect his or her understanding of the software system to be developed. The experience of using the prototype encourages the users and developers to think more concretely about their needs, and the prototype is quickly revised several times as the users get more specific and detailed about their requirements. While the discovery prototype may be quite successful for developing small systems from scratch in a matter of week, it is not suitable for big projects, where the scope of the project, system boundaries and subsystems interactions can not be just a part of screen prototypes development.

Refinement prototyping starts from the point where a data flow diagram of the system has been partitioned into procedure - units (Pus), and is most significant for those Pus where the user and developer know that there will be a significant interactive dialogue, but cannot define easily with simple screen layouts how it is to function. Given a suitable software tool, a prototype of the dialogue can be produced, and refined until the dialogue is workable. Refinement prototyping also helps resolve more particular questions, such as the value of a wide scope vs. a cluttered screen, a summary information screen together with scrolling areas for some detailed information, or a separate screen for each specific kind of data, and so on.

As a general rule a prototyping as a convenient tool for defining a front - end interactive system, and developing a demonstration or pilot project, but cannot be used for design of a complex system. It does not address such questions as system architecture, optimal performance, or data integrity and hierarchy. But these reasons an application of these method is limited to specific types of projects.

AREA OF RESEARCH

At present time intelligent networks is an area of intensive research conducted in many different directions. The general approach to intelligent network design is defined. There is a number of examples of implementation, practical utilization and a big commercial success of first intelligent networks, such as 800- and 900-numbers. Further developments in this field are based on extensive research in areas of network architecture, structure of a knowledge module and its functional blocks, methods of queries processing and software engineering.

Development of a commercial intelligent network for medical services requires years of taskwork of many trained professionals, coordination of efforts of several departments of a specialized organization (such as AT&T), may be even cooperation of several institutions, and definitely cannot be achieved by means of this or any other dissertation. The scope of this dissertation is limited to the:

- Design of an architecture of the knowledge-based intelligent telecommunication systems applicable to application-oriented networks;
- Research and further development of knowledge module;
- Analysis of query processing by a knowledge-based intelligent network and design of an object-oriented model of an intelligent telecommunication system, based on this analysis;
- Development of a universal algorithm of query processing by an intelligent network;
- Selection of universal identification and codification system for the medical network, based on existing knowledge base of medical informatics;
- Analysis of a health care system and design of an object-oriented model of a health care system;
- Development of some prototype software modules for the network. This software modules are incorporated into the Data-Mail Electronic Consultation System at the Mount Sinai Medical Center, which is a pilot project developed with an intention to demonstrate the feasibility and capabilities of an intelligent medical LAN.

All above-mentioned parts of the dissertation were performed in accordance with the plan earlier approved by the Examining Committee of the Department of Computer Science of the CUNY GC. Some additional problems were solved during the course of the work on the dissertation, which went beyond the approved plan, such as selection of search criteria, interfaces for various databases, data security.

By developing an architecture for a specific network for medical and health care services, more general questions related to the development of universal knowledge-base intelligent network may be addressed. So the development of a medical network will lead to the creation of templates of the software modules common for all intelligent networks, and should be considered as a prototype of a generic universal knowledge-based intelligent network. At the same time this dissertation demonstrates how a pertinent intelligent network (in this case - medical and health care) may be built, and proves the feasibility of creating an intelligent network for a particular type of medical application .

Based on performed analysis, various software engineering methodologies were utilized on different stages of the dissertation project. A Structured Analysis / Structured Design was initially utilized for the development of the architecture of the intelligent medical network and its knowledge module, as better suited for function-oriented rather than data-oriented systems. On the stage of design of the architecture of Knowledge Module these methods were supplemented by Object-Oriented Analysis and Design (OOA&D). The analysis of a health care system was also made based on the Object - Oriented Methodology. This approach, which makes a greater emphasize on complex data structure seems to be more useful in building a model of a medical knowledge base. And, finally, a rapid prototyping approach was used to develop and implement software modules used to illustrate the feasibility of a practical realization of algorithms developed in the course of the dissertation.

LAYOUT OF THE DISSERTATION

Chapter 1 presented an overview of a history of the Medical Informatics field as well as an analysis of current computer applications in medicine and health care. The result of this study determined a need of development a communication mechanism which would facilitate an exchange of information between different members of medical / health care community even when the participants are unable to provide an exact network address of another party.

Chapter 2 of the dissertation analyzed a technical approach to achieve the above-mentioned goal. The knowledge-based intelligent telecommunication network was proposed as a possible solution. An evolution of intelligent networks leading to a modern architecture of knowledge-based intelligent telecommunication systems was also discussed in this chapter. As an outcome of this analysis the development of a knowledge module architecture was chosen as an important segment of the dissertation research.

Chapter 3 was dedicated to examination of various existing medical codes, data formats and medical telecommunication messages standards. The result of the study was the selection of the most appropriate medical codes and standards to be used in the intelligent medical network.

Chapter 4 contained the detailed analysis of the query processing by intelligent medical networks. The scenarios based on case studies were created, and the architecture of the knowledge module was elaborated. The Object-Oriented models of an intelligent telecommunication system and its Knowledge Module was designed as a foundation for a further software development. Functional Module comprises two groups of Functional Blocks: Service and Application.

Chapter 5 included implementation details for each Service Functional Block of the Knowledge Module. These details included a logical algorithm of the Universal Request

Processing Unit and related data structure, mathematical analysis for a search criteria, examination of different types of interfaces between databases and discussion of data protection and security issues.

Chapter 6 introduced an Object - Oriented Model of a health care system. This methodology was found to be the most appropriate for development of Application Functional Blocks of the Knowledge Module. This model included the description of object's hierarchy, attributes, operations, processes and information flows for all defined objects, as well as object, functional and dynamic models.

Chapter 7 devoted to the implementation of an intelligent medical LAN at the Mount Sinai Medical Center as an example of a practical realization of the theoretical principles developed in the dissertation.

1. COMPUTERS AND HEALTH SCIENCE.

There was a widespread notion in a scientific community some time ago, that computers have a much lesser impact to medicine and health care than to any other area of science and business. Today it is not true any longer. According to Dave Chase, worldwide health care industry director at Microsoft Corp., Redmond, Wash, "there is an increasing recognition in medical community that health care is an information-based industry. About 70% of a physician's time is spent processing information, either collecting it or reviewing it." [44].

There is a great variety of applications of computers to medicine and health care.

One must admit that one of the first expert system ever to be developed in 1976 was MYCIN - the system for computer - based medical consultation, developed by E. H. Shortliffe and others at Stanford University [118].

Neural Networks provide an excellent example of mutual influence and interaction between medicine and computer science, which greatly benefited both parties [13, 73]. Developed as a method of simulation of a brain activity, this model became one of the most prominent techniques among the other Artificial Intelligence methods. And as a proven AI methodology, it may be used to apply the technical results of research and development in a neural networks area back to its origin - the organization and neuronal structure of living organisms, its brains and cells.[13, 102]

A Human Genome Project, aimed to decipher three billion nucleotides of human DNA and to create a universal database of human DNA's, establishes a precedent to a world-wide computer - based scientific project with database records created and updated by hundreds of participants in different countries. [76, 89]

The recent discovery of DNA-based computations [2, 56] may, in fact, completely change the relationships between computer science, being so far an object of reluctant studies by medical community, and the health science to be an area of computer science application; between computer scientists being developers and acting in a teaching capacities, meanwhile health care professionals being students. Now it is in the best interests of computer scientists to study biology, genetics and other medicine - related disciplines. This research opened the new perspective for the whole discipline of medical informatics and may significantly expand the boundaries of this field.

Among various applications, interactions and mutual influence between computers and health science, the new discipline - Medical Informatics have recently emerged. Medical Informatics is dealing with the systematic processing of information in medicine. Medicine in this context will stand for human science as well as for health-care institutions [104]. The term medical informatics in this meaning comprises also, e.g., health informatics, nursing informatics or dental informatics.

Initially the history of medical informatics could be characterized as the operational success of the data - oriented applications (e.g., signal and image processing), the operational demonstration of information - oriented applications (e.g., patient management systems), and the conceptual demonstration of knowledge - oriented applications (e.g., artificial intelligence in medical decision making).

Because medical informatics is a technology - driven discipline, its accomplishments were constrained by its technology's limitations. Therefore the data - oriented projects have been dominated by the domain that the computer supports. It was more common to speak of the biomedical engineering than medical informatics.

The current trend in medical informatics is toward merging of information- and knowledge-oriented applications. It is likely that most medical informatics applications will integrate and access both medical information and medical knowledge.

In parallel with the medical concern for both information and knowledge, the information- and knowledge - based technologies are merging. The result has been increased research in the integration of knowledge representation schemes into information systems.

As a result, computing technology has been introduced into many aspects of medical and health care. Computer - assisted diagnosis and decision making has for some time been considered as a means of bringing together the vast output of medical research and the best known methods of treatment. Another notable example is the scanning and imaging technologies which produce precise images of anatomical cross-sections with little discomfort to the patient, thereby dramatically reducing the use of invasive techniques.

Hospital Information Systems are being installed to automate, in whole or in part, a great many of the patient - oriented information processing tasks that are performed thousands of times daily in a hospital. These systems decrease the time and costs of transmitting medical orders, decrease the time and costs of reporting test results, reduce errors in medication, and eliminate misplaced reports.

The technological impact on the clinical laboratory has been particularly pronounced. As an example, in the domain of clinical microscopy, 50 years ago the work of manipulation of tissue and reagents was exclusively carried over by physicians. By now the work is carried out by trained technologists. The work of the technologist now became one of monitoring the equipment for quality control and managing the exceptions the machine could not handle.

Technology is one of the major forces reshaping the health-care industry, with computers and telecommunication services being the leaders. Since the function of an intelligent medical network is to link existing medical and health care information systems and databases and to provide an access to remote and isolated establishments, the review of different types of such system ought to be performed.

1.1 THE HISTORY OF MEDICAL INFORMATICS.

One of the early definition of Medical Information Science was as the study of the nature and principles of information and its application to the science and art of diagnosing, treating, curing and preventing of disease. Health Information Science was defined as the study of the nature and principles of information and its application within all aspects of health - care delivery [116].

The objectives of medical informatics are to contribute to a high-quality health care (especially patient care) and to gain new medical knowledge.

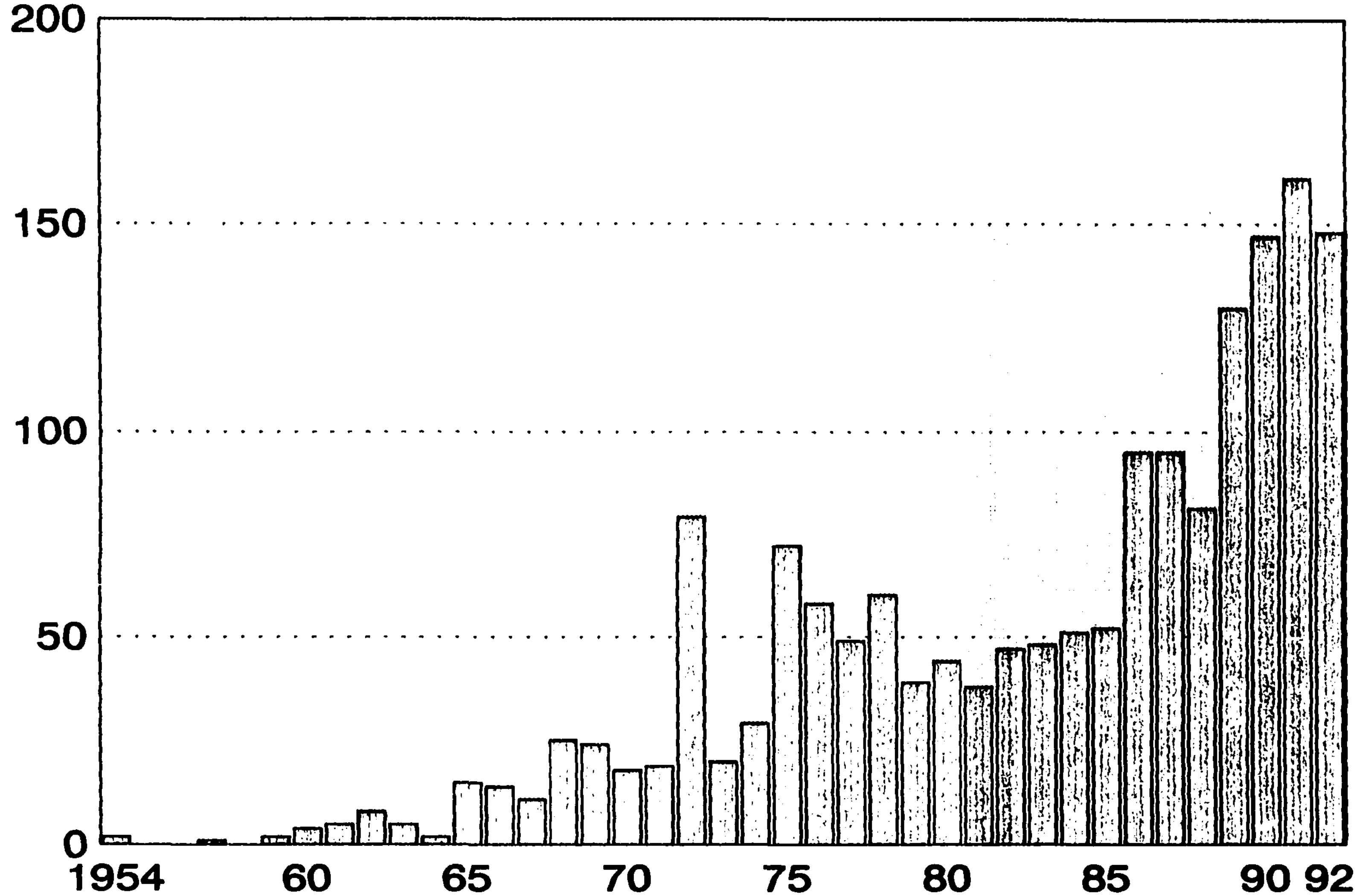

Fig. 1.1 Publications in Medical Informatics / Medical Diagnostic Decision Support System

The field of health and medical informatics has been around for some twenty years. Figure 1.1 illustrates the development of this discipline in quantitative terms of number of publications relevant to medical diagnostics decision support systems [88]. The history of information technology in health care is slightly shorter than the history of computer science itself. By the end of 50's it was reported that errors in differential diagnosis resulted more frequently from errors of omission than from other sources [104].

The classical paper [77] observed that physicians have an imperfect knowledge of how they solve diagnostic problems. This paper detailed the principles underlying work on Bayesian and decision - analytic diagnostic systems that has been carried out over subsequent decades. It stated that both logic (as embodied in set theory and Boolean algebra) and probabilistic reasoning (as embodied in Bayes' rules) were essential components of medical reasoning. The authors mentioned the importance of protocol analysis in understanding human diagnostic reasoning. They stated that they had reviewed how physicians solve New England Journal of Medicine clinico-pathological conference cases as the foundation for their work on diagnostic computer systems. Both for practical reasons and for philosophical reasons, much work on medical diagnostic decision support systems has focused on the differences between logical deductive systems and probabilistic systems.

Since then, the literature has been full of accounts of computers being well-suited to help health professionals collect and process clinical information.

Prior to 1975 the half - life of a computer application was equal to that of the publication cycle. That is, half the papers about computer applications reported on systems that no longer were operational. [21]. Some of this had to do with the cost of equipment. However, most of the early project failures stemmed from the immaturity of the field and uncertainty about the operational constraints. Programs that ran in a laboratory setting had little value in a clinical environment.

The period following 1975, which established the foundation for most of today's applications, has seen the widespread proliferation of computing (both mainframe and PC's), lowered costs for equipment, and increased user participation (often through the purchase of existing products).

Innovations in medical informatics result from a cyclical spectrum of research, development, and implementation activities. For some years the research was conducted in different areas quite independently from each other. Later one could observe the creation and modifications of various professional associations in the field :

The Society for Advanced Medical Systems (SAMS) was formed in 1969. Then the Society for Computer Medicine (SCM) was formed in 1971. SCAMC, the annual symposiums, begun in 1977. The American Association of Systems and Informatics (AAMSI), formed through merger of SAMS and SCM in 1981; and the American College of Medical Informatics (ACMI) was established in 1984. Finally, the American Medical Informatics Association (AMIA) was established as a unifying association in 1988, replacing AAMSI, ACMI and SCAMC. And the first issue of the official Journal of the American Medical Informatics Association (JAMIA) was published in January 1994.

The Board of Directors of the American Medical Informatics Association recommended specific approaches to standardization in the areas of patient, provider, and the site of care identifiers; computerized health care message exchange; medical record content and structure, and medical codes and terminology in their position paper "Standards for Medical Identifiers, Codes, and Messages needed to Create an Efficient Computer - stored Medical Record " [22].

The areas of research in medical informatics, according to chapters in the Yearbook of Medical Informatics [144], include, but not limited to, health and clinical management, computer - based patient records, health and medical information systems, image and signal processing, decision - support systems and knowledge processing. The computer systems in medicine and health care may be classified by the following criteria [121]:

By functions:

- Administrative;
- Medical (patient) information;
- Bibliographical;

By goals:

- Informational databases;
- Decision support systems;

By structure:

- Centralized;
- Modularized;
- Networks;

By users:

- Doctors;
- Nurses;
- Researches;
- Patients;
- Administration;

By entry languages:

- Natural languages;
- Special languages;
- Codes.

This division is in a great degree just a matter of convenience and correspond to a specific stage of research in medical informatics. As the medical infrastructure for computing and communication develops and as computers play a more important role than ever before, data acquisition, storage, retrieval and processing are about to improve health and clinical management. The integration of health data and decision support has become much easier and much research has been carried out in this area. [110].

This dissertation does not follow the above classification computer and information technology to medicine and health care, but rather divide them according to two major functions these systems perform: clinical and administrative. Incidentally, this division also separates two groups of users - medical and health care specialists, and administrators - and goes along the demarcation line in computer technology between PC's, which constitute the technological base of clinical and laboratory research, and mainframe, which is the foundation of practically all existing management information systems.

Although telecommunications in medicine and health care did not seem to reserve a status of independent area of research in medical informatics, it definitely requires a special attention. Besides being an important tool in providing further advancement in medical technology and informatics, it also serves as the necessary link between aforementioned classes.

1.2 COMPUTER APPLICATIONS IN CLINICAL MEDICINE

Clinical applications of computers vary from computer - based laboratory instruments to three - dimensional processing to decision - support systems and computer - based diagnosis.

Computer-based clinical and lab instrumentation

In general, the computerized clinical and lab instruments consist of an analyzer, which creates a raw data file (usually in ASCII code), and an attached computer or a workstation with a specialized software, which process the file with a raw data and creates the required results file. This workstations may operate in a stand alone mode as well as being connected through LAN to each other and / or server workstation. In the latter case the results obtained may be shared across a network and available to other users.

Let's consider the CompuRecord Anesthesia Recording System, developed by PPG Biomedical Systems [36]. The CompuRecord Anesthesia Recording System is an automatic data collection and information management system designed to replace the traditional handwritten anesthesia record. Many physiological measurements needed during an anesthesia are automatically made by monitors in an operation room. The CompuRecord system may be configured for the measurements and monitors used in a particular case. It gathers information from the various operating room monitors, store it indefinitely, and prints it in a legible format similar to the traditional handwritten record. The user controls the system with a touch screen or a keyboard. In addition, it performs calculations for total drugs, infusion drugs, IV's, fluids, blood products, and cardiac output. It also allows the user to mark artifacts and make certain changes to the record.

The system allows monitoring of vital signs of a patient, I.V.'s and blood products, infusion drugs and patient's output. The CompuRecord System also accepts information on what, when, and how much was poured off. From this information the CompuRecord System calculates the amount of total outputs during the case.

The CompuRecord System contains and displays on the screen of the monitor the names of drugs, agents, and occasionally physiological measurements, such as SaO2 and EtCO2, that are commonly used during a typical anesthesia. The system contains eight sets of seven variables to choose from.

During the course of an anesthesia, activities take place that need to be documented in order to have a complete and accurate record. Induction, intubation, and the start of surgery are events that take place during especially busy times, and so these are documented using speed keys on the touch screen. Other events such as going on bypass, or applying a cross clamp are documented using the EVENTS function, which requires certain navigation through the system screens.

An example of computerized medical instruments in medical diagnostics is YABA (yet another blood analyzer) [74]. The YABA is a medical diagnostic instrument for determining the characteristics of certain components of white blood cells. The goal of the YABA is to automate the steps of the testing protocol. The YABA was comprised of two subsystems: the instrument subsystem is concerned with the processing of the sample. Utilizing Object - oriented methodology for analysis and design, the instrument subsystem were developed to contain objects of the instrument such as the Input Load Station, the Pipettor, and the Reader Robot. The other application subsystem contained such objects as Patient, Result Report, and Test List. A few objects, such as Sample and Test, were shared by the two subsystems.

Another example is in the domain of clinical microscopy. Some time ago the work of manipulation of tissue and reagents required high qualification of a physician.

Currently the work is carried out by trained technologists, who is monitoring the equipment for quality control and managing the exceptions the machine could not handle. Now, with newer, more sophisticated machines, quality control and exception, management has also been incorporated into the instrument.

Computer - based clinical and lab instrumentation also include such technology, as Nuclear - Magnetic Resonance, Computer Tomography, Ultrasound Imaging and

Angiography. Each of these technologies would require a comprehensive and detailed analysis. Since these topics are not directly related to the dissertation thesis's, theirs analysis is omitted

Image Processing Systems

Image and signal processing techniques abstract and interpret data for diagnostic, therapeutic and monitoring purposes. Before these techniques may be diffused into clinical practice a thorough evaluation must be passed. This include the validation of a new algorithm and the evaluation of the procedure in which algorithm is embedded.

The testing of a new algorithm consists of several steps [112]. First a new algorithm must be shown to work in laboratory conditions with a limited patient sample. After feasibility has been demonstrated the algorithm must be validated against a more comprehensive set of patient cases. This normally leads to changes in the algorithm requiring a new validation cycle. Once the algorithm has been "tuned" with the available patient cases it must be validated against a new independent set of patient cases to rule out bias in performance. There are only a few of such reference signal and image libraries available.

The development of a global medical network could significantly help in solving this kind of problems by providing access to remote and currently isolated libraries and databases of related patient cases.

Among different application of image processing in medicine we can mention digital image analysis of cell profiles [97]. Particularly, this technique was used to classify cell profiles for human T-lymphocytes and hairy leukemic cells.

Another example of utilizing image processing in medicine may be robotics assistance in surgery [81] . A robotic arm has been used to assist the surgeon in planning, positioning and orientation of cuts and holes in a very complex orthopedic surgery. The rationale for using robotic assistance lies in the fact that the procedure is very complex and requires a highly skilled surgeon for the attachment of replacement parts in an optimal way.

The robotic approach is based on templates in the planning phase. The surgeon selects a template that meets the requirements best. This approach is based on complete 3-D geometrical plans stored as templates which robot than translates into orientation and positioning instructions of the actual surgery. The robotic assistance system may be considered as a kind of knowledge system, in which the templates are the high - level representations of allowed procedures which can be translated into instructions on how to carry out such a procedure.

Three - dimensional image processing can also be used for a magnetic resonance imaging (MRI) reconstructions [30], for electro-cardiograms (EKG) processing and comprehension [92], for skeleton growth measurement [125] and so on. All applications of this kind would greatly benefit from utilization of interactive telecommunication.

Medical simulation modeling systems.

An example of such system is PK-SIM [PK-SIM], a simulation program that provides information about drug distribution in an "average" patient who has the exact values of the pharmacokinetic parameters supplied by the program. It has been designed to teach and demonstrate the pharmacokinetic principles that are relevant to the administration of intravenous drugs. Since all patients are different, the results in a given patient will vary, sometimes considerably. Furthermore, the pharmacodynamic effect of drugs also vary widely among patients. Therefore, PK-SIM should not be used to direct the therapy of a patient in a clinical setting. Rather, clinical judgment should be employed in the management of patients receiving intravenous agents.

Features of the Licensed Version of PK-SIM include:

- a written tutorial that uses PK-SIM to teach pharmacokinetics
- an intravenous anesthesia cost analyzer (with user modifiable drug prices)
- additional drugs in the drug library
- ability to add new drugs and kinetic constants

- predictions to time of plasma or effect site decay to any percentage of the current value or to a fixed value
- a utility to convert to micro rate constants from other kinetic data sets

Systems to provide computer-assisted diagnosis.

Computer-assisted diagnosis refers to the use of computers to identify alternative diagnoses, the clinical process of differential diagnosis. Attempts to reproduce the diagnostic process in mathematical terms have taken the form of creating algorithmic, heuristic, or fuzzy models [61, 73, 99, 117, 122, 129] .

The basic components of a computer-assisted diagnostic system include the database, the computer algorithm, and an interactive program for communications between the machine and user. The database contains disease incidence probabilities, relationships between symptoms and diseases, and information on treatments and diagnostic tests.

The computer algorithm is the logical and statistical processes used to find a solution to a problem from the database and the inputted information. The computer algorithm may be

statistical or logical. Statistical algorithms calculate the most likely diagnosis from an analysis of disease symptom frequencies and disease probabilities. Logical algorithms proceed in a sequential branching fashion and a decision must be made at each step with an "if A, then B" type of reasoning.

Logical algorithms.

Logical systems, based on "discriminating questions" to distinguish among mutually exclusive alternatives, have played an important role since the first works in this area [119].

Logical algorithms include flow charts, sequential questioning, and decision trees to make a diagnosis. A flow chart encodes the sequences of actions a good clinician would perform for any one of a group of patients.

A decision tree may resemble the clinical methods of formal differential diagnosis and consist of a sequence of questions, "decision nodes" and branches. A logical database may consist of laboratory tests required, questions to be asked, and conclusions to be made.

A system for acquiring medical data and implementing decision logic has been under development at the University of Utah for over 15 years. The HELP system is presently operational at Latter Day Saints Hospital [105, 106, 121, 21].

The clinical database consists of a long-term abstract of demographic and clinical data and a short-term comprehensive collection of all data gathered during the current hospital admission. All data are stored in coded form so they can be retrieved and analyzed for use in research and decision logic.

A most interesting aspect of the HELP system is the ability to allow construction of modular sectors, plan sets, that may be used in the medical decision-making process. The logic consists of straight deterministic "if ...Then..." rules or probabilistic applications. There are currently 2,147 operational sectors with clinical applications. The most widely used sectors are those involved with EKG interpretation, blood gas interpretation, pharmacy alerts, predicted x-ray findings, and clinical laboratory alerts.

Generally, logical systems are applicable to narrow domains, especially those where it is fairly certain that only one disorder is present. Ideal application areas are those where detailed knowledge of pathophysiology or extensive epidemiological data make it possible to identify parameters useful for dividing diagnostics sets into non-intersecting subsets based on specific characteristics.

Artificial intelligence methods.

Artificial intelligence(AI) is a field of computer science that emphasizes symbolic reasoning and logical approaches rather than numeric computations and only data storage and retrieval. Classically, AI has focused on solving problems that have a symbolic rather than algorithmic flavor [21]. For example, there is no algorithm that can be used to diagnose diseases; rather, a program must search through a space of possibilities looking for candidates based on symptoms. As interesting search spaces are effectively infinite, it is impossible to use exhaustive methods. Instead, the search must be heuristically guided, pruning unpromising paths and highlighting those that appear to lead to solutions.

Leaders in the use of artificial intelligence to solve medical problems were several major Universities- all of which had an associated medical school and were closely connected which a University hospital. These leaders have been Stanford University, the University of Pittsburgh and Carnegie-Mellon University, M.I.T. in association with Tufts University Hospital and Rutgers University.

Knowledge-based expert systems is one of the directions for development of AI methods. In the early years of AI, it was felt that if-then, or production, rules could be used effectively to model human behavior. For example, MYCIN system, described in more details later, employed a rule - based approach to diagnose blood infections. In rule - based systems, production rules represent individual chunks of knowledge. Facts or goals concerning the particular session are entered into a working memory and a recognized-act cycle is invoked. In this cycle, the rule interpreter first matches appropriate rules to the data of the working memory, then performs conflict resolution to select a single rule from the set of candidate rules, and finally applies the selected rule to the working memory. The process iterates until either a goal state has been reached or until no rules are applicable.

Typically, rule - based systems can reason forward from a set of facts, reason backward from a goal, or reason alternately in both directions. Forward chaining is useful in closed systems (e.g., monitoring systems) where little interaction is required between the expert system and the user. Backward chaining is useful in interactive systems (e/g/, diagnosis systems), in which the system attempts to validate goals by establishing subgoals until facts are subgoals or until a user provides information supporting or refuting the subgoal under consideration.

Several systems exploit special knowledge to solve difficult problems in specialized areas, including MYCIN and other systems for medical diagnosis.

MYCIN system was developed by Shortliffe and his colleagues at Stanford University School of Medicine. It is a medical diagnosis program, which has been enhanced by a collection of computer programs designed to function as a consultation system for diagnosis and therapy selection. The primary source of medical knowledge in the system is a set of decision rules that are comprehensible to a clinician. The system uses the rules to make decisions about the patients. There are 450 rules in MYCIN [118].

The ideas used in MYCIN were further explored in expert systems PUFF and ONCOCIN [21].

PUFF, which employed some of the MYCIN concepts, demonstrated that the technology could be applied operationally in a closed setting, i.e., with no interaction.

ONCOCIN, which uses modern workstations, has shown that medical knowledge can be applied to cancer treatment in a clinical setting. Thus, the sequence illustrates the evolution from the demonstration of a concept, through an early (but limited) application, to a modern, operational prototype.

The other knowledge-based system is Internist-I program developed at the University of Pittsburgh. The current knowledge base encompasses over 500 individual disease profiles and 3550 manifestations of disease and includes roughly 70-75% of the major diagnoses in internal medicine [88].

While rule - based system can be considered the first successful commercial AI technology, there are at least two major weaknesses that must be considered [21]:

- Pure rule - based representations are too weak to represent the complexities of the real worlds either effectively or efficiently.

- Rule - based systems perform poorly outside their boundaries. Some of this is due to the closed - world assumption, which requires that all facts be known to system, implying that unknown facts are false.

Several innovative techniques have been added later to previous models for computer - assisted medical diagnosis. The trend has been to develop more formal models that add mathematical rigor to these models.

To counteract some of the problems of rule - based systems, newer expert systems, such as KEE, ART, GoldWorks II, integrate frame - based representation structures with rule - based processing. With these tools, complex object - oriented knowledge bases can be established that mirror the world of interest. Instead of working with simple facts, rules can access the slots (and slot facets) of frames. The frames are organized in object - oriented lattices consisting of classes, subclasses and instances. Methods can be defined over classes to realize specific behavior, and rules can be used to reason over instances of arbitrary classes. Additionally, advances reasoning capabilities often are available that facilitate "what if" type scenarios, truth maintenance, and retraction of information.

Neural networks represent an entirely new approach to medical diagnosis [13, 73]. Development of a neural network for a specific application involves selection of topology (number of input units, number of output units, number of hidden layers, number of units in each layer, connections among units - including feedback loops in some cases), selection of a training rile (the overall feedback mechanism used to adjust weights when network performance for a simple case is sub-optimal; in some cases, this may include manual as well as automatic adjustments), selection of training cases or examples, and determination of how far training is to proceed (criteria for determining when a network is "trained"). Problems with neural networks include selecting the best topology, preventing overtraining and undertraining, and determining what cases to use for training. The more complex a neural network is (number of input and output nodes, number of hidden layers), the greater the need for a large number of appropriate training cases. Often, large epidemiologically controlled patient data sets are not available. Use of "artificial" cases to train neural networks may lead to sub-optimal performance on real cases.

Fuzzy set theory [1, 93, 122, 147] includes formal methods for addressing the incompleteness, inaccuracies, and inconsistencies that are often found in medical data and medical knowledge. Fussy set theory have been applied to diagnosis of medical conditions such as rheumatologic disorders and pancreatic diseases. Medical Diagnostic Decision Support Systems based on fuzzy set theory embody representation schemes for the degree to which a given patient exhibits a set of findings, and represent confidence or certainty of a given diagnosis on a continuum from 0 to 1. By formally tracking upper and lower bounds on patient parameters; by representing symptom - disease relationships, symptom - syndrome (intermediate state) relationships, symptom - symptom relationships, and disease - disease relationships, using, in effect, sensitivity (frequency) and predictive value (strength of confirmation) fuzzy measures; and by using basic operators of conjunction, disjunction, negation, and conditional inference, it is possible to derive bounded certainty values for possible disease states.

Statistical Methods.

Another approach to computerized diagnosis and treatment is based on medical statistics. This approach requires knowledge about how disease is distributed in the population.

A patient record compiled as a matter of routine can serve a larger epidemiological need. A historical collection of records of many patients is an invaluable resource in the investigation of patterns of health and disease in a population.

Some mathematical approaches implemented to facilitate statistical analyses include cluster analysis, discriminant analysis, Bayesian methods, computer approaches, game theory, information theory, stochastic representations, stepwise procedures, decision analysis, and pattern-recognition techniques.

Common statistical models use conditional probability based on Bayes' theorem, linear discriminant functions, and matching procedures. Conditional probability based on Bayes' theorem is the most widely used and requires data on the probability of the disease, probability of the symptom, and probability of the symptom given the disease. Linear discriminant functions distinguish which of the two possible groups an individual belongs to, based on normally distributed measurements. Matching procedures compare a patient's symptoms with those of everyone in the database of those of a calculated average symptom profile representative of each disease in the database.

An example of such approach is the system at the Mayo Clinic in Rochester, Minnesota, where the records are indexed by diagnosis and demographic characteristics and are used to determine the incidence of a wide variety of disease, including multiple sclerosis, Parkinsonism, stroke, and almost every form of cancer.

In late 70's- early 80's I was participant in the group of researches who created and developed the national (All Union) database for the psychiatric care system in the USSR. All psychiatric hospitals and other related institutions maintained the standardized medical computer record for each patient. In a central Statistical Center for Psychiatry in Moscow these data were utilized to determine statistical correlation between number of patient being treated and quality of treatment and amounts of human, financial and other resources distributed among different regions in the USSR.

1.3 MEDICAL MANAGEMENT INFORMATION SYSTEMS

The centerpiece of a typical Management Information System (MIS) is a database, containing big volume of information. The functions of application software, which is another important part of an MIS is to retrieve, add, update and delete pieces of information for particular cases. In particular case of medical systems the structure of data plays and important role, and is a subject of a research. Another component is an entry language to the system. All these components of medical MIS are to be discussed here.

An example of such a complex system is Regenstrief, a system which operates at the Regenstrief Health Center of Wishnard Memorial Hospital, an inner-city hospital affiliated with Indiana University School of Medicine.[85] This ambulatory care clinical information system combined computer - stored medical information with coded medical knowledge to produce reminders. The system contains the demographic data, results of all diagnostic studies, and all medical treatments from the emergency room, wards, and clinics of the hospital. For example, if the standard of care was that all women should have a Pap smear every six month, then the RMRS would recognize when this condition was not satisfied and print a reminder for the physician. With a language called CARE, rules can be programmed by physicians to instruct the computer to determine which patients need particular tests and treatments. There are over 1410 CARE statements in operation.

OCIS (Oncology Clinical Information System) illustrates how information systems can be applied in a tertiary care environment to integrate long - term care in both an inpatient and outpatient setting. In addition to managing most clinical and administrative functions at the John Hopkins Oncology Center, OCIS also supports highly specialized features such as

protocol-directed care planning and blood product management. Of particular significance is that OCIS was entirely paid for out of patient care fund since it became operational.

There is a clear trend that clinical systems have advanced far beyond the simple management of administrative data. The information is becoming organized to facilitate access, and our understanding of how to structure the underlying knowledge for interpreting the information has grown. The state of the art has advanced to the point that major systems, such as OCIS, can be developed and justified solely on the basis of local benefits. Ideally, one would expect the new commercially - supported systems would build on this experience in merging information and knowledge.

Medical databases.

Medical databases are computer-based systems that receive, create, and maintain computerized records of data for patient care or of an epidemiological research (as well as administration and planning). They are not designed to specifically act as "consultants" and do not add information from other sources outside the system. The advantage of a computerized medical record include single entry and visual verification of the data, reduced paper work, increased legibility and accuracy, easier access to information, uniform procedures, and increased efficiency and effectiveness.

The disadvantages include inflexibility, unreliability, slowness, high costs, loss of control, dependence on the system, and failure to meet objectives and it may be no more effective than handwritten notes.

The medical record is supposed to contain diverse information about a single episode of illness, long-term care and prevention, and be a basis for the evaluation of the encounter. The same medical record is expected to serve for the care of patients with diverse problems. It is expected to serve as an aid to memory, a legal document, and a means of communication between providers.

An effective medical record should allow easy retrievability of data that have been entered, contain justification for action taken, and put events in the context of previous and subsequent observations. The record should be legible, accurate, and easy to use and should facilitate improved medical care.

The Total Medical Record (TMR) was developed at Duke University. [9, 124]. It is a medical information system that manages a patient's encounter from the time an appointment is made to the closing of an account.

COSTAR (COmputer STored Ambulatory Record system) is a flexible medical and management information system designed by the Massachusetts General Hospital Laboratory of Computer Science in collaboration with the Digital Equipment Corporation, the National Center for a Health Services Research and the Mitre Corporation [15, 21, 121]. This was the first large - scale, ambulatory care system to implement computer - stored medical record. COSTAR was designed to support the medical, financial, and administrative needs of a practice. The availability of the medical information in machine - readable form enables a degree of planning, control, and retrospective analysis, that otherwise would be impossible with traditional paper records. Initially developed for a Harvard HMO, the system was upgraded as a public domain system.

The American Rheumatism Association Medical Information System (ARAMIS) represents a national chronic disease data bank system of parallel, longitudinal, clinical data sets from 17 rheumatic disease centers containing an aggregate of 22,000 patients and 183,000 observation time points [86].

It is necessary to note that such systems as ARAMIS or Duke cardiology database, while being highly successful, are limited to the research purposes. Clinical databases that result from routine collection of data will never be of the same quality as a research database [110].

Computer - Based Patient Records.

It has long been recognized that the paper - based medical chart is inadequate to meet the current needs of health are providers [66]. The diversity of the interests of medical record users has resulted in widely differing definitions for an electronic medical record.

Historically a patient record format went through a number of significant transformation due to advances in science and technology and social changes in a society, which led to different roles of a health care provider and a patient and new kinds of relationship between them. The historical forms of the patient records took forms first as diary or monologue, taking its origins far in the past; the second, medical record as database, became more prevalent after the introduction of the computer but has since been subsumed by broader efforts, the third, the problem - based patient record, led to one of the earliest clinical information systems, the fourth, patient record as artifact of conversation, is a plausible evolutionary outcome of the integration of databases, text - management systems, networks, electronic mail, and "groupware"; the final model, a decision - based patient record, is a hypothetical construct based on the previous models [50].

The Institute of Medicine (IOM) defines a computer - based patient record (CPR) to be :"An electronic patient record that resides in a system specifically designed to support users by providing accessibility to complete and accurate data, alerts, reminders, clinical decision - support systems, links to medical knowledge, and other aids." [64].

Stating, that "no operational clinical information system in 1990 can manage the entire patient care record with all its inherent complexities", the IOM patient record committee concluded that:

- health care was in desperate need of CPRs;
- despite the status of current systems, technology was not the limiting factor in CPR development;
- a concerted effort could make CPRs a reality sooner rather than later.

The report, which focused on the computerization and communication of patient and provider information, identified five objectives for the CPR:

1) support patient care and improve quality of care;
2) enhance productivity of health - care professionals and reduce administrative costs of health - care delivery and financing;
3) support clinical and health services research;
4) accommodate future developments in health - care technology, policy, management, and finance;
5) ensure patient data confidentiality at all times.

Neither paper - based records nor contemporary computer - based records can effectively support all these objectives today. The Institute of Medicine report also noted that the future CPR must be "far more flexible, allowing its users to design and utilize reporting formats tailored to their own special needs and to organize and display data in various ways. The patient-record system of the future must provide other capabilities as well, including links to administrative, bibliographic, clinical knowledge, and research databases. To meet the needs of clinicians, CPR system must be linked to decision - support systems; they must also support video or picture graphics and must provide electronic - mail capability within and between settings."

The CPR systems found in hospitals today typically treat the hospital as the primary, and often sole, provider and venue of care delivery. Until recently, this orientation was appropriate and relatively effective. With the decentralization of health - care delivery and the consequent rise in specialty services and organizational alliances, this centralized model for patient information management is becoming less appropriate. Further, within individual institutions, patient record information is becoming decentralized, driven largely by an industry-wide transition from centralized minicomputer and mainframe systems toward distributed, client / server system (Fig. 1.2). Health - care providers, patients, and payers are restructuring their relationships, and the CPR is changing as well. It is being transformed from a centralized model through a distributed model to a longitudinal model.

Thus, in addition to recommending that health care professionals and organizations adopt the CPR as the standard for patient records, the IOM report presented a road map for CPR development which included establishing an organization to promote development, implementation, and dissemination of CPRs; research and development in critical technologies for the CPR; promulgation of data and security standards; federal and state laws and regulations; sharing costs of CPRs; and educating health care professionals.

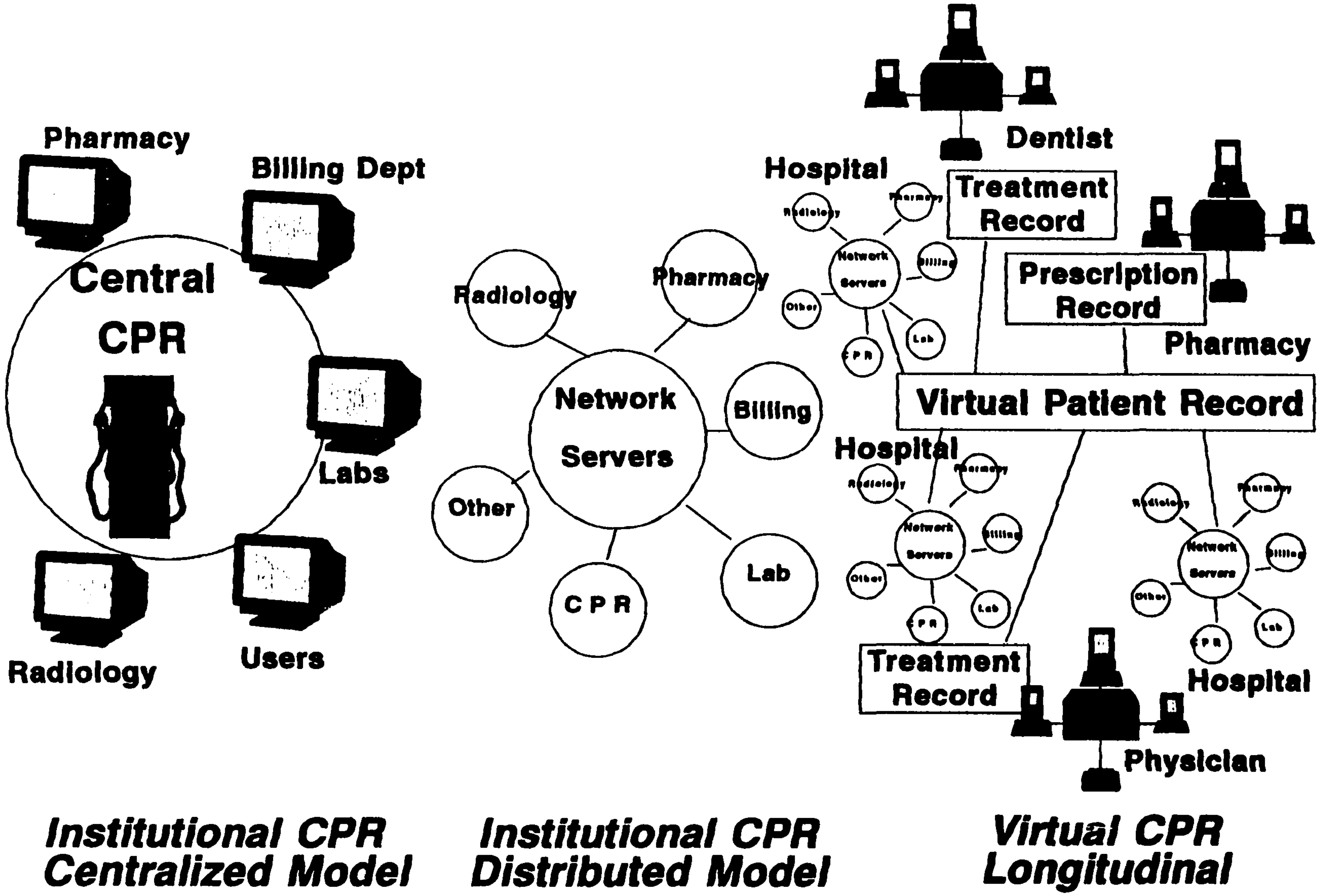

Fig. 1.2. The Computerized Patient Record in Transition

In 1991, an IOM committee declared CPRs and essential technology for health care and called for widespread CPR implementation within a decade. Given that telecommunications and computing infrastructures at health - care institutions typically lag five years behind mainstream business users of information technology [134], the report poses quite an aggressive challenge. In addition, the Workgroup on Electronic Data Interchange proposed an even more ambitious timetable for the establishment of a complete electronic data exchange system for sharing clinical data among health care providers, payers, and government [26]. Standards for the electronic transfer of clinical data has been established [63]. In 1992, federal legislative initiatives were proposed in both the House of Representatives and the Senate that would have required hospitals to submit to the government a wide range of patient - specific clinical data in electronic format well before the year 2000.

There are two important aspects of Computer - Based Patient Record [43]. First, the record is focused on and integrated around the patient - across settings of care, across disciplines, and across time. Second, the record is computer - based, not computerized: true CPRs are more than automated versions of current patient records. CPRs are a resource with much enhanced utility in patient care, management, and extension of knowledge. Thus, CPRs must reside in systems that support users by offering complete and accurate data as well as tools to aid the clinical decision process. CPRs should be the core of institutional or enterprise health care information systems.

According to the IOM committee, comprehensive CPRs and CPR systems should

(1) contain a problem list;

(2) support systematic measurement of health status and functional level;

(3) document the clinical rationale for patient care decisions;

(4) link to other clinical records across settings and across time to provide a longitudinal record;

(5) provide comprehensive confidentiality safeguards;

(6) offer easy access to authorized users;

(7) allow selective retrieval and formatting of information;

(8) link to local and remote knowledge, literature, bibliographic, or administrative databases and systems;

(9) assist in the clinical problem solving process;

(10) support structured data collection and store data using a defined vocabulary as well as support direct data entry by practitioners;

(11) aid in the management and evaluation of quality and costs of care;

(12) be flexible and expandable.

No single CPR system will meet the needs of all settings; all CPR systems must, however, meet minimum connectivity standards and offer a set of standard functions that meet the criteria listed above.

Entry Languages for Medical Systems.

Medical data are "fuzzy", and imprecise terminology and observer variation are probably the major reasons computers have less impact in medicine that in other areas.

This situation can be dealt with by accepting the data as imprecise and adopting a complicated mathematics to deal with them, or by doing something about the clinical terminology.

The easiest way to collect non-numeric data is as free text. Despite the additional work however, encoding data are useful because they are more readily checked for validity.

A number of medical information system designers have chosen to capture the natural language form of patient data, either in whole or in part, for ongoing patient care or as part of a clinical data bank.

To access the information in the stored text, standard retrieval methods of free-text search can be used, supplemented by a medical thesaurus, as was done in the four large clinical databases (Surgical Pathology/Bone Marrow, Autopsy Pathology, Nuclear Medicine and Neuroradiology) maintained by UCLA Hospital and the natural language radiology retrieval system POLARS.

The Bellevue Hospital Health Information System was one of the first to capture data in narrative form. The SCAMP system routinely captures a large number of patient encounters (710,567 accumulated by 1981), including all free test laboratory values, vital signs, and medications. The system provides a retrieval capability based on logical combinations of keywords derived from natural language user queries, and provides procedures for data analysis from the retrieved documents.

Automatic encoding of the natural language input in a specialized area, using an available medical terminology, is another approach that has been successfully employed, most notably in the program developed at the National Institutes of Health (NIH) for the translation of pathology reports into the numerical codes of the Standard Nomenclature of Pathology (SNOP). The SNOP terminology embodies a semantic analysis of the phrases of a pathology report and functions as an artificial language into which the natural language of pathology reports can be translated. It is divided into four highly structured lists:

- Topography (body sites);
- Morphology (structural changes in tissues due to disease);
- Etiology (causative agents);
- Function (physiological manifestations of disease).

System, based on automatic encoding of the subset of natural language includes the topographic portion of SNOP. The program uses techniques of exact match, disinflection, spelling correction and some simple rules of phrase analysis to interpret phrases for use in a computerized instructional program and other applications.

MUMPS (Massachusetts General Hospital Utility Multi - Programming System) was originally developed in the late 1960s and early 1970s for minicomputer systems and it still has a strong presence in health care as well as engineering and scientific markets [135]. Particularly, it was used to create applications for a distributed client / server MIS at Brigham and Women's Hospital in Boston, Massachusetts [134].

The MIS at Massachusetts General Hospital also includes the program, which translates natural language phrases into codes (International Classification of Diseases, Adapted [65])

These medical encoding systems have in common that input consists of (usually, short) phrases as opposed to full narrative, and the method of analysis is primarily dictionary look-up, with linguistic analysis employed as an aid to the matching procedure. A different approach, applicable to full narrative, is based on a syntactic analysis which reduces the input text to its component informational elements in the form of elementary assertions. It achieves its semantic effect by recognizing in these assertions classes of words that carry the same kind of information in all documents of the given type.

Other systems of this type employ the analysis of the full narrative text. Examples of such systems are a system for processing of surgical operative reports developed by the Biostatistics Department of Roswell Park Memorial Institute and LSP system for converting natural language data into the structured form called ' information formatting '. The LSP clinical information format is similar to the multidimensional Medical Event Vector, used in PHAMIS medical information system.

1.4 MEDICAL TELECOMMUNICATION NETWORKS

The number of medical telecommunication networks have rapidly increased during the last few years and continues to be growing. This is due to several factors:

- a proliferation of managed - care health services networks established by numerous insurance companies and health centers;
- an increasing number of multi-team and multi-national medical research projects, such as Human Genome Project of AIDS research, which require cooperation, data sharing and active interaction between participating members.

- the advancements in technology, which brought up a number of tools available for medical researchers and other health care professionals.

These networks vary from distributed databases and Local Area Networks (LAN) within a particular hospital of other kind of medical / health care institution, to international cooperation based on the Internet.

Hospital - wide networks

Distributed systems provide direct support for decentralized business units, making use of their own local processing, while being given access to hospital - wide information systems. Therefore institution - wide LAN allows communication between independent heterogeneous systems of different departments and wards. At this time there are still few examples of decentralized Hospital Information Systems. The most notable and promising are those of the John Hopkins Hospital in Baltimore [128], Brigham and Women's Hospital in Boston, Massachusetts [134], and DIOGENE at the Geneva Canton University Hospital in Switzerland. [114].

The scope of applications in the latter are ADT (A = Admission, D = Discharge, T = Transfer) for in / out patients, Laboratories, Radiology information system, RX reports, Image manipulation platform and PACS, Teleradiology for satellite hospital, Pharmacy, patient care team management, integrated medical office automation, archiving and medical documentation, personnel management, management applications and tools.

Brigham and Women's Hospital, the teaching arm of Harvard Medical School, like most hospitals, has a heavy legacy of centralized, minicomputer - based support systems.

Unlike most institutions, the Brigham has successfully migrated to a LAN - based, distributed, client / server, desktop environment at the same time as dramatically increasing the availability of on-line patient information and the number of supporting applications. At the hospital's main campus, over 3300 Intel clients and 120 servers are connected via 70 4-MB Novell NetWare 3.0 token rings and two 16-MB backbones (Fig. 1.3). This infrastructure supports more than 65 applications software systems, such as Pathology Laboratories, Patient Accounting, Result Retrieval, and Physician Order Entry. Applications are written in resource - conserving MUMPS (Massachusetts General Hospital Utility Multi - Programming System), a client / server applications development and run - time environment.

Global medical network

At the other - global - end of the specter of health care telecommunication network may be found a very powerful and far-flung computer network, called SUMEX- AIM . This global network has been established in the US, so that researches in the field can communicate readily with each other and spare medical and computer expertise.

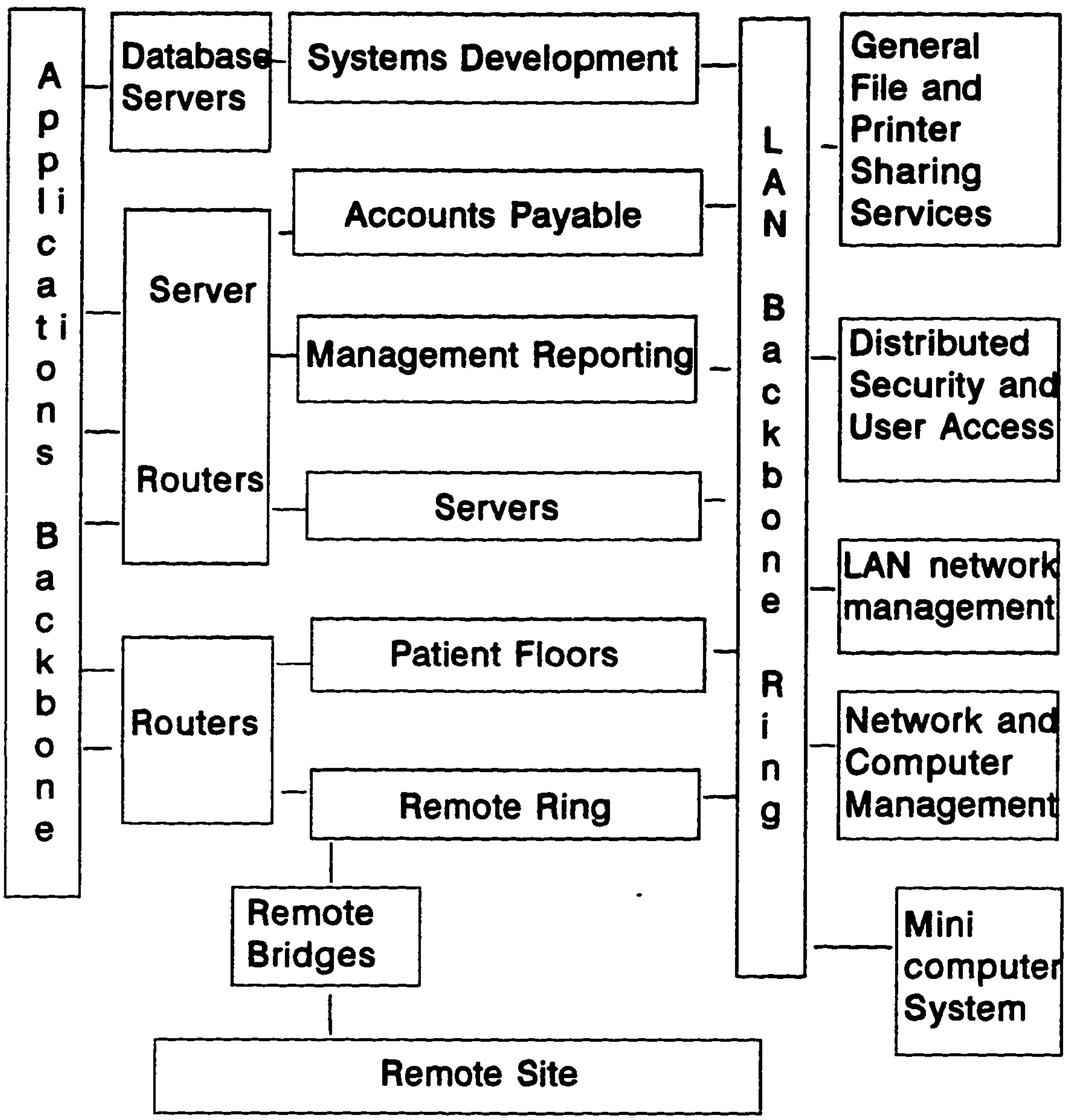

Fig 1.3 Hospital Information System Infrastructure

SUMEX-AIM (Stanford University Medical Experimental computer center for A.I. in medicine) consists of a number of powerful computers and related equipment, and is a major resource for work in A.I. and medical knowledge engineering. SUMEX-AIM not only allows University researches from all over the country to work together, it also has connections to ARPANET (Advances Research Projects Agency Network), which is obtained by the Defense Communication Agency for the Department of Defense, and to TYMNET, a commercial data communication network.

Community Health Information Networks

The initiatives to create Community Health Information Networks (CHIN) are on the way in such areas as statewide Illinois, Metropolitan Chicago and Northeast Ohio (Cleveland).

One of the first CHIN to be built in the USA is an Illinois statewide health information network serving Chicago and all of Illinois [16]. The network is being developed by Ameritech Corp. In addition, the regional Bell operating company also has entered a contract with Blue Cross and Blue Shield of Illinois to transmit information electronically to the plan's provider network.

The Illinois network will offer a wide range of applications in its software package. For example, the network will give the Blues plan connections with physicians in its managed care network to transmit eligibility verification and patient referrals electronically. Other functions, such as electronic billing and payment, will grow as network participation builds.

The network will function as community governed utilities, directed by community - led boards that set policy and provide oversight. Ameritech will function as a company that invest capital in infrastructure and sells services. It will seek to acquire or enter partnerships with companies that can add services that network participants want. The customers will be permitted to select whatever services they want, from basic connectivity to the use of its Keystone data repository.

The competing Chicago Metropolitan CHIN is being developed by the eight - vendor ChinAlliance in cooperation with the Metropolitan Chicago Healthcare Council, representing about 100 hospitals in the six - county area.

The existence of two or more CHINs in the same area raises such issue as creating a connection between networks that are easy for users to navigate and allow seamless exchanges of information and data.

Another state - wide CHIN is being developed in Vermont. In May 1992, the General Assembly of the state of Vermont created a Health Care Authority charged with developing plans to support universal access to health care for residents. In support of that goal, a non - profit corporation called the Vermont Health Care Information Consortium, or VHIC, was formed. Its mission is to plan and develop a modern, regional. integrated health - care information system. It oversees research and policy development activities, working with all stakeholders - vendors, providers, payee organizations, and consumers - to develop definitions of functionality for the system and to identify interface standards and telecommunications policies that support the individual needs of institutions and the needs of the population at large.

In December 1993, the C. Everett Koop Institute at Dartmouth sponsored a conference for health - care professionals, policymakers, and technologists to discuss the ways and means of developing an integrated health - care information network to serve the population of Maine, New Hampshire, and Vermont. The problems raised by the former Surgeon General Koop at the conference included identification of obstacles of creation an information superhighway, and creation of plans to remove them. Among the question to be addressed before robust and effective networks can be implemented are defining the information to be communicated as well as sources and users of this information (Fig. 1.4)

Internet

The Internet is a powerful tool being used for many purposes that are potentially useful in support of biomedical research. Services on the Internet include electronic mail, file transfer, remote information access and information browsing , utilizing various discovery tools, such as Wide Area Information Servers (WAIS) project, Gopher, the World Wide Web (WWW), Netfind and some others [97].

Particularly, there is a large and growing set of national data repositories accessible over the Internet, which are useful for bioscience (P. L. Miler). These include repositories for biological sequence data, for gene mapping data, for protein structure information, and for many other, sometimes highly specialized, types of biological data.

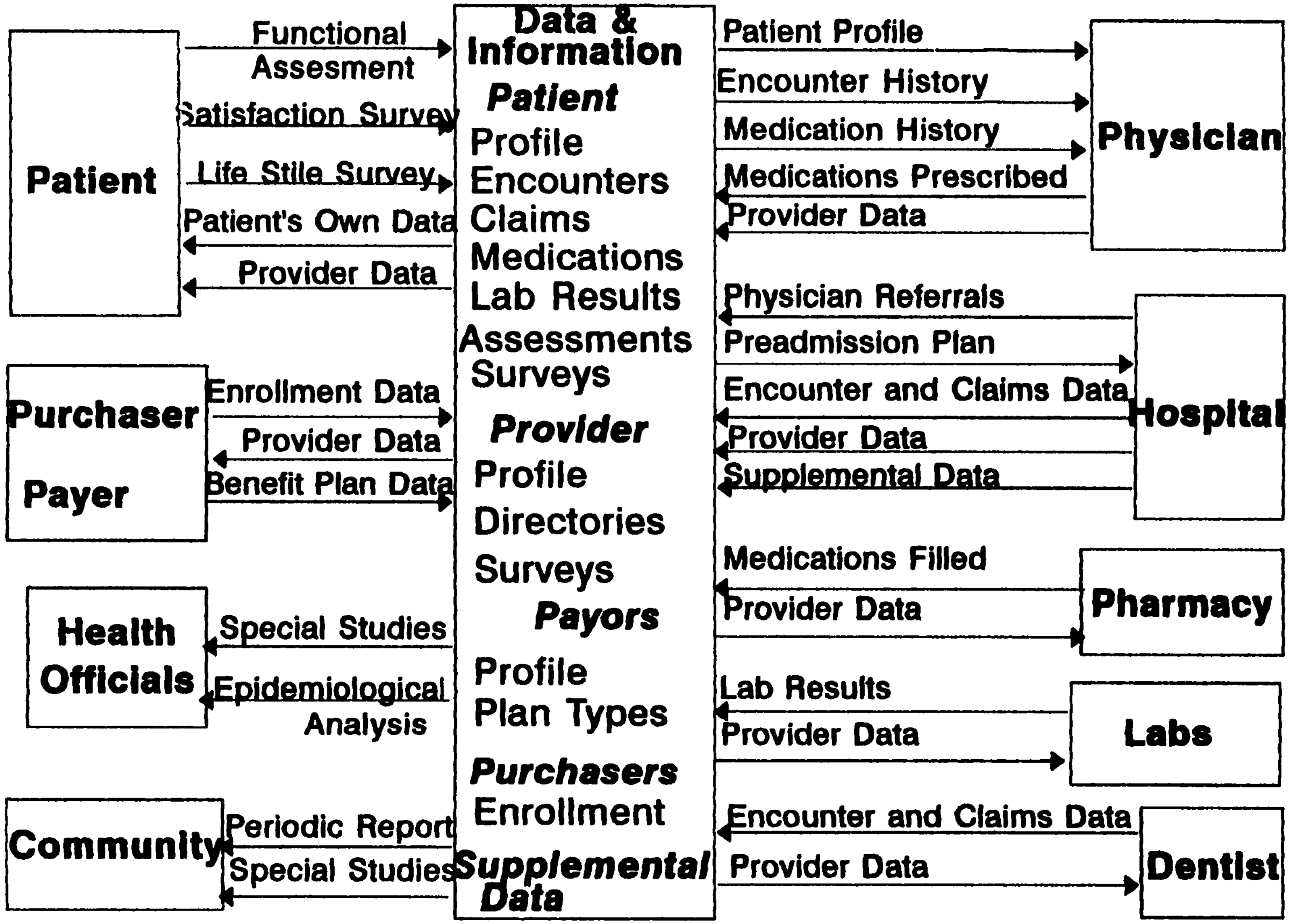

Fig. 1.4 Sources and Users of Information in Computerized Patient Record

HospitalWeb is a site on the World Wide Web that lists all hospitals with connections to the web.[120] . Hospitals connect to the web to share information on-line with Internet users. Information a hospital might share includes lists of physicians, physician's specialties, medical information, departments and research projects.

Additionally, HospitalWeb contains a message board that provides an interactive forum for health care industry Internet users

Internet - based informatics support is used in a collaborative Genome mapping project [89]. There are now roughly 20 Genome centers in the United States supported by the National Institutes of Health (NIH) National Center for Human Genome Research and by the Department of Energy, and many other centers worldwide. The type of client - server Internet - based architecture described in this paper represents a direction in which parts of the genome mapping field are heading, but one that has yet to be extensively implemented of described.

Generally, using the Internet:

- - Physicians and other can electronically access huge health databases at the Centers for Disease Control and Prevention, the National Institutes of Health and other private sources of information.
- Hospitals throughout the country are publishing and electronic page serving as an index to information about their facilities. Those searching for information can access these hospitals' Internet connections from one central source of information called HospitalWeb.

- The University of Iowa College of Medicine is producing a "virtual hospital" for physician education, including quick and organized access to multimedia textbooks, case presentations, medical pamphlets and medical museum exhibits.
- The Health Industry Business Communications Council is making information, from electronic formats to bar code standards, available at its own Internet address.

The home page of the National Library of Medicine not only allows contact with people and information at the library but also enables connection to the national Institutes of Health, the National Information Center on Health Services Research and other databases.

The Internet will not replace community health information networks (CHIN). The Internet represents a vehicle for exchanging information, but that exchange will be haphazard, unorganized and centered around narrow searches for information. CHINs, on the other hand, will involve high levels of organizations; collection and / or access to data through clinical data repositories or distributed databases; and standard data collection agreements between participating organizations.

2. INTELLIGENT NETWORKS

Intelligent Networks (IN) are defined as the carriers of information with distinct algorithmic adaptation [2].

Intelligent Networks are comprised of switching systems, transmission facilities, and common channel signaling networks used to control the switching systems to route transmission paths through the network and monitor and control the transport of data. IN nodes have programmable memories and are software controlled.

The evolution of IN over the years have been done in phases. The common components of all the phases are the following:

Service Switching Points (SSPs): Nodes that permit easy access points between the network and the users. A node has a specialized software environment to recognize the service conditions demanded by the users. It forwards the request for further instructions to the STPs. It also receives the response to the request and completes the service request by the user.

Service Control Points (SCPs): Nodes in the *Common Channel Signaling System number 7 (CCS7)* network that provide responses to the queries from the users. These are introduced and activated to communicate with the Service Transfer Points (STPs) in the CCS7 network. In the earlier IN versions the responses are stored in an active and well managed data base. The response to the user query is a quick look up in the on-line database in the SCPs. In the more recent SCPs for later versions of INs (IN/1+ and IN/2), new software support of the service logic interpreter is added to find responses by executing the functional components (FCs) associated with the service demanded by the user. Service validation function can also be accomplished in the SCPs.

Service Transfer Points (STPs): Nodes embedded in the CCS7 signaling network, switch (or transfer) signaling messages from the SSPs and SCPs. Standard communication interface permits easy access from most of the SSPs and SCPs in the CCS7 network. Switch manufactures also make the STPs.

Service Management Systems (SMSs): Systems that provide the management and the updating of the databases in the SCPs. Data and Statistics may be provided to the querying node. The administration of the databases for the maintenance and introduction of services is accomplished via the SMSs that communicate with the SCP via the dedicated BX.25 link.

2.1 THE EVOLUTION OF INTELLIGENT NETWORKS

The evolution of IN over the years have been done in phases, and there are three distinct network architectures accepted by the Regional Bell Operating Companies around the United States and classified as *IN/1*, *IN/1+* and *IN/2* [3].

The first phase in evolution of IN, IN/1 represents hierarchically controlled system, which is service specific. Geared for automatic reverse and alternate billing services, it has a service specific software for all elements (SSP, STP, SCP, SMS) used.

In the IN/1+, the use of Intelligent Peripherals (IP) to interface the intelligent networks of the American Regional Holding Companies and/or other intelligent nodes is provisioned.

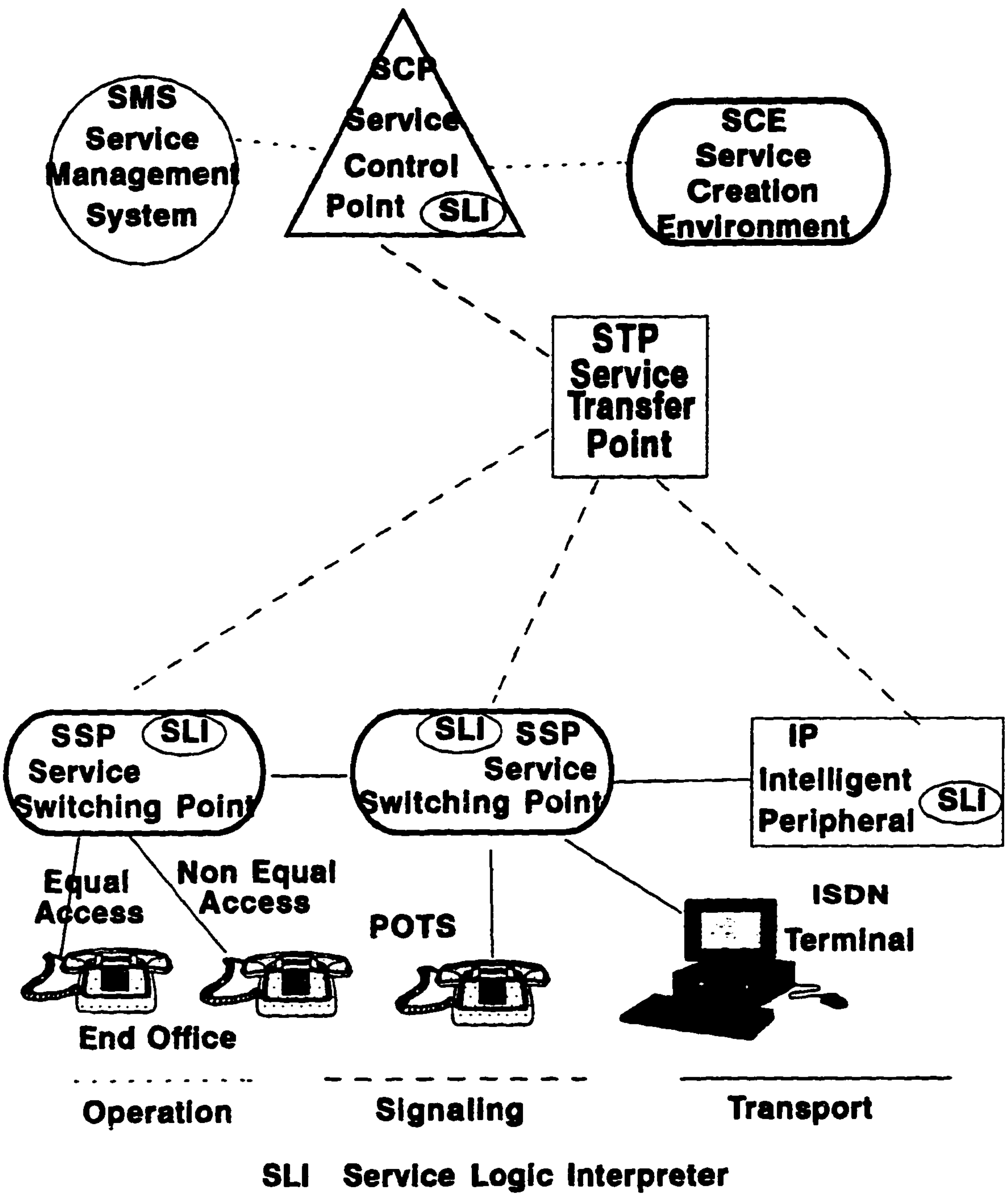

Fig 2.1 IN/2 Architecture

Intelligent Peripherals (IPs) are peripheral support devices that are computer driven programmable systems that enhance the network services such as speech recognition, synthesis, announcements, and voice messaging. They are controlled by SCPs or SSPs in the network and add another dimension of specialized services that the network can provide to the end users.

Additional features of this IN environment include service independence, faster feature introduction, and standard node interfaces at various switching centers.

The architecture of IN/2 reflects distributed services and object oriented methodology, where centralized SCP based control and service specific software are replaces by independent nodes and application independent software with functional components representing network transactions (Fig. 2.1).

In addition to IP, the new features Functional Modules (FM) are incorporated into the network.

Functional Modules (FM), also known as *Functional Components (FCs)* permit the easy introduction of new services in the IN/2 environment by being modular in their functionality. They are capable of being executed in the interpreter mode by the service logic interpreter (SLI) to build new service quickly and efficiently. For example, an FC such as JOINT connects a new line to an existing call, and the new number is conferenced into the existing telephone path.

The development and implementation of IN is also based on the utilization of:

- advanced transmission technology (Integrated Services Digital Networks -
- ISDN, based on fiber optics);

- customized integrated circuit chips with sophisticated layout , and their interconnection (hardware);
- software methodology, incorporating client - server architecture, distributed databases and object - oriented methodology;
- firmware, where intelligence is microcoded into the control memories of the monitoring computers;
- hierarchical network architecture, which allows a flexibility in providing new and modifying existing services.

2.2 KNOWLEDGE - BASED INTELLIGENT NETWORKS

The further development of intelligent networks is dictated by the necessity of performing knowledge oriented functions.

The Knowledge may be defined as the explicit functional associations between items of information and/or data [3], whereas *Knowledge systems* are generally systems implementing knowledge, in one or another form, as a programming language [4].

The knowledge base networks will not only be able to provide fast and efficient connection between pre-identified nodes, but also will have the capability of processing inquiries which do not specify the location of a network member capable to resolve a query. The location of an expert, able to answer a particular inquiry, is determined by applications of logical rules and conditions. Unlike existing telemedical applications based on use of Internet services and tools, and requiring an extensive human - computer interactions, a knowledge-based network is able to provide a fully automated environment for queries processing. A participating member of an intelligent medical network will have a specialized intelligent peripheral (IP) - a multimedia workstation with software designed specifically to communicate with other members on this network, and will have a universal telephone number for the IP to call in order to address all specific inquiries. This IP will define possible types of services the network can provide and will assist a customer in creating an inquiry to be sent to the network in a specific format. The network can accept the inquiry, identify it and locate the best source of knowledge related to a specific inquiry. This may be an internal knowledge base, a knowledge base of a participating network member, or a human expert. After the inquiry is resolved, a response is sent back to the calling party.

The architecture of knowledge - base network has yet to be developed, and may be based on the utilization of the concepts of Advanced Intelligent Networks (AIN), distributed services and object-oriented methodology. An Advanced Intelligent Network (AIN) is a network in which two layers are built on the top of the "transport layer", which consist of switching systems and transmission lines [56].

The top layer is concerned with overall network management, including the creation of new services. This is an Administrative Module, described earlier in 2.1.

The second layer contains functional nodes and knowledge bases (KBs) dedicated to implementing particular features, such as 800 service and voice mail, outside the switching systems themselves (where features are traditionally implemented). Hence, in addition to three subsystems of existing networks (communication, switching and administrative) a new module (Knowledge Module) is added.

The new task of knowledge processing requires not only adding this new module. The functions of existing three subsystems are also changed, and the architecture of a knowledge-based network has to be elaborated, based on the new functions of all the units of the network, leading to the new architecture of communication systems.

These modules are now organized in a multi-level fashion, with the bottom layer containing communication and switching subsystems, the next layer having knowledge module, represented by functional nodes and databases, and the top level occupied by administrative module, whose functions now also include the creation of new services (Fig 2.2).

The function of the communication module in knowledge-based environment, in addition to existing functions of providing communication between nodes of network, as also to support a connection between the knowledge module and other subsystems and to organize the inputs and outputs of the discrete processes. In distributed environment an interaction between different parts of the global network may require an assistance from Communication Module. The exchange of information between the various modules of the system requires optimal protocol design and packet structure.

The switching module in knowledge-based environment is supposed to select and switch between large quantities of information and between different sources of relevant information.

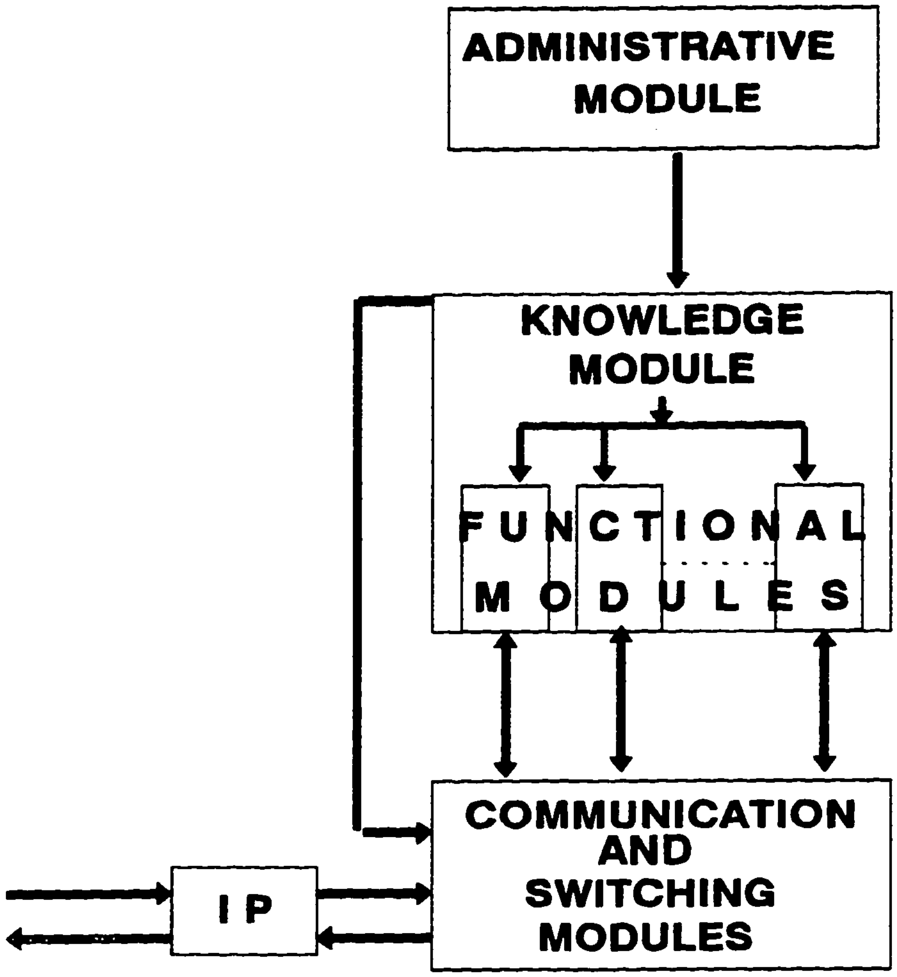

Fig 2.2

Archiecture of a Knowledge-Based Intelligent Network

The administrative module of the Knowledge-based system is supervising the complex multi-processor, multi-tasked system which is able to handle many hundred of problem at the same time. The functions of this module include security supervision, resource allocation, real-time multitasking and scheduling the tasks during knowledge processing. It also becomes a function of the administrative module to maintain and update knowledge bases and software units in the other three modules.

The Knowledge module is by no means the most complex and less elaborated unit. It contains Functional modules along with knowledge bases dedicated to specific applications. Based on object-oriented programming tools, fuzzy logic and distributed environment, the knowledge module should be able to discover and establish new relationships between various objects and processes.

The architecture of the knowledge module greatly influences the architecture of the whole system. The architecture of the knowledge module is, in turn, application dependent. It may utilize a single processor or multiprocessor based architecture. In case of multiprocessor environment we may choose between hierarchical or distributed systems, or combination of both.

The addressing of the distant KB's is done via a subject matter identifier allocated to a distant KB. This identifier of the KB is consistent with the information stored in that particular bank, thus reducing the switching time to these massive information stores. In such systems, the instruction to the knowledge bank is followed by a burst of input data via the packet switching network.

Every subprocedure is executed via an individual packet command, and the result of the procedure is conveyed to the user by a series of packet transactions. Such transactions are systematically processed and the output is accumulated from subroutines, procedures and runs.

2.3 INTELLIGENT MEDICAL NETWORK

Today's progress in medicine is in a great part possible because of advances in computer technology and successful research on the application of such technology to medicine. The advances include, but are not limited to, new more powerful computers as well as to telecommunication systems and network that permit electronic storage, transmission, and display of big volume medical images and other information distributed around the globe.

Currently, there are many databases available to the international and domestic users, which contain related medical information and knowledge. They may include medical records of same patients, statistical and epidemiological data concerning identical problems and medical knowledge related to same topics. An example of an international project based on the database distributed around the world is the Human Genome Project.

One of the current problems is to provide medical community with means of modern communications utilizing the advanced telecommunication technology. Many existing tele-medical applications are based on telecommunication between parties where the address of a destination party is either known in advance, or is accessed by manually navigating over the Internet. When a customer wants to find some information which is not formally defined, as is often the case in the medical and health care field, the process of finding the required information can become a very time consuming and tedious job. On the other hand, the functions of numerous existing specialized medical networks (sponsored, supervised and maintained by insurance companies) are to provide limited, narrowly defined areas of data. This data, mostly insurance or financial in nature, is available to a limited number of members of a particular managed care organization.

In contrast, the function of an Intelligent Medical Network (IMN) is to provide an environment for the automatic processing of medical queries, when the address of an expert, who can answer such a query, is not known in advance. The network which process a query is able to transmit it to the right destination based on the content of query. The architecture of such a network is based on its ability to recognize, identify and classify medical queries utilizing medical knowledge. Ideally, a participating member of an intelligent medical network will have a specialized intelligent peripheral (IP) - a multimedia workstation with software designed specifically to communicate with other members on this network, and will have a universal telephone number for the IP to call in order to address all medical - related inquiries. This IP will define possible types of services the network can provide and will assist a customer in creating an inquiry to be sent to the network in a specific format. The network can accept the inquiry, identify it and locate the best source of knowledge related to a specific inquiry. This may be an internal knowledge base, a knowledge base of a participating network member, or a human expert. After the inquiry is resolved, a response is sent back to the calling party.

The types of functions the IMN can perform include, but are not limited to, automatic and expert-assisted diagnostics, interactive tele-conferencing and tele-counseling, patient medical history requests, insurance information, and reference and thesaurus data. Along with inquiry recognition and resolution functions, the network will also provide educational, administrative and financial services, as well as a Bulletin Board for all members.

2.4 INTELLIGENT PERIPHERAL FOR MEDICAL NETWORK

As was mentioned earlier, the function of Intelligent Peripherals (IPs) is to facilitate user's interface with a network. Specific implementation details of an intelligent peripheral used for a particular application depend on the purpose of this application system. IP in medical and health care applications may utilize multimedia technology, image transmitting tools, censoring devices and various medical apparatuses, both attached and built-in. It also may incorporate certain software modules designed for an user's interface in some application systems. In such a case these software modules of an IP may be considered as being also shared by application Functional Blocks of a Knowledge Module.

Examples of IP prototypes for medical and health care applications presented in this dissertation include workstation for the Compurecord Anesthesia Recording System and Consultant front-end subsystem of the Data-Mail Electronic Consultation System developed as a pilot project of an Intelligent LAN at the Mount Sinai Medical Center in New York.

CompuRecord Anesthesia Recording System.

The function of the CompuRecord Anesthesia Recording System is to automatically collect data from the various operating room monitors, to store them in the form of computer files (either locally or over a network), and to prepare various reports in response to user's quires. Data are collected and recorded on-line, with some data written to a computer file as a result of user's input, and some data continuously monitored by the system and written as a computer file record every 15 seconds.

The Compurecord system is able to gather and register the following kind of information:

- *Surgery and Anesthesiology events.* Various pre-defined events recorded during a surgery, such as Induction, End of Intubation, Surgery Start, Incision, On-bypass, Off-bypass, Defibrillate, and so on (over 80 pre-defined events). The events records are entered into the system by a user (anesthesiologist);
- *Drugs and/or agents given to a patient.* A user can select from a pre-defined list of drugs commonly used during a typical anesthesia, or enter a substance of his/her choice. A user also enter an administered drug dose, also by either selecting the correct pre-defined amount or by typing in a number. The time is registered automatically;
- *I.V.'s and blood products.* A user can make a selection from a menu of blood products (fluids and crystalloid), specify Add/subtract function and enter the amount.

The Compurec system automatically calculate the total amount administered for each drug;

- *Monitor a drug infusion.* In the context of the Compurecord system an infusion is a drug solution that is administered intravenously at a precisely controlled rate, usually by an intravenous pump. A user can enter one parameter, either a flow rate, or a dosage of an administered drug, and the Compurec system will automatically calculate another parameter. The dosage is calculated in units per minute per kilogram of body weight. The rate is calculated in ml per hr. A user may enter the time when infusion start and when it ends;
- *Monitor output.* The CompuRecord System accepts information on what was poured off, when it was poured off, and how much was poured off. From this information the CompuRecord System calculates the amount of total outputs during the case.
- *Monitor vital signs.* The CompuRecord system accept data from monitors, which automatically measure many physiologic parameters, such as heart rate, blood pressure, respiratory rate and so on. A user may mark some data as being artifacts, if the readings from the monitors are affected by external factors, such as reading received after turning off an arterial line to remove a blood sample, or during cardiac bypass. Also, a user can invalidate some reading (i.e. during bypass stage of an operation).

Another part of a CompuRecord system is a query processing/report generating subsystem. After all the data for a case is recorded as a computer file a user can retrieve any information related to this particular case, or for all cases in a specific time interval in days.

A user may request all data for a case or stipulate what kind of information in particular he/she wants to obtain. This information may be delivered in form of a binary file or a collection of database tables.

3. DATA AND INFORMATION IN MEDICAL COMPUTER AND TELECOMMUNICATION SYSTEMS.

Medical network is unique in terms of information structure.

On the one hand, all members of network use basically same type of information and, contrary to the business environment, are willing to share the information. Many of Medical Information System has similar functions, users, goals and even subsystems.

On the other hand, since most of medical systems were created independently, they all bear unique data structure and format, architecture, access methods and so on. The implementation of a global medical network should start with the standardization of technical terms being used, and then continue to development of a common technical structures. Medical informatics as a field may be organized according to the objects that are processed and the tools that are used. For this purpose three classes of objects may be identified [21]:

- Data: These are the individual items made available to the analysts;
- Information: This is a set of data with some interpretation or value added;
- Knowledge: This is a set of rules, formulas, or heuristics used to create information from data and information.

The diagram representing the relationships between these three classes of objects is presented on Fig. 3.1.

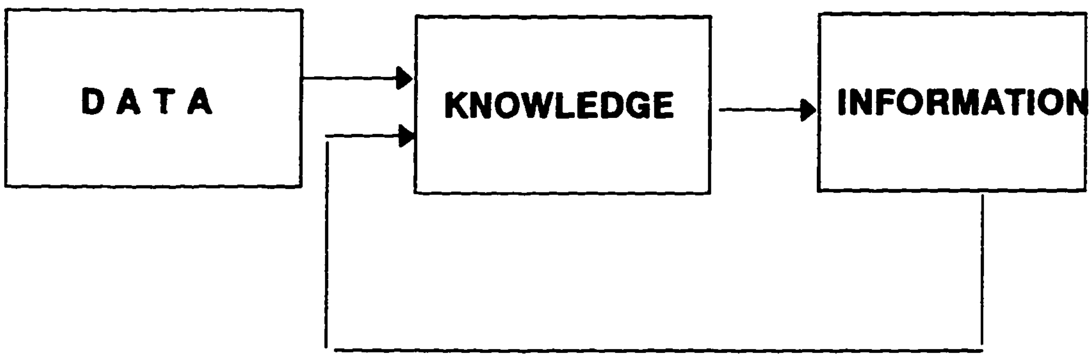

Fig. 3.1. Data, Information, Knowledge

As there were no universal approach in development of existing medical systems, few problems become immediately apparent. Thus, all systems utilize:

- different technological bases;
- different types of Medical Information Systems and databases;
- different structures of information records even in systems with databases of the same type;

The possible solution to the first problem is the development and utilization of the open platform by different vendors.

To incorporate different types of Medical Information Systems and databases into a global network, the development of such a universal medical network should be based on the utilization of standard identifiers commonly shared by all participants of a network. The Board of Directors of the American Medical Informatics Association in their Position Paper [22] proposed specific approaches to standardization in the areas of medical identifiers, message exchange, medical record content and codes.

In order for different types of databases to communicate with each other the informational interfaces should be developed. And the necessity to handle different information structures requires the utilization of intelligent networks architecture. An architecture of such a global network requires a special consideration as well.

3.1 CLASSIFICATION OF DATA UTILIZED IN MEDICAL AND HEALTH CARE SYSTEMS

Over the years practically all health - related institutions developed their own systems of classification and codification of data in use. Based mostly on common sense rather than on non-existed at that time standards, these classes and codes have, in fact much in common among different establishments across the wide specter of enterprises.

The most common classes of data, shared by almost all medical institutions and insurance companies are as follows:

Patient.

May be characterized by a patients unique identifier, his/her name, address, sex, age, medical history and current conditions in terms of symptoms, lab analyses, patient observation, diagnoses and treatments (drugs and procedures).

While the universally adopted form of Identifier is patient's Social Security Number (SSN), and name, address, sex and age are the commonplace data, the forms of formal and detailed description of medical data are not defined yet, and are the areas of very intensive research, which are discussed at length in the following paragraphs of this chapter of the dissertation.

Medical Provider.

The class of Medical Provider may be divided on subclasses of Hospitals, M.D., RN, Pharmacies, Ambulances, Labs, Special Services. The common characteristics of any provider are Id, License number, Address and Specialty. While being a common attribute for all of the subclasses of Medical Provider, such characteristics as Id and License number have specific formats and meanings for each individual subclass. In addition, each subclass of medical providers may have its own individual attributes.

For example, additional characteristics of hospitals , as described in Hospital Blue Book [62], may include hospital code, types of hospital facilities, codes for programs and approvals, types of special services, numbers for employees total number of beds,, number of beds for nursing home and rehabilitation programs, outpatient visits and so on. (Over 20 characteristics are used in the Hospital Blue Book). Attributes for the class of physician , as used in the Directory of Physicians [45], include Physician primary and secondary specialty, type of practice, American Specialty Board and so on. The medical lab class may have attributes equipment and certification. For the special services class attributes specialty and equipment may be added.

Site of Care

The Site of Care item is routinely included in many medical documents and insurance forms and is considered to be one of the required standard information in these types of documents [62]. Nevertheless practically all health care and insurance companies use their own classification and codification of this parameter.

Data Transmission

Several American Standards for Testing and Materials (ASST.) and other standards, such as those by Accredited Standards Committee, Institute of Electrical and Electronic Engineers (IEEE), and some other organizations, regulate the transmission of medical data within or between computer systems and computer-based instruments.

Some of these standards define a signal transmission on the instrumentation level, while some standards deal with the formats of medical knowledge bases and exchange of medical information.

Medical Data and Information Codes (Diagnoses, Symptoms, Drugs, Procedures, etc.).

Among the most commonly used codes for clinical data and information are the follows [62]:

- Drugs;
- Diagnoses;
- Symptoms and Findings;
- Anatomic sites;
- Microbes and etiologic agents;
- Clinical observations;
- Patient outcome variables and functional status;
- Medical devices;
- Units of measure;

- Diagnostic study results;
- Procedures.

Medical data have very complex structure with close resemblance to a natural language, where ambiguity is the commonplace. At the same time it is a centerpiece of a medical / health care telecommunication system. By these reasons the existing systems of medical codes require a detailed review which is presented in the following paragraph.

In addition to the above standard of just common systems of medical and health care codes, each health - related organization may introduce extra codes for any types and number of data it is using in its practice. For example, a small fraction of various codes in use at Empire Blue Cross and Blue Shield is listed below:

- ICD9
- Procedure Codes
- Provider Code
- Provider-Id
- Subscriber - Code
- Subscriber Id
- Patient-id
- Pricing-zip Codes
- Zone Codes
- Charge Codes
- Department Codes

- Submitter Codes
- Hospital Reject Codes
- Hospital Accommodation Codes
- Location Codes

This list is far from being complete or even extensive. For example, just the Customer Service subsystem alone required a codes dictionary, which contained 14 inquiry-related codes.

3.2 REVIEW OF EXISTING MEDICAL CODES

3.2.1. GENERAL MEDICAL CODING SCHEMES

International Classification of Diseases (ICD)

The archetypal coding system for medical record abstraction is the International Classification of Diseases (ICD). Other major coding schemes are usually presented in terms of their compatibility with ICD and their ability to resolve some of ICD's problems with granularity of coverage of a particular domain. ICD was first published in 1893. It has been revised at roughly 10-year intervals, first by the Statistical International Institute and later by the World Health Organization (WHO). The Ninth Edition (ICD-9) was published in 1977, and the Tenth Edition (ICD-10) in 1992 [65]. The coding system consists of a "core" classification of three - digit codes which are the minimum required for reporting mortality statistics to WHO. A fourth digit (in the first decimal place) provides an additional level of detail; usually .0 to .7 are used for more specific forms of the core term, .8 is usually used for an "other" category and .9 for "unspecified". Terms are arranged in a strict hierarchy, based on the digits in the code.

While ICD proper is limited to disease terminology, WHO also provides a set of expansions for different "families" of terms for medical specialty diagnoses, health status, disablements, procedures and reasons for contact with health care providers.

There were some concerns regarding inadequacy of ICD-9 for general coding and specific specialty coverage [32]. In order to address these and other perceived problems with ICD-9, the United States National Center for Health Statistics published a set of "clinical modifications" to ICD-9, known as ICD-9-CM [65]. While completely compatible with ICD-9, the additions provided an additional level of detail in many places by adding a fifth digit to the code, corresponding to another level in the hierarchy.

Diagnostic-Related Groups (DRGs)

Diagnostic-Related Groups (DRGs) were developed initially at Yale University for use in prospective payments in the Medicare program [99]. The DRG coding system is applied to lists of ICD-9-CM codes which are themselves derived from medical records. The purpose of DRG coding is to provide a relatively small number of codes for classifying patient hospitalization while at the same time providing some separation of cases based on the severity of illness. The principal motivation for the grouping are factors which affect cost and length of stay.

International Classification of Primary Care (ICPC)

Created under auspices of the World Organization of National Colleges, Academies and Academic Associations of General Practitioners / Family {physicians (WONCA), ICPC provides seven axes of terms and a structure to combine them to represent clinical encounters. While the granularity of the terms is generally less than that of other classification schemes (e.g. all pneumonias are coded as R81), the ability to represent the interactions of the concepts found in a medical record is much greater through the postcoordination of atomic terms [32]. In postcoordination, the coding is accomplished through the use of multiple codes as needed to describe the data. So, for example, a case of bacterial pneumonia would be coded in ICPC as a combination of the code R81 and the code for the particular test result which identifies the causative agent. This is in contrast to the precoordination approach, in which every type of pneumonia is assigned its own code.

Medical Subject Headings (MeSH).

Maintained by the US National Library of Medicine (NLM), Medical Subject Headings (MeSH) is the vocabulary by which the world medical literature is indexed. MeSH arranges terms in a structure that breaks from the strict hierarchy used by most other coding schemes. Terms are organized into hierarchies and may appear in multiple places in the hierarchy. Although it is not generally used as a direct coding scheme for patient information, it plays a central role in the Unified Medical Language System.

3.2.2. SPECIALTY CODING SCHEMES

Professional specialty groups find that general coding schemes are of little use for their purposes and often resort to developing their own coding schemes for medical record abstraction.

Examples of such specialty codes are listed below.

Current Procedural Terminology (CPT)

The American Medical Association developed the Current Procedural Terminology (CPT) in 1966 [7] to provide a precoordinated coding scheme for diagnostic and therapeutic procedures which has since been adopted in the US for billing and reimbursement. Like the DRG codes, CPT codes specify information about the codes which differentiates them based on their cost. For example, there are different codes for pacemaker insertions, depending on method [32].

American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM).

The Reversed Third Edition (DSM-III-R) of this coding scheme was published in 1987 [8]. Publication of the Fourth Edition (DSM-IV) has been coordinated with the development of psychiatric diagnoses in ICD-10 [8 , 65]. The DSM nomenclature provides definitions of the disorders including diagnostic criteria. Thus it is used not only for coding patient data but as a tool for actually assigning diagnoses. Each edition of DSM has been coordinated with corresponding editions of ICD. Compatibility between

ICD-9 and DSM-III-R was found to be reasonably good; a number of studies have shown that compatibility between ICD-10 and DSM-IV is variable across its different sections.

Standard Nomenclature of Pathology (SNOP)

The College of American Pathologist developed Standard Nomenclature of Pathology (SNOP) based on the New York Academy of Medicine's Standard Nomenclature of Diseases and Operations (SNDO) [22]. SNOP is a multiaxial system for describing pathologic findings through postcoordination of topographic (anatomic), morphologic, etiologic and functional terms. SNOP has been used widely in pathology systems in the US; its successor is the comprehensive coding system the Systematized Nomenclature of Medicine (SNOMED).

3.2.3 ELECTRONIC MEDICAL RECORD (EMR) SYSTEMS

The primary functions of the abstract medical coding systems are to provide health statistics reporting and health insurance reimbursement. A significantly more challenging task is the coding of data in a record in a way that retains sufficient detail for a care provider to use it directly in patient care [32]. Coding of detailed data must consider the additional uses for the data, such as case review, summary review, decision support, research, quality assurance and, of course, reporting of mortality and morbidity.

Electronic medical record (EMR) systems typically have the greatest vocabulary requirements, assuming that the data in the record are to be encoded. In general, developers of health care applications have difficulty using existing coding systems.

The Medical Record (TMR)

The developers of TMR (The Medical Record) at Duke University have explicitly rejected standard vocabularies as inappropriate for use in an EMR [124] . They, and others, have resorted to developing their own controlled vocabularies. In some cases, they are created in an ad hoc manner, adding coded terms as needed. In other cases, developers have applied a deliberate methodology to vocabulary development.

The HELP System

One of the most comprehensive EMRs is the HELP System in use at the LDS Hospital in Salt Lake City, Utah [105]. The data in HELP are drawn from most of the hospital departments, cover a wide range of functional types, and are used for a variety of purposes. Almost all of the data in HELP are encoded with the PTXT data dictionary. This dictionary is structured as a strict hierarchy with each term having an eight-byte code in which the first three bytes specify general information about the type of data being stored and the last five define the term's position in the PTXT hierarchy. The system is now commercially available and the PTXT vocabulary is common across the various HELP installations. However, PTXT has not been implemented in any other EMRs [32]. Furthermore, while PTXT is used successfully by the on-line decision support capabilities of the HELP system, it has proved difficult to use for a diagnostic expert system developed by the same research group [139].

Computer-Stored Ambulatory Record (COSTAR).

This system, developed at the Massachusetts General Hospital [15], also makes extensive use of a formal controlled vocabulary called the Directory. COSTAR Directory is a medical coding system specially developed for this project. Like PTXT, the COSTAR Directory is a strict hierarchy with a coding system (in this case, three alpha - numeric digits, plus a check digit and optional modifiers) which provides terms for coding a wide range of information in the record. COSTAR is available from commercial vendors, but can also be obtained in a public domain form that is available from the COSTAR Users Group. A standard Directory is supplied with the software; however, it only specifies the uppermost levels in the hierarchy. It is left to each installation site to flesh out the hierarchy with specific terms for their own institution. There has been no attempts to standardize these individual development efforts [32].

The Regenstrief Medical Record System (RMRS)

The Regenstrief Medical Record System (RMRS) at the University of Indiana [85] also uses a coded vocabulary for representing a portion of its data. This particular vocabulary construction task was complicated by the need to coordinate terminologies from four different hospitals. Despite the effort expended to make RMRS inter - institutional, it remains institution - dependent and has not been adopted for use in other systems.

So far, all described medical coding systems were not able to satisfy the requirements of Electronic Medical records which could be widely used in a clinical practice. There is one exception, though. This system was developed outside of US, and can not be directly utilized in this country. Nevertheless the results achieved are so impressive, that the systems deserved the status of a case study.

ELIAS System

Developed at Erasmus University in Rotterdam and now in use in a majority of private practitioners' offices in the Netherlands, the Elias system makes use of the ICPC for coding diagnoses and reasons for encounters [132]. An extensive project was undertaken to translate ICPC to Dutch and to match the ICPC codes with the terms entered by users of the ELIAS system [46]. This project resulted in a greatly enhanced version of ICPC, with a significant addition of index terms and synonyms. Evaluations thus far have shown relatively good general acceptance [32].

The Medical Entities Dictionary (MED)

The Medical Entities Dictionary (MED) used in the Columbia - Presbyterian clinical information system is based on a semantic network model. This vocabulary integrates terms from national coding schemes with those from local ancillary systems to produce a unified coding scheme that retains the fine granularity from the original coding schemes while accommodating the coarser granularity of a variety of applications making use of the patient data [32]. The semantic network model is useful both for supporting the addition of new terms from ancillary system and for maintaining currency with changes in the national vocabularies.

3.2.4. THE CURRENT DEVELOPMENTS OF MEDICAL CODING SYSTEMS

The developers of each EMR have dealt with controlled vocabulary in a unique way. The results have been generally satisfactory for supporting the needs at each site; however, the ability to share the coding scheme for use at other sites has been limited, when it occurs at all. The implication is that other developers may enjoy the same successes but they will be required to start all efforts over. With several decades of experience in computer - based vocabulary requirements, researches are now beginning to collaborate to apply their individual experience to the task of developing general purpose, comprehensive controlled vocabularies to support health care applications.

The Systematized Nomenclature of Human and Veterinary Medicine (SNOMED)

The Systematized Nomenclature of Medicine (SNOMED) was developed by the College of American Pathologists. First version was published in 1975, and then revised as SNOMED II in 1979. It has recently been released in a greatly expanded version: the Systematized Nomenclature of Human and Veterinary Medicine (SNOMED International) [22]. SNOMED consists of a set of axes (now eleven), each of which serve as a taxonomy for a specific set of concepts (organisms, diseases, procedures, etc.), containing a total of over 130,000 terms. Coding patient information is accomplished through the postcoordination of terms from multiple axes to represent complex terms, which may be desired but do not exist n SNOMED.

The main problem with using SNOMED for coding patient information is that it is too expressive. Because there are few rules about how the postcoordination coding should be done, the same expression might be represented differently by different codes.

3.3 THE STANDARDS PROPOSED BY AMERICAN MEDICAL INFORMATICS ASSOCIATION

One of the major obstacles in developing global medical networks is the lack of standards that would permit government, care provides, insurance companies, and medical computer systems developers to share patient data easily.

Addressing these needs, the Board of Directors of the American Medical Informatics Association recommends the following specific approaches to standardization in the areas of medical identifiers, message exchange. medical record content, and codes.

Patient Identifier

The Social Security Number (SSN) is recommended as a universal patient identifier. In fact, this is de-facto patient identifier used by practically all medical institutions, insurance companies, and any other organization dealing with patients. Nevertheless this approach have some deficiencies. First, SSN are not currently assigned to infants and some non-citizens. Second, some patients have multiple SSNs, while some SSNs are used by multiple patients. The AMIA Board of Directors proposes the following answer to these criticisms. The procedure for assigning SSNs can be changed to accommodate infants (currently children are supposed to obtain their SSN by the age of one year) and non-US citizens, and temporary numbers (John Doe numbers) could be assigned to deal with emergencies. Multiple - number problem may exist for any system providing unique identification numbers for such a huge set as an entire population of the US. Therefore any method that can be applied to increase the non - ambiguity of any newly constructed identifier could be applied to the SSN as well.

Overall, the overriding advantage of the SSN, as an existing and widely used identification system, is that any entirely new alternative would take much more time (three to ten years) and increase costs. In addition, the AMIA recommends the addition of a self-check digit to the SSN to reduce errors of identification whenever the number is hand - entered by and operator.

Physicians

Those physicians who accept Medicare patients are assigned an Universal Physician Identifier Number (IPIN) by the Health Care Financing Administration. This number can be extended to all physicians, as it is already being supported by a government agency and its development costs have already been absorbed [22]. An alternative for HCFA-assigned physician code is the prescribers' code being developed by the National Council of Prescription Drug Programs, Inc. (NCPDP) in collaboration with American Medical Association. Another common characteristics of Physicians, such as Physician primary and secondary specialty, type of practice, American Specialty Board and so on, can be found in the Directory of Physicians [45].

Site of Care

The Board of Directors of the American Medical Informatics Association considers two alternatives to assigning a standard identifier to a site of care [22]. The first alternative is to use identifiers assigned by the Health Industry Business Communications Council's (HIBCC's) and corresponding to the address of a particular institution or office at a particular site. Another alternative is to expand Medicare site identification to all participating health care providers. This can be done together with the expansion of Universal Physician Identifier Number.

Data Transmission

Several American Standards for Testing and Materials (ASST.) and other standards regulate the transmission of medical data within or between computer systems and computer-based instruments.

On the instrumentation level there are such standards as:

- ASST. E1394 Clinical Laboratory Instruments to Computers. This standard, developed by a consortium consisting of most US manufactures of clinical laboratory instruments, is being implemented in the current generation of laboratory instruments for communication of information from laboratory instruments to computer systems.

- Institute of Electrical and Electronic Engineers, Inc. (IEEE) P1073 Medical Information Bus (MIB), for Control of and Linking with Critical Care Instruments. This standard is exploited for communication and control of critical care instruments.
- American College of Radiology (ACR) / National Electrical Manufactures Association (NEMA) Imaging Standards, ACR-NEMA Standards Publications. This standard is used for the transmission of radiological images and for message transmissions within radiology Picture Archiving and Communication Systems (PACS).

The following standards define the transmission of information between medical and health care computer systems:

- ASST. E1467 Standard Specification for Transferring Digital Neurophysiological Data between Independent Computer Systems. It defines codes and structures needed to transmit the signals and results produced by electroencephalograms (EEG) and electromyograms (EMG). It is being adopted by most of the EEG and EMG systems manufactures.
- Accredited Standards Committee (ASC) X12 Billing and Insurance Transmission. Within ASC X12 several message standards are defined, such as X12 834 Benefit Enrollment Transactions, X12 835 Health Care Payment Transactions, and X12 837 Health Care Claim Transactions. These standards are used for billing and insurance transactions between a health care provider and a third-party payer.

- National Council of Prescription Drug Program (NCPDP) Telecommunications Standard Format for Transmission of Community Pharmacy Information. This standard was developed in 1985 and is being used by almost 90% of the community pharmacies in the United States for 60% of the prescription volume. NCPDP is used for communication of prescription billing information and eligibility information between the community pharmacies and third-party payers.

Medical Information / Knowledge Bases

- ASST. E1238 Clinical Data Interchange Standard, which is being used by most of the largest commercial laboratory vendors in the United States to transmit laboratory results. It is also used by many public health departments to transmit patient data required for health statistics and by pharmaceutical manufactures to transmit clinical trial data. It may be used for most interchanges of clinical data between institutions.
- ASST. E1460 (Arden Syntax) Standard Specification for Defining and Sharing Modular Health Knowledge Bases. Arden syntax provides a standard format and syntax for representing medical logic for writing reminder rules and guidelines that can be automatically executed by computer systems.
- Health Level 7 (HL7). Being a practical superset of ASST. E1238, this standard defines the format of messages used for transmission of orders, clinical observations, and clinical data (including test results): admission, transfer, and discharge records; and charge and billing information.

Medical Data and Information Codes (Diagnoses, Symptoms, Drugs, Procedures, etc.).

American Medical Informatics Association proposes the following subject domains where codifications are needed:

- Drugs;
- Diagnoses;
- Symptoms and Findings;
- Anatomic sites;
- Microbes and etiologic agents;
- Clinical observations;
- Patient outcome variables and functional status;
- Medical devices;
- Units of measure;
- Diagnostic study results;
- Procedures.

3.4 THE STANDARDS FOR MEDICAL TELECOMMUNICATION SYSTEMS

Health Level Seven

The *Health Level Seven* (HL7) is a telecommunications standard protocol, developed specifically to address demands and requirements of a particular group of users in medical and health care. This is an application protocol for electronic data exchange n health care environment. The primary goal of the standard s to provide for the exchange of data among health care computer applications. This eliminates or substantially reduces the custom interface programming and program maintenance that are required. The HL7 standard defines the messages as they are exchanged among application entities and the protocols used to exchange them.

The Health Level Seven organization [11] was initiated by groups of interested users, system providers and consultants in the US to standardize health care information interchange. HL7 is being used in more than 150 US health care institutions, including most leading university hospitals. It is being used in Japan, Germany, Sweden and Holland, and has been adopted by Australia and New Zealand as their national standards. It is also supported by most of the large health care system vendors. [22].

The scope of the HL7 work has grown over the years starting by defining messages that address basic admission, transfer, and discharge functions. At the current moment it also includes other types of messages, such as billing between hospitals and insurance companies, synchronization of database master files, observation reporting, and management of pharmacy orders. Fig. 3.2 represent currently available HL7 messages. As the name implies, HL7 alludes to an OSI layer seven application protocol.

The Open Systems Interconnection (OSI) reference model, adopted by the International Organization for Standardization (ISO) in 1984, is a framework for defining standards for linking heterogeneous computers. The OSI model provides the basis for connecting "open" systems for distributed applications processing. The term "open" denotes the ability of any two system conforming to the reference model and the associated standards to connect.

A widely accepted structuring technique, and the one chosen for ISO for OSI, is layering. The communication functions are partitioned into a vertical set of layers. Each layer performs a related subset of the functions required to communicate with another system. It relies on the next lower layer to perform more primitive functions and to conceal the details of those functions. It provides services to the next higher layer. Ideally, the layers should be defined so that changes in one layer do not require changes in the other layers.

Admission

Discharge

Transfer

Order Entry

Result Reporting

Queries

Finance

Patient Accounting

Pharmacy Orders

Master File Updates

Fig. 3.2

Health Level 7 Messages

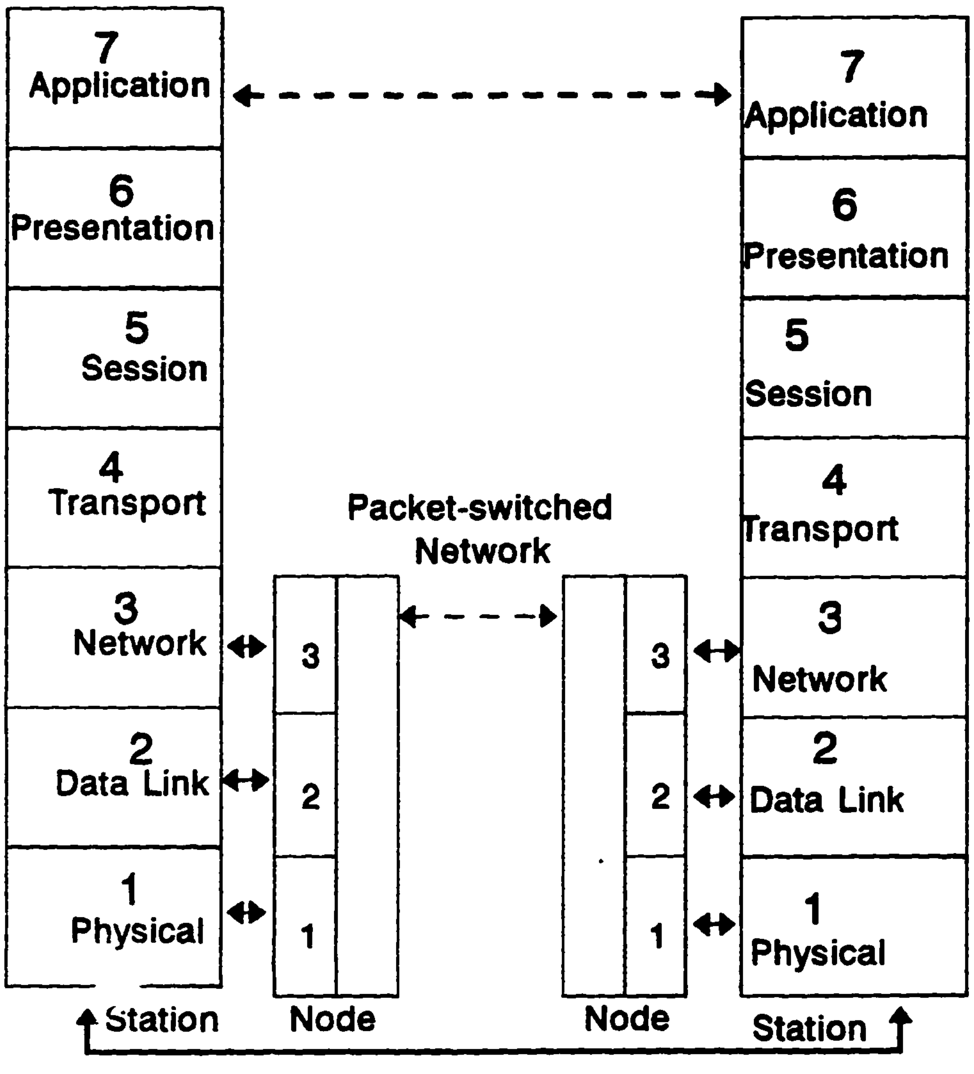

Fig. 3.3

Open Systems Interconnection (OSI)

The OSI reference model has seven layers, which are listed below with a brief definition:

1. Physical — Concerned with transmission of unstructured bit stream over physical medium;
   Deals with the mechanical, electrical, functional and procedural characteristics to access the physical medium.

2. Data Link — Provides for the reliable transfer of information across the physical link;
   Sends blocks of data (frames) with the necessary synchronization, error control, and flow control.

3. Network — Provides upper layers with independence from the data transmission and switching technologies used to connect systems;
   Responsible for establishing, maintaining and terminating connections.

4. Transport — Provides reliable, transparent transfer of data between end points;
   Provides end-to-end error recovery and flow control.

5. Session — Provides the control structure for communication between applications;

Establishes, manages and terminates connections (sessions) between cooperating applications.

6. Presentation Provides independence to the application processes from differences in data representation (syntax)

7. Application Provides access to the OSI environment for users and also provides distributed information services.

The architecture of OSI is presented on Figure 3.3.

Besides level - 7 *application* protocol, HL7 also specifies a layer six - *presentation* protocol made up of its own abstract message format and encoding rules. As far as lower level layers concerned, especially *session* and *transport* services, HL7 is not very descriptive. Therefore HL7 may be implemented over any number of possible protocol stacks (Fig. 3.4).

For example, HL7 can be used in a conversational mode (similar to remote procedure calls) as well as in a store and forward mode, as in electronic mail or batch file transfers. At the application level HL7 defines the following messages that deal with the following aspects of computerized health care:

- Admission, Discharge and Transfer;
- Order Entry, Result Reporting (generic and specific);
- Queries;

- Finance, Patient Accounting;
- Master File Updates;

The underlying HL7 operational model is that of a client - server system. HL7 distinguishes between two message exchange scenarios, such as Trigger Events and Unsolicited Messages (where activity at one system triggers a message to other systems) and Queries, which may occur, for example, when an application lacks the data it needs to continue processing.

HL7 messages are the atomic units of data exchanged between the communicating systems. A message is made up of a number of segments, that group related data fields together. The first segment is always the message header segment, which identifies the type of the message and contains a unique message identifier. Subsequent segments are specific to the message type. Segments consist of typed message fields, which in turn may be split into subfields. Some message segments may be optional or used alternatively, whereas some segments may appear more that once in a message (Fig. 3.5) .

According to the OSI model, the HL7 Standard simply defines the data elements that are exchanged as abstract messages, and does not lay down the exact bit stream representation of the messages that flow over the network. Lower level network software developed according to the OSI model may be used to encode and decode the actual bit stream. However, the ISO protocols are not universally implemented.

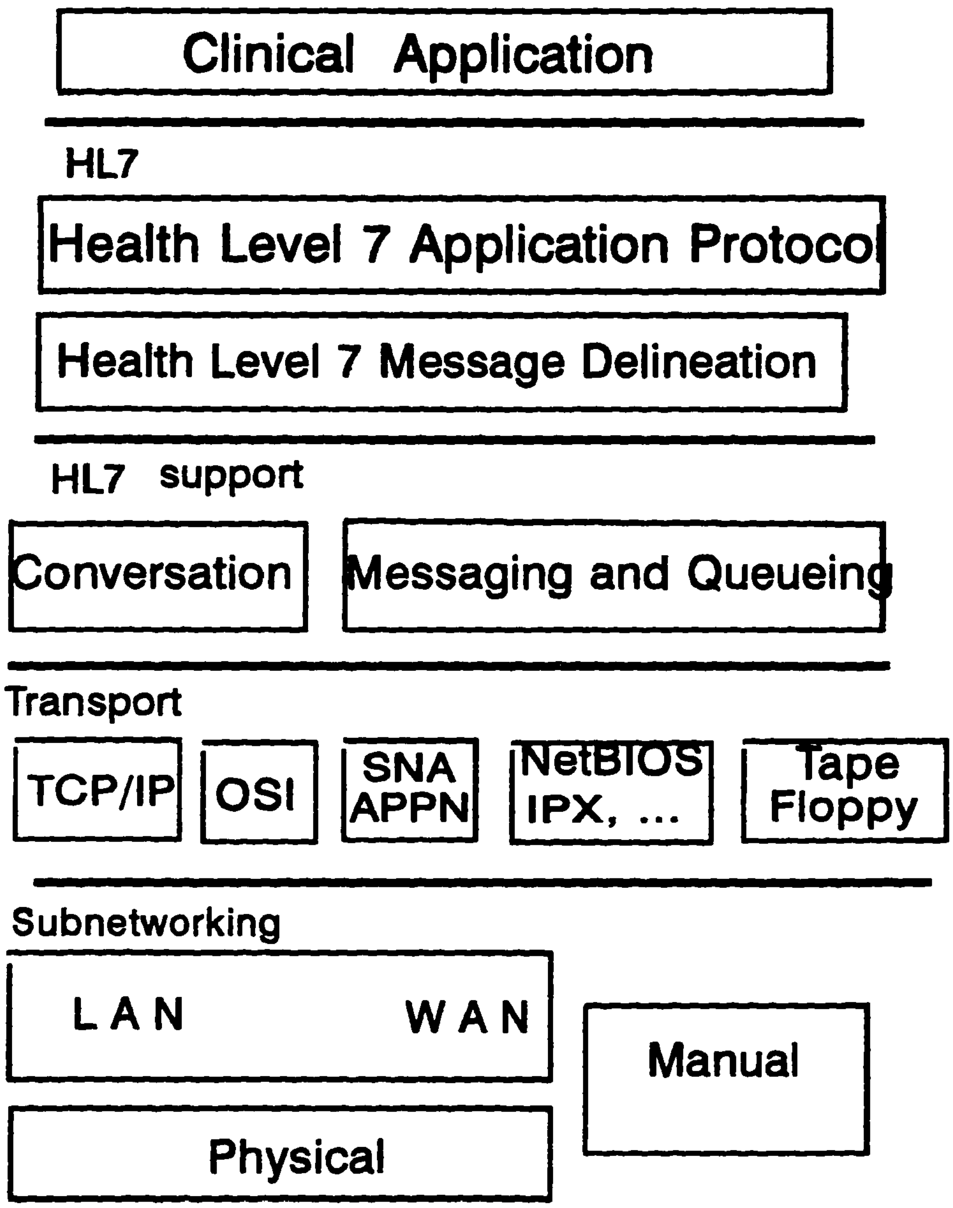

Fig. 3.4 Health Level 7 Protocol Stack

To facilitate the use of HL7, a set of encoding rules for defining the exact representation of a message is also specified. To make use of these encoding rules, application programmers have to directly encode and decode HL7 messages that are constructed using the HL7 encoding rules.

The Workgroup for Electronic Data Interchange

The initial role of the Workgroup for Electronic Data Interchange (WEDI), created in 1991, was to examine the state of health care EDI and make recommendations for increased automation. After completing this mission, the group defined its future role. The primary mission of WEDI is to encourage uniform implementation of standard electronic health care transactions [11]. For example, WEDI will endorse specific implementation guides. Although the workgroup has developed implementation guides for several financial transactions, it may pass that responsibility to the American National Standards Institute's ASC X12N Committee.

WEDI also will monitor the work of standards organizations to ensure that they are not duplicating each others' effort or developing standard transactions that conflict with other transactions.

The organization intends to be a consensus - building group that all segments of the health care community can use to resolve problems. WEDI's four technical advisory groups will monitor automation activities, educational programs, implementation guides and legal issues.

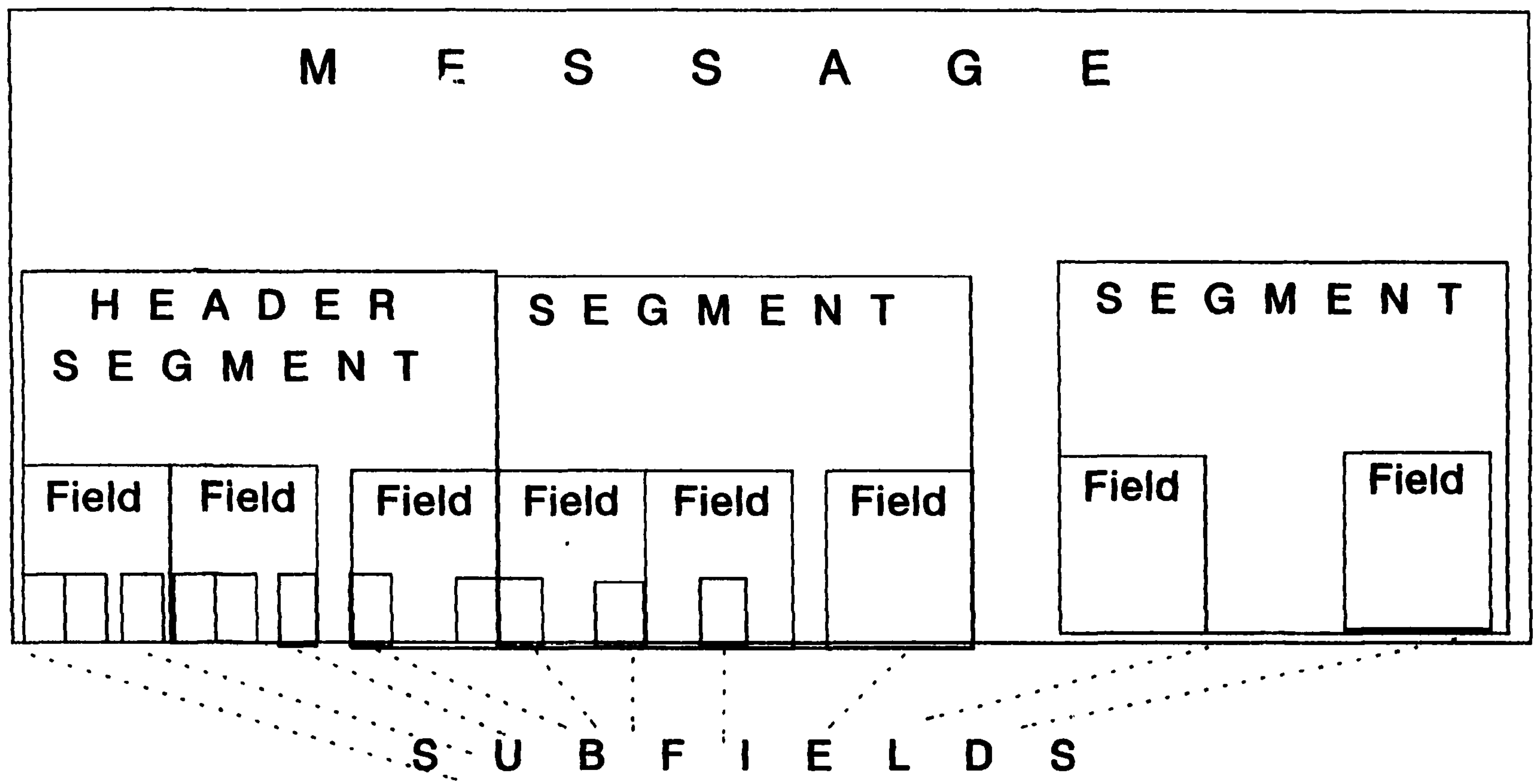

Fig. 3.5 HL7 Message Structure

The board includes representatives from various groups, such as Consumers (National Association of Claims Assistance Professionals, American Association of Retired Persons), Government (Health Care Financing Administration and others), Providers (American Dental Association, American Health Information Management Association, American Hospital Association, American Medical Association, Mayo Clinic, Medical Group Management Association), Payers (Blue Cross and Blue Shield Association, Health Insurance Association of America, Aetna, CIGNA, Mutual of Omaha and Self-Insurance Institute of America), Provider/payers (Group Health Association of America, Kaiser Permanente, United HealthCare Corp.), Standard-settings groups (American National Standards Institute's ASC X12N Committee, Health Care Informatics Standards Planing Panel), Vendors (Association for Electronic Health Care Transactions, National Electronic Information Corp.)

3.5 THE SELECTION OF BASE MEDICAL CODING SYSTEMS FOR INTELLIGENT MEDICAL NETWORK

The development of a universal medical network should be based on the utilization of standard identifiers commonly shared by all participants of a network. The Board of Directors of the American Medical Informatics Association in their Position Paper [22] proposed specific approaches to standardization in the areas of medical identifiers, message exchange, medical record content and codes.

Diagnostic codes: The universally accepted by US hospitals and insurance companies, diagnostic codes are published in "International Classification of Diseases and Related Health Problems", the tenth revision of which came into use in 1993 [65]. The classification has three digit diagnostic codes with 1 or 2-digit optional subcodes. All possible 999 codes are utilized within system, and are broken down by 17 categories.

Procedure Codes: Two supplementary classifications for medical procedures are included in ICD-9-CM:

- A V-supplementary classification of procedures, where each procedure may be identified by a two position code with 2 - position subcodes. So far 82 codes are utilized (V01 through V82);
- An E-supplementary classification of external causes of injury and poisoning (codes E800 through E999).

Drugs Codes: There are about 3000 drugs included into official Physicians Desk Reference [99]. Each drug is provided with its unique NDC Identification Number. The format of NDC ID number is 5-digit code, 3-digit subcode and 2-digit dosage/packaging size code. Therefore the full identification number for drugs is 10 digits long. This is enough to identify 10 billion of unique drug units.

ICD-9-CM

1.	Infectious and parasitic diseases	001 - 139
2.	Neoplasms	140 - 239
3.	Endocrine, nutritional and metabolic diseases and immunity disorders	240 - 279
4.	Diseases of the blood and Blood-forming organs	280 - 289
5.	Mental disorders	290 - 319
6.	Diseases of the nervous System and sense organs	320 - 389
7.	Diseases of the circulatory system	390 - 459
8.	Diseases of the respiratory system	460 - 519
9.	Diseases of the digestive System	520 - 579
10.	Diseases of the genitourinary system	580 - 629

11.	Complications of pregnancy, childbirth and the puerperium	630 - 679
12.	Diseases of the skin and subcutaneous tissue	680 - 709
13.	Diseases of the musculoskeleted system and connective tissue	710 - 739
14.	Congenial abnormalities	740 - 759
15.	Certain conditions originating in the prenatal period	760 - 779
16.	Symptoms, signs and ill - defined conditions	780 - 797
17.	Injury and poisoning	800 - 999

4. ANALYSIS OF QUERIES PROCESSING IN INTELLIGENT MEDICAL NETWORK

4.1 TYPES OF QUERIES PROCESSED BY INTELLIGENT MEDICAL NETWORK

An application-oriented intelligent network is supposed to provide a number of services pertinent for the specific application. Services provided by a telecommunication system may be defined in terms of types of requests this particular network is able to handle. In a specific case of intelligent Medical / Health Care telecommunication system, the following types of requests may be supported:

- patient's history;
- patient's condition telemonitoring;
- automatic diagnostics;
- epidemiological studies;
- expert - assisted diagnostics;
- insurance transactions;
    - membership;
    - billing / payment;

In addition, the following functions may be provided within any knowledge-based network:

- tutoring;
- direct information retrieval;
- References;
- thesaurus;
- knowledge base maintenance;
- administrative;
    - financial;
    - membership;
    - authorization.

Each type of function and associated with this function requests require specific class of the knowledge base in medical knowledge-based network. Some of the required knowledge bases may be already developed and exist within medical information systems of participating hospitals, medical centers, insurance companies, and other potential members of medical network. Examples of such knowledge bases are patients records, billing and payment records, ICD-9-CM, etc. Certain knowledge bases required to process all specified requests has yet to be developed. Universal Codes of Medical Equipment is a good example of the required knowledge base which has to be added to the network. Other types of knowledge bases, such as internal service KBs, should be developed and maintained by network personnel specifically for use within network. They may be accessed exclusively by functional modules of the intelligent network and represent private and protected information. This information includes administrative data (financial, membership, security, etc.).

Which of the aforementioned KB's are external, and which are used and maintained internally is somewhat arbitrarily. It may be economically feasible to provide general knowledge reference and thesaurus data by the network itself, rather than locate the right destination and transfer the request of this type to the appropriate member. Therefore the network may create and maintain the internal reference/thesaurus knowledge base. Yet another possibility is that the request may not be automatically processed and answered by any existing knowledge base (internal or external) within the network. In this case the function of the medical network may be to locate a human expert capable of handling the required type of request. The expert should be located according to specific criteria which may include such parameters as expert's specialization, level of knowledge, locality and so on.

The function of knowledge module of intelligent network in this case is to identify the location of the required knowledge. or an expert. The knowledge module does not discriminate between a computer-based knowledge base or a human expert. Its function is to determine the right location (address) of a network member, having a specific knowledge, and to transfer a request to this location. The function of the Intelligent Peripherals is to translate the universal format of the requests within the network into specific format of medical information system / databases utilized by the member of network, or to present a query in a user-friendly GUI format to a human expert.

The network should be designed as an open-end system, and therefore is not limited to processing of the aforementioned types of requests. It should be capable to expand itself both in terms of adding new members of the network and adding new types of requests.

4.2 TRANSMITTING A QUERY IN A KNOWLEDGE-BASED INTELLIGENT NETWORK

Scenario

The request processing in an intelligent network originates when a customer enters an inquiry in the network with a help of an intelligent peripheral.

The user's request is accepted by an Intelligent Peripheral (IP) of the network, which validates and edits the request. This stage may require several iterations of a human (customer) and artificial (IP) intelligence interaction. After the request is recognized and approved by the IP, it is transferred to the Knowledge Module (KM) via Communication (CM) and Switching (SM) Modules. When a request is accepted by the KM, the request's type is identified. This task may be performed by one of the FM of the KM. Then the functional module (FM) for the specific type of request is selected, and this may be done by another FM. Yet another FM will generate the formal request in accordance with the selected FM syntax. In a distributive environment the request is transmitted to the appropriate application FM using CM and SM again. The ultimate role of FM is to resolve each request it receives. Upon receiving the request by a FM, it has to be identified, resolved and the result has to be send back to the sender of the request.

There are the following stages in the processing of each request by the FM:

- Request identification;
- Request resolution;
- Response formatting.

Each stage during its execution refers to a corresponding Knowledge Base (KB) for the appropriate information. In order to correctly identify the request, the internal KB's of the requests are accessed. These KB's contain information pertinent to each type of request, which identify, among other things, the next processor of the request, i.e. related FM and KB.

On the first step of request identification (Request type identification by KM) the particular FM is identified by referring the particular KB which contains request's type.

On the second step of request identification (Request identification by FM) either the internal KB, or external KB of one of the member of the network, which contains the required information, are identified, using KB of request.

On the request resolution stage the request is processed by accessing the particular KB which was identified on the previous step. The response formatting may be performed by ether IP for the external request resolution, or by FM for the internal KB processing.

Scenario 1
Transmitting a Query in a Knowledge-Based Network

Caller | **IP** | **SSP/SCP** | **KM**

Enter Query
------------------------------->

Edit/Validate
<-------------------------------

Re-Enter Query
--------------------------------->

Format & Transfer Query
---------------------------->
Over Data Channel

Detect Call

Store Caller Address

Transfer Query
------------------------------>
Over Data Channel

Fig. 4.1

Scenario 2a
Internal Query Resolution by Knowledge Module

Caller **IP** **SSP/SCP** **KM**

Locate Functional Block
Reformat Query

Transfer Location
<--------------------------------
Over Signaling Channel

Send Query to Functional Block
---------------------------------->
Over Data Channel

Locate Knowledge Base
Create SubQuery

Transfer Location
<--------------------------------
ver Signaling Channel

Send SubQuery to Knowledge Base
--------------------------------->
Over Data Channel

Resolve Query

Send Answer
<--
Over Data Channel

Fig. 4.2

Scenario 2a
Internal Query Resolution by Knowledge Module

Continued

Caller	IP	SSP/SCP	KM
		Detect Call	
		Find Caller Address	
		Transfer Answer	
	<-------------------------------		
		Over Data Channel	
	Format Answer Present Answer to User		
<-------------------------------			

Fig. 4.2a

Scenario 2b
Resolving a Query calling an External Expert

Caller **IP** **SSP/SCP** **KM** **External Expert**

Search for expert

Transfer Expert's Location
or "No Answer"

<------------------------------

Over Signaling Channel

Send Query

--->

Over Data Channel

Resolve Query
Send Answer

<--

Over Data Channel

Detect Call

Find Caller Address

Transfer Answer

<------------------------

Over Data Channel

Format Answer
Present Answer to Use

<------------------------

Fig. 4.3

Therefore a number of different KB's should be accessed during each request processing by the network. Some of this KB's may be quite remote from the KM and participant FM and linked to them via a high speed network. Therefore the communications between FMs and KBs are performed by creating and executing multiple internal requests by the network.

The scenarios of transmitting a query in a Knowledge-Based Network are presented on Figs. 4.1 - 4.3. The corresponding flowchart of query processing in presented on Fig. 4.4. It represents all stages of the request processing and demonstrates the similar and repetitive actions on each stage.

Analysis of Communication Algorithm

It follows from the analysis of the Fig 4.4, that we can represent the processing of a typical request by the KM in the network in the form of generic algorithm. When request is accepted by KM it has been recognized and identified. This is a two step process:

- First, the request type is recognized by KM, utilizing the request type KB; then a corresponding FM is selected;
- After the request is received by a corresponding FM, this FM distinguish the request and selects the appropriate KB to resolve the request.

On both steps the reference to a relevant KB is made. As this may be a remote KB, the reference may be made via Communication/Switching Modules. It means that FM should generate the new internal request, which will be processed by the network the same way as any other request. Similarly, on the stage of request resolution the correct location of a network node capable to answer the request has to be identified. This is done by addressing the locations knowledge base. The locations knowledge contains the address of a network node which is able to resolve the request. Sometimes it may be a multi-step process with a number of de-referencing. Then the request is sent to this newly found address to be resolved there, and answer is sent back to the FM. All this operations of communicating with remote KBs and network nodes also involve creating new internal requests and processing it by the network.

On the last stage of response formatting and returning back, the response formats KB is utilized. Once again, the same procedure of creating and processing internal requests is executed. As a result, we have a generic algorithm, where all requests are resolved by utilization of a universal procedure of generating and resolving detailed local inquiries on each step of a global request processing/resolution. This schema of request processing in an intelligent network is presented on Fig 4.5.

The top level is responsible for user's interface. The primary function of this layer is to accept a user's request and to identify its type. This task may require generating of an internal request and sending it to a CM / SM. This task can be delegated to one of the FM. It is an application independent task and it will by performed by a service FM. The next level will identify the functional module for the specific request or the need for a human expert. This task may also be performed by a service FM. The third level would generate the internal formal request in accordance with the selected functional module syntax and convert it into a packet format. This is also a function of one of the service FM.

The request is transmitted to the appropriate application functional module via the Communication / Switching module. After the request is received by an application functional module, it has to be identified, resolved and the result has to be send back. It means, that in order to accomplish its role, an application FM has to call service FM to perform specific subtasks.

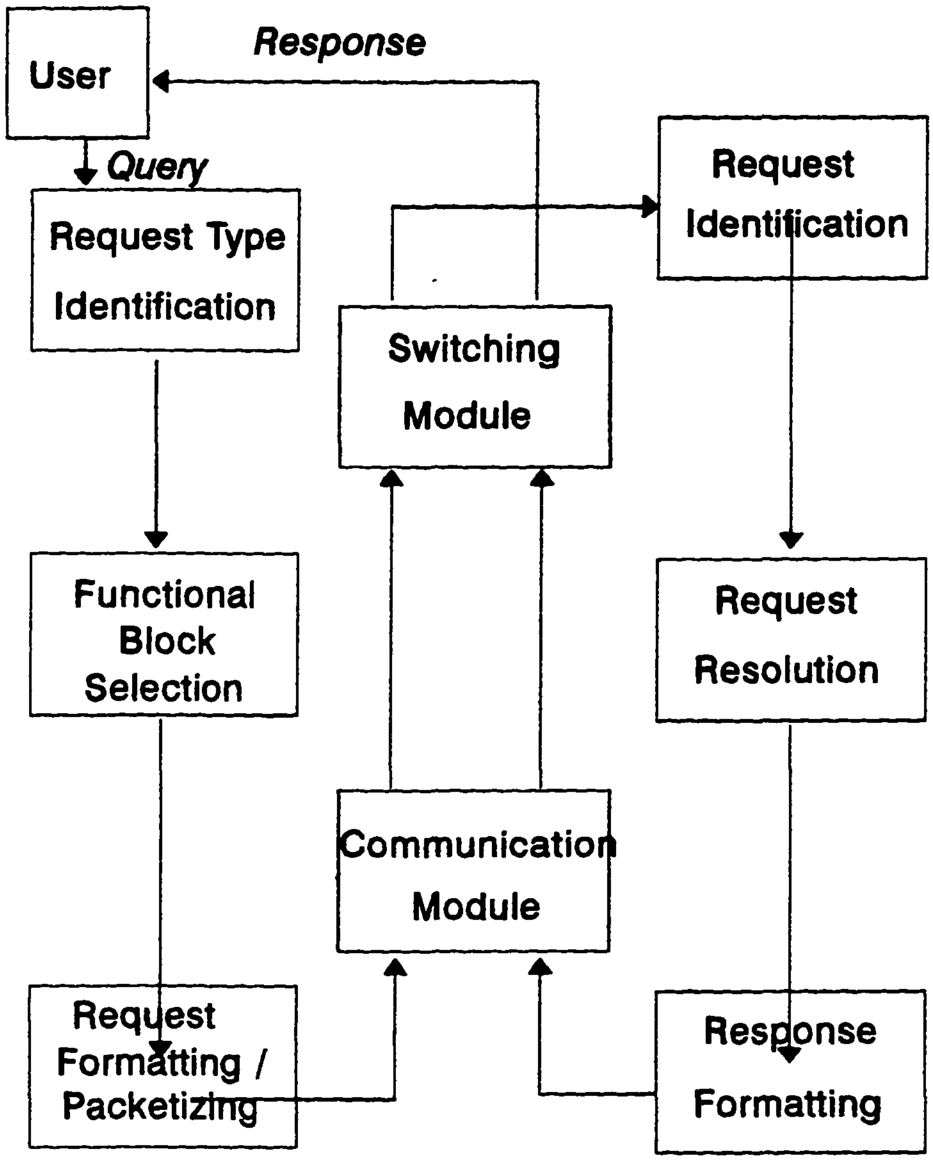

Fig. 4.4

Query Processing
by a Knowledge-Based Intelligent Network

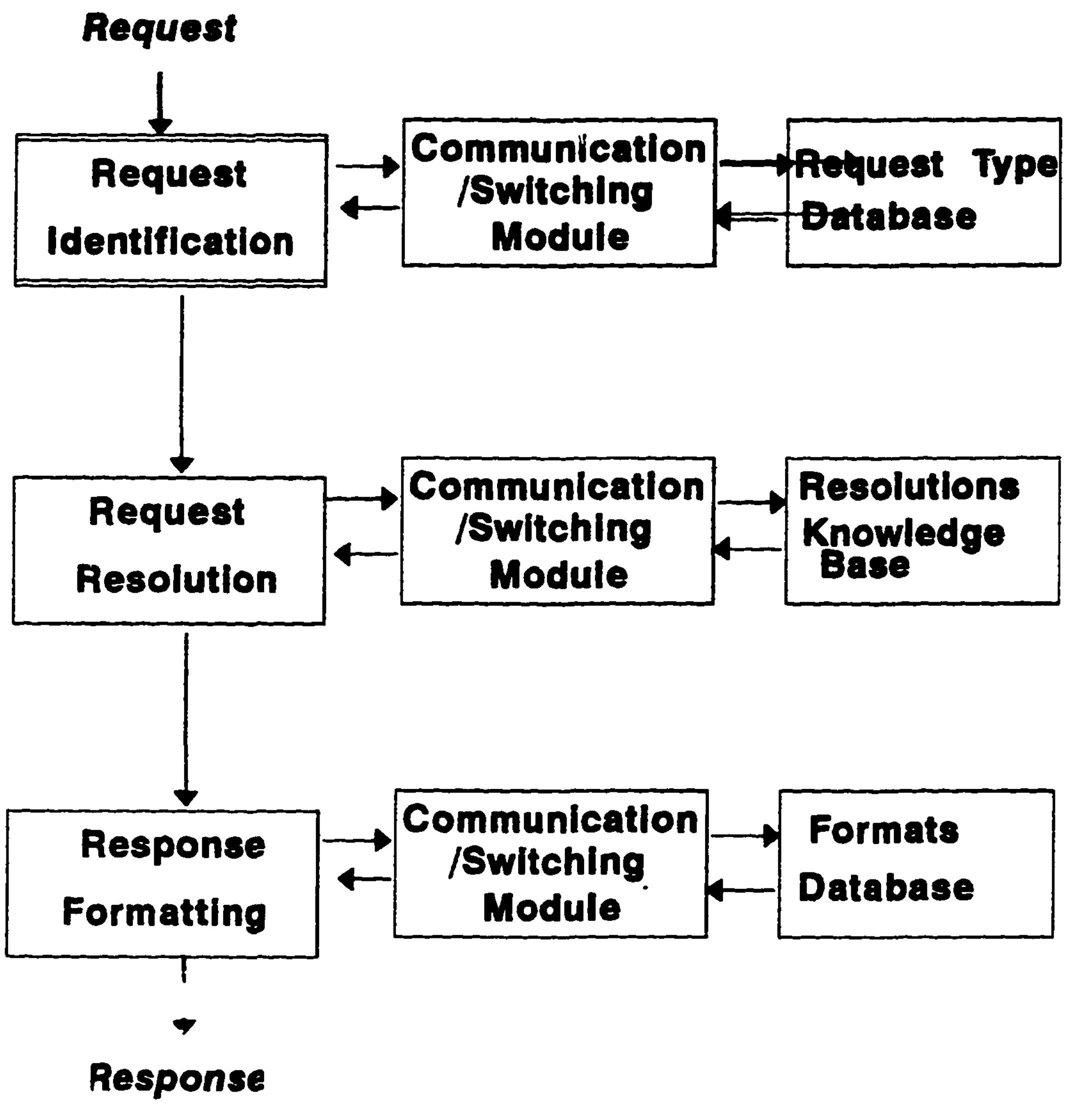

Fig. 4.5

Flowchart of Request Processing in a Knowledge-Based Network

4.3 ARCHITECTURE OF INTELLIGENT NETWORK FOR MEDICAL SERVICES

As was described earlier in 1.2, the modules in an intelligent network are organized in a multi-level fashion, with the bottom layer containing communication and switching subsystems, the next layer having knowledge module, represented by functional components and knowledge bases, and the top level occupied by administrative module, whose functions now also include the creation of new services. This architecture was presented on Fig. 2.2.

The knowledge module contains functional modules along with knowledge bases dedicated to specific applications. The architecture of the knowledge module greatly influences the architecture of the whole system. The architecture of the knowledge module is, in turn, application dependent. As have been shown in the previous section, the proposed interaction between knowledge module and communication / switching modules in intelligent medical network is much more complicated than a primitive single way communication presented on a Fig. 2.2. There CM/SM and FM are independent modules which interact just sending packets of data to each other without any logical interconnection between these pieces of information.

More detailed analysis reveals much more complicated nature of interactions between KM and CM/SM. In order to resolve an incoming request, the KM has to communicate with a number of possibly remote KBs The CM and SM has to participate in this communication. Hence there are additional connections between KM and CM / SM, which operate in a master/slave mode.

Therefore we can detect 2 types of communication between KM and CM / SM:

- CM / SM serve as subprograms to KM when called to execute inner communication between different parts of KM, namely - FMs;
- CM / SM communicate with KM as independent modules.

Fig. 4.6 represents this upgraded version of the architecture of an intelligent network for medical services. The tasks of the KM may be subdivided into separated subtasks. All this subtasks may be referred to as service procedures or application procedures, performed by designated FMs. Further, these procedures correspond to the steps by which the main task of KM - resolving the request - is performed. These steps may be organized in several levels. Therefore, the proposed architecture of a KM is a multi-level layered model.

Since the communications between FMs and KBs may be performed by carrying through numerous internal requests by the network, we may develop a generic algorithm. There all requests are resolved by utilization of a universal procedure of generating and resolving detailed local inquiries on each step of a global request processing/resolution.

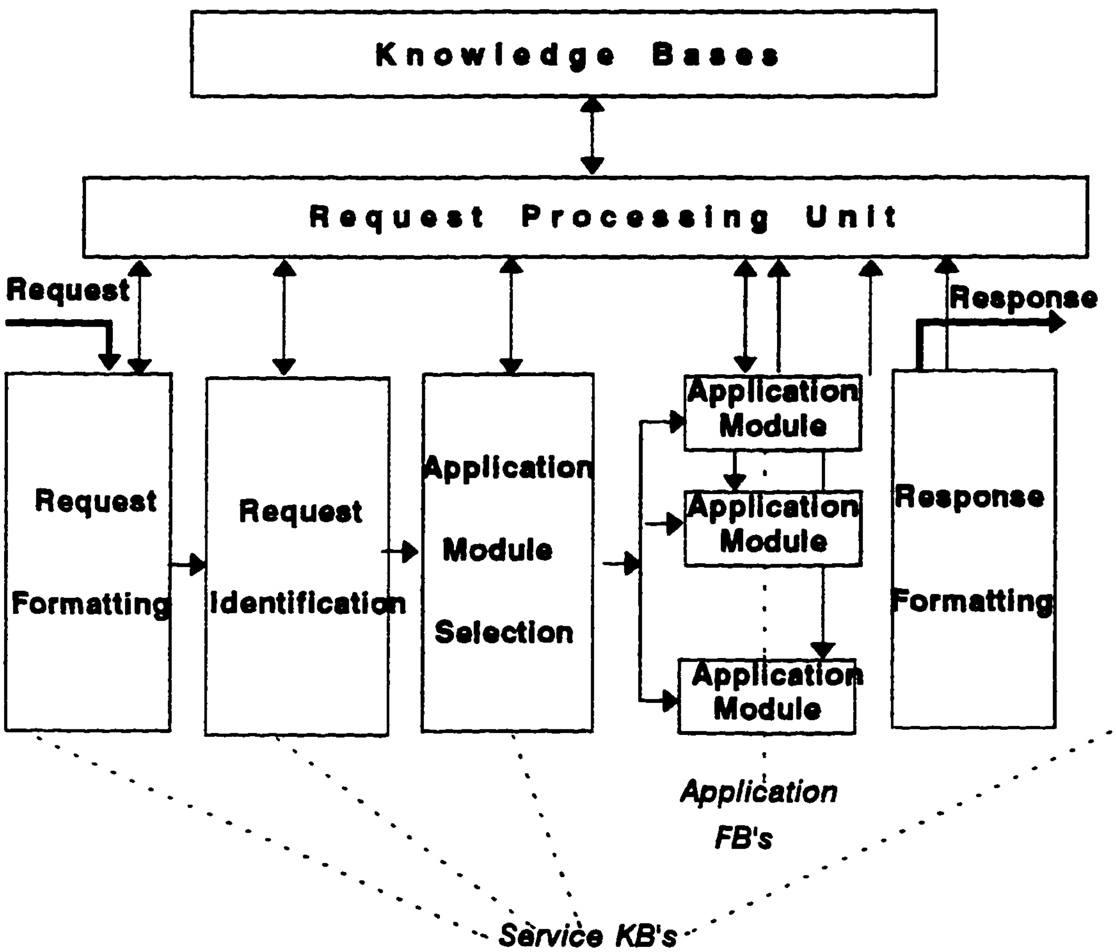

Fig. 4.6 Architecture of a Knowledge Module

In order to accomplish this goal, the tasks of the KM are subdivided into separated subtasks. All this subtasks may be referred to as service procedures or application procedures, performed by designated FMs. These procedures correspond to the steps by which the main task of KM - resolving the request - is performed. These steps may be organized in several levels. Therefore, the proposed architecture of a KM is a multi-level layered model.

The top level is responsible for user's interface. The primary function of this layer is to accept a user's request and to identify its type. This task may require generating of an internal request and sending it to a CM / SM. This task can be delegated to one of the FM. It is an application independent task and it will by performed by a service FM. The next level will identify the functional module for the specific request or the need for a human expert. This task may also be performed by a service FM. The bottom level would generate the internal formal request in accordance with the selected functional module syntax and convert it into a packet format. This is also a function of one of the service FM. The request is transmitted to the appropriate application functional module via the Communication / Switching module. After the request is received by an application functional module, it has to be identified, resolved and the result has to be send back. It means, that in order to accomplish its role, an application FM has to call service FM to perform specific subtasks.

Both service and application FMs refer to corresponding KBs in order to retrieve the necessary information. Some of these KBs are local, and some are remote. Therefore, in addition to a specific task performed by each individual FM, all of them has to execute the same standard procedure of accessing a related KB and possible call other FMs as subprograms to execute specific subtasks. These standard procedures may be organized in one *Request Processing Unit (RPU)*, which is called by each FM. This RPU may be arranged in the form of another service FM. The advantage of this approach is that a generic format for FMs may be utilized. The disadvantage is that when a multi-step solution is required for a request, then different FMs are used on each step, and additional communications between different FMs and between FMs and KBs are involved.

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The type and number of application functional modules in this system depend on the types and number of requests which the network is capable to process. In fact, at this level of design it may be assumed that they are the only modules which have to be developed specifically for the Health Care System, while the structure of other modules may be developed as templates for different types of applications.

Each type of function and associated with this function requests require specific class of the knowledge base. The function of knowledge module of intelligent network in this case is to identify the location of the required knowledge. The function of the Intelligent Peripherals is to translate the universal format of the requests within the network into specific format of information systems / databases utilized by the members of network.

4.4 OBJECT ORIENTED MODEL OF AN INTELLIGENT NETWORK

The development of any complex system usually starts with the analysis of its components. The purpose of object - oriented analysis is to model the real - world system so that it can be understood and to develop a model of what the system will do. The model is expressed in terms of objects and relationships, dynamic control flow, and functional transformations. The design model is related to the computer implementation and must address low level details that are omitted from the analysis model.

In a case of a knowledge - based application-oriented telecommunication network the elements of the system the major components of an IN , such as SSP, SCP, STP, IP, as well as the institutions participating in the network and their knowledge bases. The results of an analysis may be presented in a form of a model, describing both major characteristics, parameters and attributes of elements and relationships between them. In this dissertation models of an intelligent telecommunication system and of a health care system in the USA are built based on the object - oriented analysis and design (OOA&D). Object technology is a proven way for analysis, design and programming of various application systems, which became well known and quite popular in recent years, due to promising capabilities of software re-use on one hand and support for programming implementation (C++, Smalltalk) on the other hand. The shortcoming of object - oriented approach in case of knowledge - based systems is that it has no explicit features for rules implementation. If a design with rules is programmed directly in Smalltalk or C++, the rules must be translated into hard - coded methods and variables.[127] This approach may work in small systems, but it does not scale well and it requires reprogramming every time the rule change. Therefore one of the challenging problem in designing an architecture of a knowledge - based system utilizing an object - oriented design is to develop a method of presentation of a knowledge base in form of an object, so the three fundamental principles of object - oriented methodology - encapsulation, inheritance and polymorphism - would be applicable to a knowledge processing.

The process of creating an object - oriented model may be subdivided to the following steps [107]:

Build an Object Model:

- Identify object classes.
- Begin a data dictionary containing descriptions of classes, attributes, and associations.
- Add associations between classes.
- Add attributes for objects and links.
- Organize and simplify object classes using inheritance.
- Test access paths using scenarios and iterate the above steps as necessary.
- Group classes into modules, based on close coupling and related function.

Develop a Dynamic Model:

- Prepare scenarios of typical interaction sequences.

- Identify events between objects and prepare an event trace for each scenario.
- Prepare an event flow diagram for the system.
- Develop a state diagram for each class that has important dynamic behavior.
- Check for consistency and completeness of events shared among the state diagrams.

Construct a Functional Model:

- Identify input and output values.
- Use data flow diagrams as needed to show functional dependencies.
- Describe what each function does.
- Identify constraints.
- Specify optimization criteria.

Objects in intelligent telecommunication network

Based on IN/2 architecture (Fig. 2.1) the intelligent telecommunication networks is composed from the following objects:

- Intelligent Peripheral

  with attributes: Query Type and Query Content

  and methods: Edit, Validate, Transform and transfer;
- Service Switching Point;
- Service Transfer Point;
- Service Control Point;
- Service Creation Environment;

- Service Management System;
- Knowledge Module.

There are two types of link connection between these objects - one for transmitting an actual data (query), and the other for transmitting control signals (Signaling Data). The diagram showing all listed above objects and links are presented on Fig. 4.7. Both Query and Signaling Data are generalizations of actual data being sent over a switching network at different stages of telecommunication. Therefore both kinds of links - Query and Signaling Data may and should be considered as abstract data classes. For each particular transaction we should use a subclass of an abstract class. These transactions may take forms of original query by a customer, internal request formulated by network modules, based in a query content and in accordance with the requirements of a network standards, responses to a query generated by a network module or an external expert (both human or computer-based knowledge base).

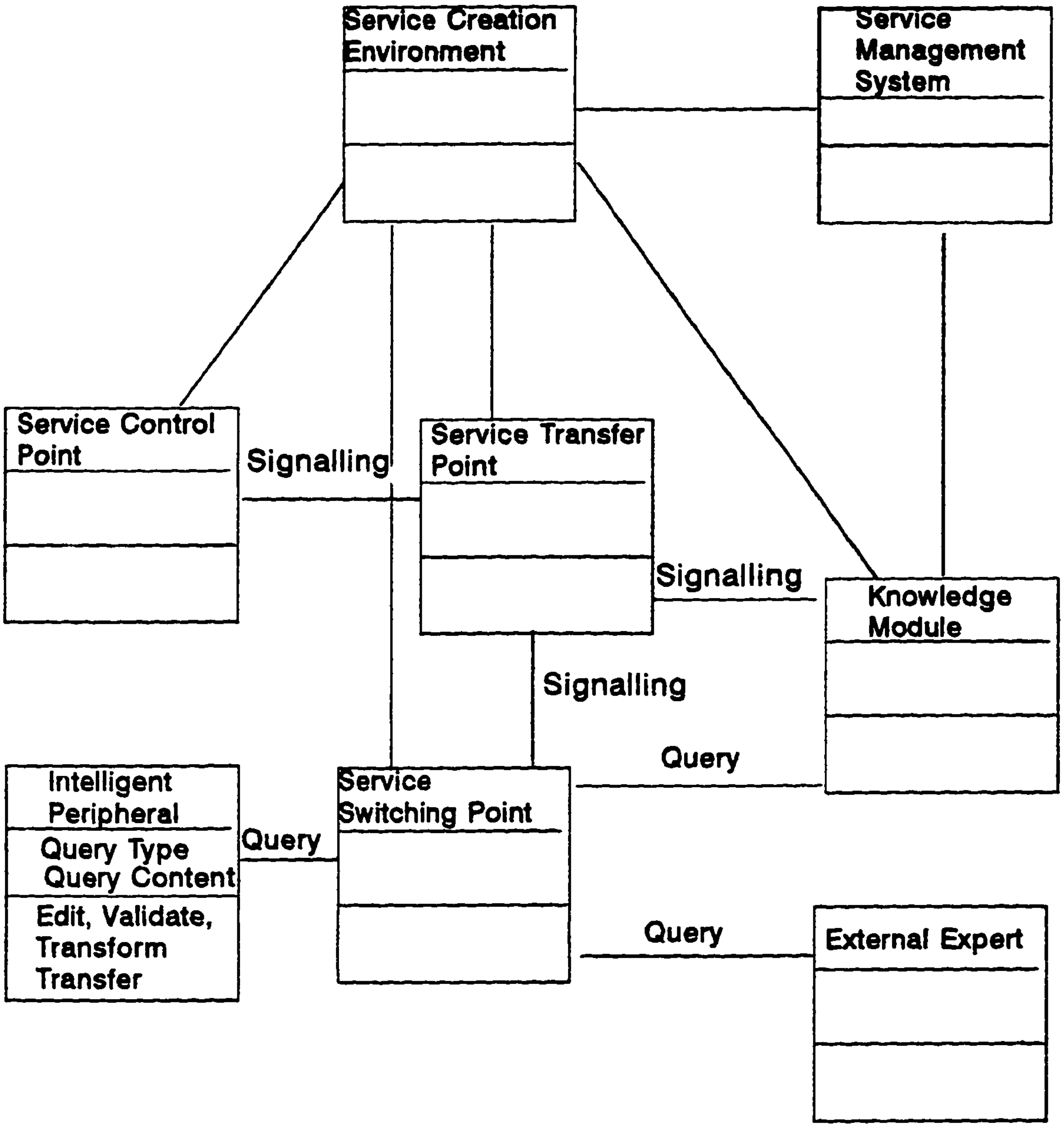


Fig. 4.7

Object Model

of an Intelligent Telecommunication System

Functional Model of Intelligent Telecommunication System

In accordance to scenarios of a query processing presented in section 4.2 and Fig. 4.1 the functional model of intelligent telecommunication system include the processes of Request Identification, Request Resolution and Response Formatting. Each of these processes may expanded to the next level of detailization, as is presented on Fig. 4.8.

The Request Identification process starts with a Validate Request subprocess, then passes control to a Switching subprocess. Switching process consults Control Database, performs a Routing process ad then transmits a query to a Perform Identification subprocess. The Identification subprocess communicates with a Request Type Knowledge Base and transmits a message back to a switching module. This time the switching module gets a routing instructions from a control database to transmit a message to a Format response subprocess. This is the end of a Request Identification routine.

The next process of Request Resolution performs the same subprocesses of a request validation, switching and routing . Then the Perform Resolution process communicates with a corresponding Knowledge Base to retrieve an answer to a query. Depending on a type of a request, it may consult either a Location Knowledge Base to determine a location of an external expert (human or computer-based knowledge base), of and Application Knowledge Base for an internal request resolution. The response is transmitted back and routed to a format response subprocess to end a request resolution processing.

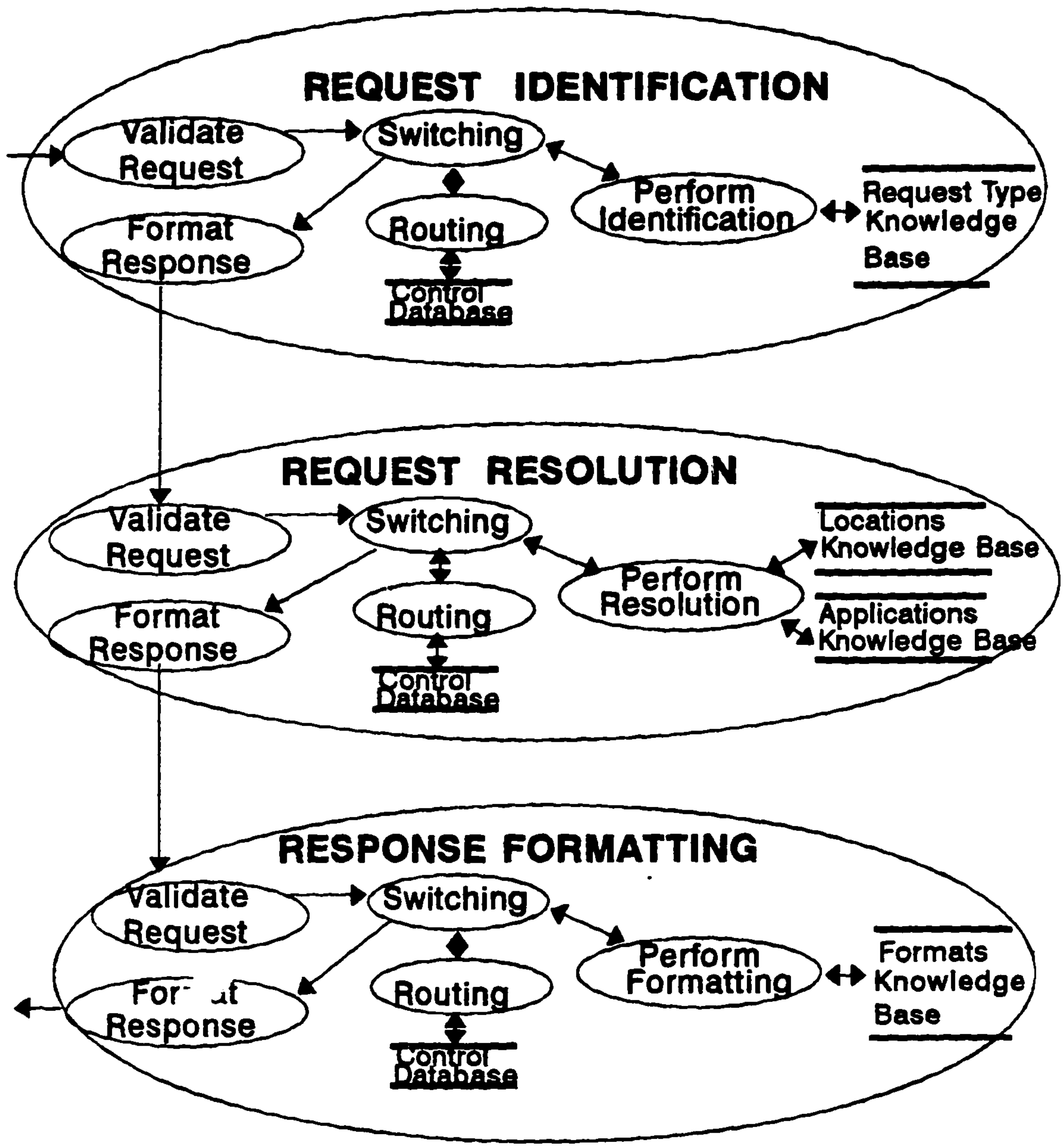


Fig. 4.8

Functional Model

of an Intelligent Telecommunicatin System

Response Formatting process executes the same routines, i.e. Validate Request, Switching, Routing and Format Response subprocesses, but to resolve a query it executes a Perform Formatting process, which communicates with a corresponding Formats Knowledge Base.

Dynamic Model of Intelligent Telecommunication Network

The Dynamic Model of Intelligent Telecommunication network presented in this dissertation in relation to an Intelligent Medical Network is limited to a query processing environment only. It recognized the following objects and their states (Fig. 4.9):

- Intelligent Peripheral states:

  Query Recognized;

  Query Formatted and Transmitted;

  Response Presented;

- Service Switching Point / Service Control Point states:

  Request Detected;

  Request Recognized;

  Connected;

  Connected;

  Request Routed;

  Message Transmitted;

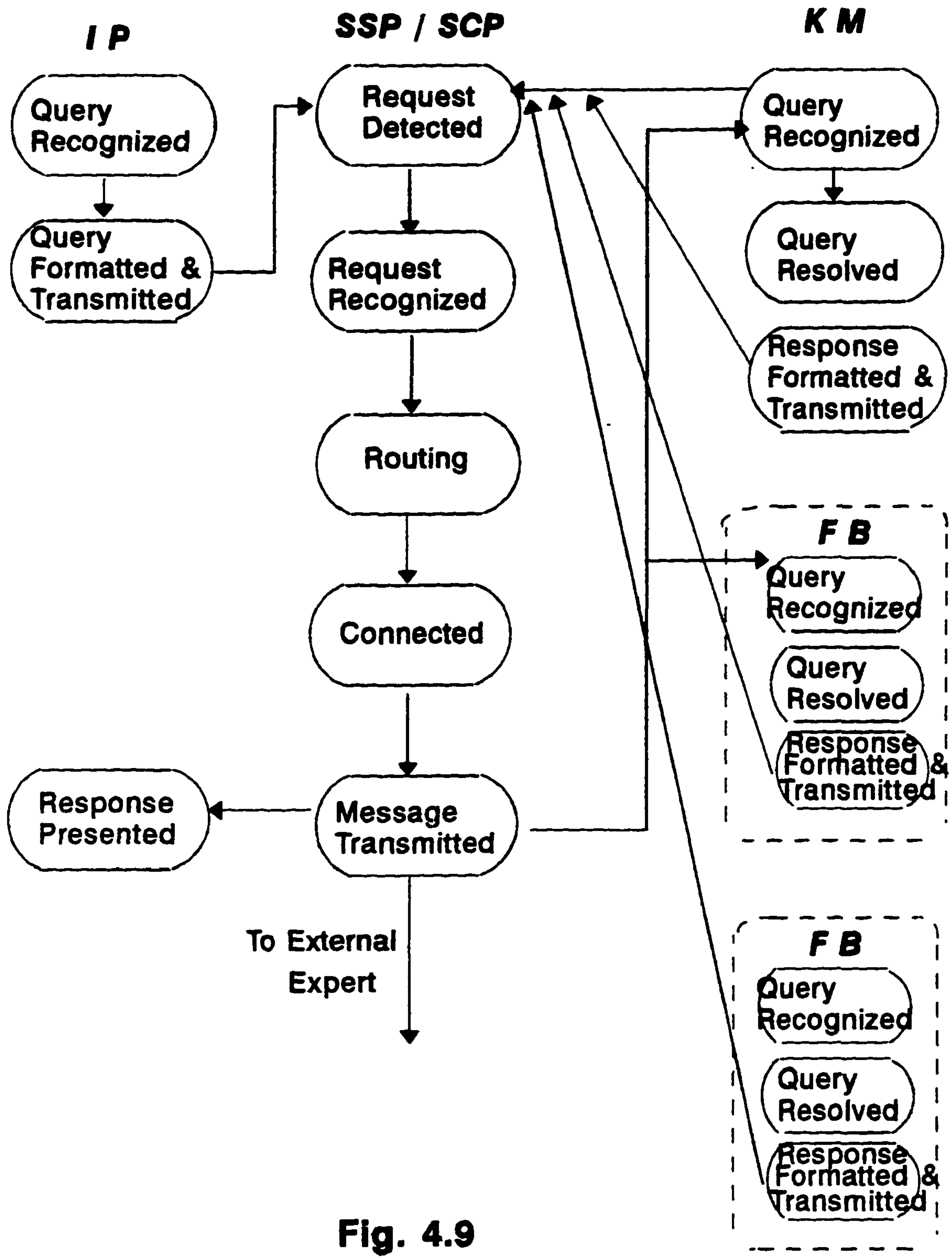


Fig. 4.9
Dynamic Model
of an Intelligent Telecommunication Network

Knowledge Module:

Query Recognized;

Query Resolved

Response Formatted and Transmitted;

- Functional Blocks states:

Query Recognized

Query Resolved

Response Formatted and Transmitted

4.5 OBJECT MODEL OF A KNOWLEDGE MODULE

An object model of a Knowledge module completes the stage of analysis of a Knowledge-Based Intelligent Telecommunication system. This model represent a hierarchical structure of all subclasses of a Knowledge Module class.

The Knowledge Module is an aggregation of Functional Blocks (FB's), a Request Processing Unit (RPU), and of Knowledge Bases (FB's). One of the goals of this dissertation is to develop a software for Functional Blocks of a Knowledge Module. Therefore the object Functional Block is further expanded as a generalization of classes Application Block and Service Block. The development of subclasses for an Application Block depends very much on the kind of a specific application. The subclasses of Services Blocks correspond to the types of Service Blocks described in the section 4.4. These blocks are:

- Request Formatting;
- Request Identification;
- Selection of Application;
- Response Formatting.

The whole Object Model is presented on Fig. 4.10.

The Service Functional Blocks (SFB) are present at any IN. They are common and perform analogous functions in all of them. These blocks has to be uniform across different applications and should be based on universal algorithms and data structures. An analysis and design of the SFB and related data structures are presented in the Chapter 5 of this dissertation.

On the contrary, Application Functional Blocks (AFB) of an intelligent telecommunication network are designed specifically for each individual network. AFB in the intelligent medical network are developed in accordance with functions and structures of different subsystems of existing health care system. The Object-Oriented model of a Health Care system is presented in the Chapter 6.

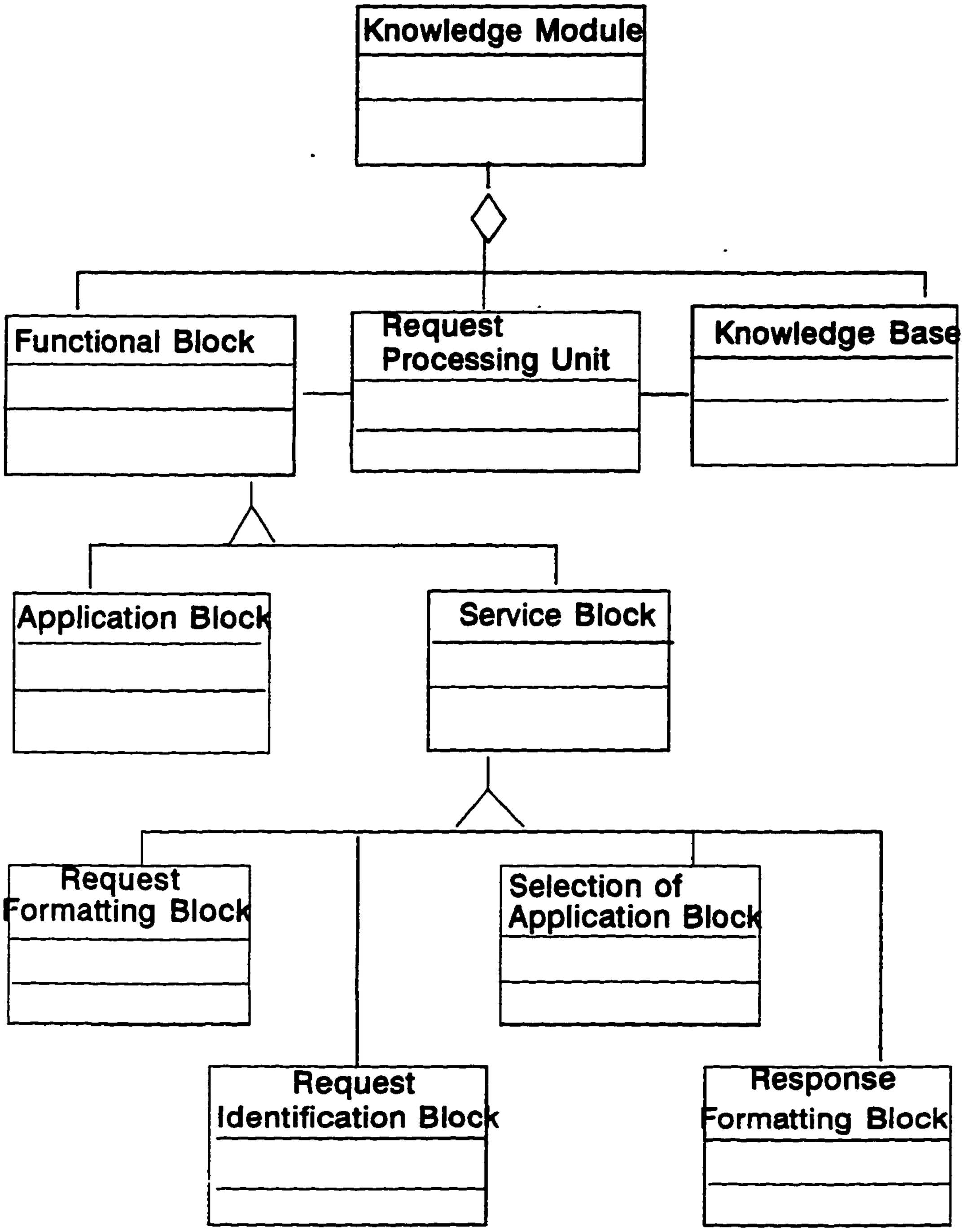


Fig 4.10
Object Model of Knowledge Module

5. DESIGN OF INTELLIGENT MEDICAL NETWORK

5.1 THE UNIVERSAL REQUEST PROCESSING UNIT

If we adopt the architecture of KM presented on Fig. 4.8 then all FM may refer to a universal RPU which handles standard operations for all FMs. We can represent the structure of the RPU in the form of a generic recursive algorithm (Fig. 5.1).

The RPU is called in a subprogram mode each time the communication with related KB is required, and this may happen on each stage of a request processing by KM or FM - Request Identification and Resolution, and Response Formatting. Each stage refers to a corresponding Knowledge Base (KB) during its execution. This knowledge base may be quite remote from the Request Processing Unit (RPU) and linked to it via a high speed network. Another problem is that the KB may not contain the direct answer to the request, but rather a reference to another KB, which may contain an answer or a reference. Local KBs may be directly linked, while remote KBs may require performing the same communication procedure on the next level.

Therefore the communications between RPU and KBs are performed by recursive calls of the same request processing algorithm. This algorithms reflects the dual mode of KB's communications by local links or by means of processing of internal requests.

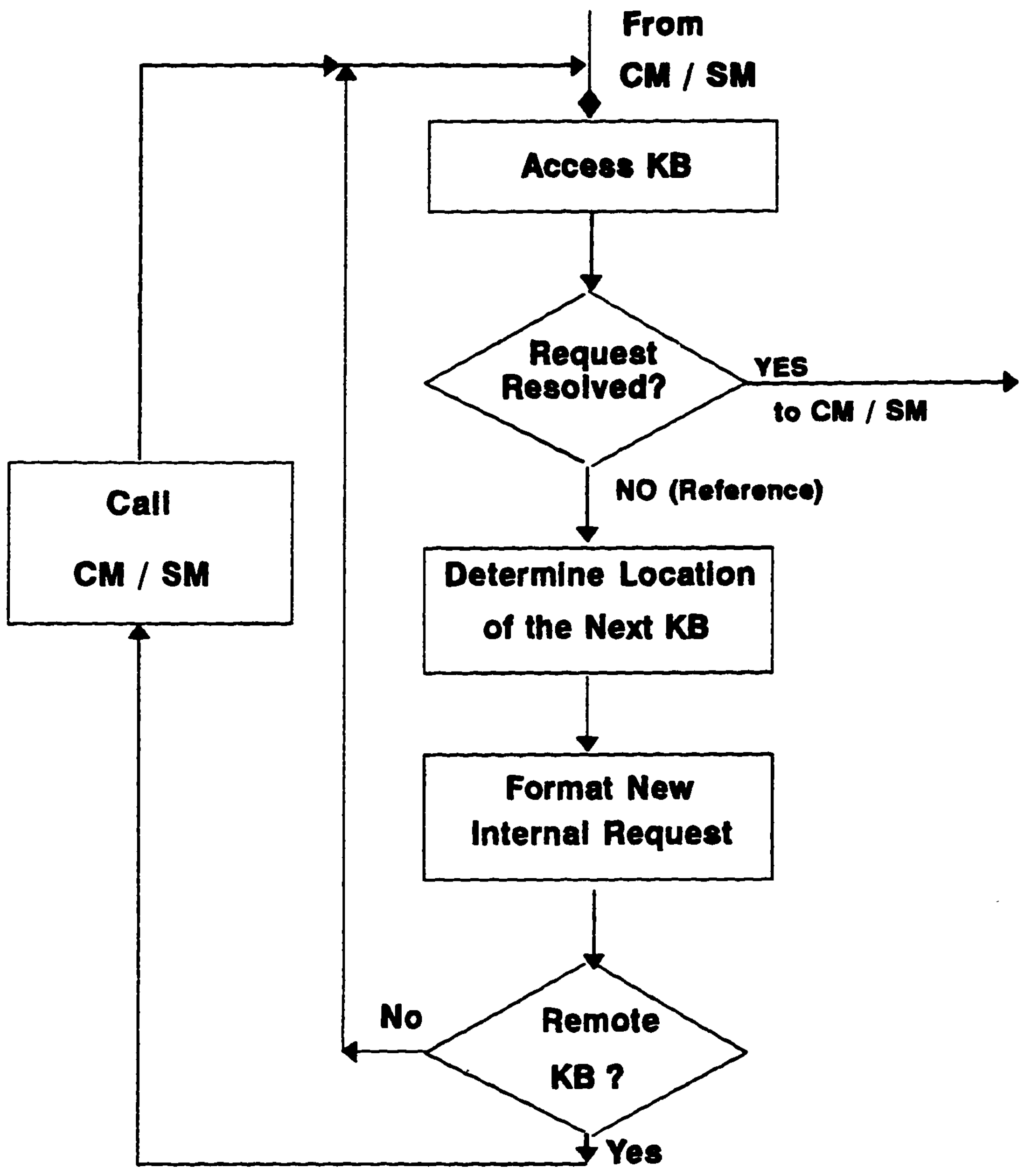


Fig. 5.1 Request Processing Unit

The proposed architecture of the knowledge base is determined by the complex multi-level structure of requests on one hand, and by the recursive organization of the request processing unit on the other hand. In analysis and development of the general format of knowledge bases in an intelligent network for medical services we have to consider the following circumstances:

- There are multiple KBs in the network which may be accessed by multiple functional modules. Different FM may be developed specifically for different types of applications, yet they should be able to use the standard interface to different KBs. Therefore all KBs in the specific network should comply to some generic format;
- The proposed architecture of KM is a multi-level structure, which utilizes recursive algorithms for requests processing. Hence the access to multiple KBs in the network may be also performed in recursive mode, and the structure of KB has to be amenable to such a recursive processing;
- The structure of KBs should reflect the distributive environment of an intelligent network;
- The network is developed as an open end system, so the KBs in the network should have a flexible structure;
- The administrative module will have the responsibility to maintain and update all the KB of the medical network, but the software of AM should not depend on the structure of a particular KB. Therefore one universal structure for all the KBs of a network has to be developed.

5.2 THE HIERARCHICAL LINKED LISTS STRUCTURE

The proposed hierarchical structure of knowledge bases is presented on Fig. 5.2. This organization may be utilized to implement different types of knowledge. The search by level may be on ascending or descending orders, depending on the type of request. For example, by searching for an ID of a specialist in certain area of knowledge within a geographic locality, the search may be from higher to lower levels, or from lower level to a highest, if this is a search of a specialist with the highest knowledge ranking.

The hierarchical structure simplifies the process of multi-step request resolution. By utilizing this structure, it is not required anymore to call multiple FMs when the answer to a request is not found in one step. The multiple FMs are not required in this case, because referencing to the next step of the solution is done by linking hierarchical levels of KBs. The universal algorithm of traversing a hierarchical linked-lists structure is built in a RPU.

Considering all the requirements listed above, the knowledge base may be organized as a multi-level hierarchical Linked List. If the required data is not found on the current level, the request is formed to search this data on the next level of hierarchy. Once the required data is found on certain level, the search is completed, and the data is passed back through all levels of recursion to resolve the request.

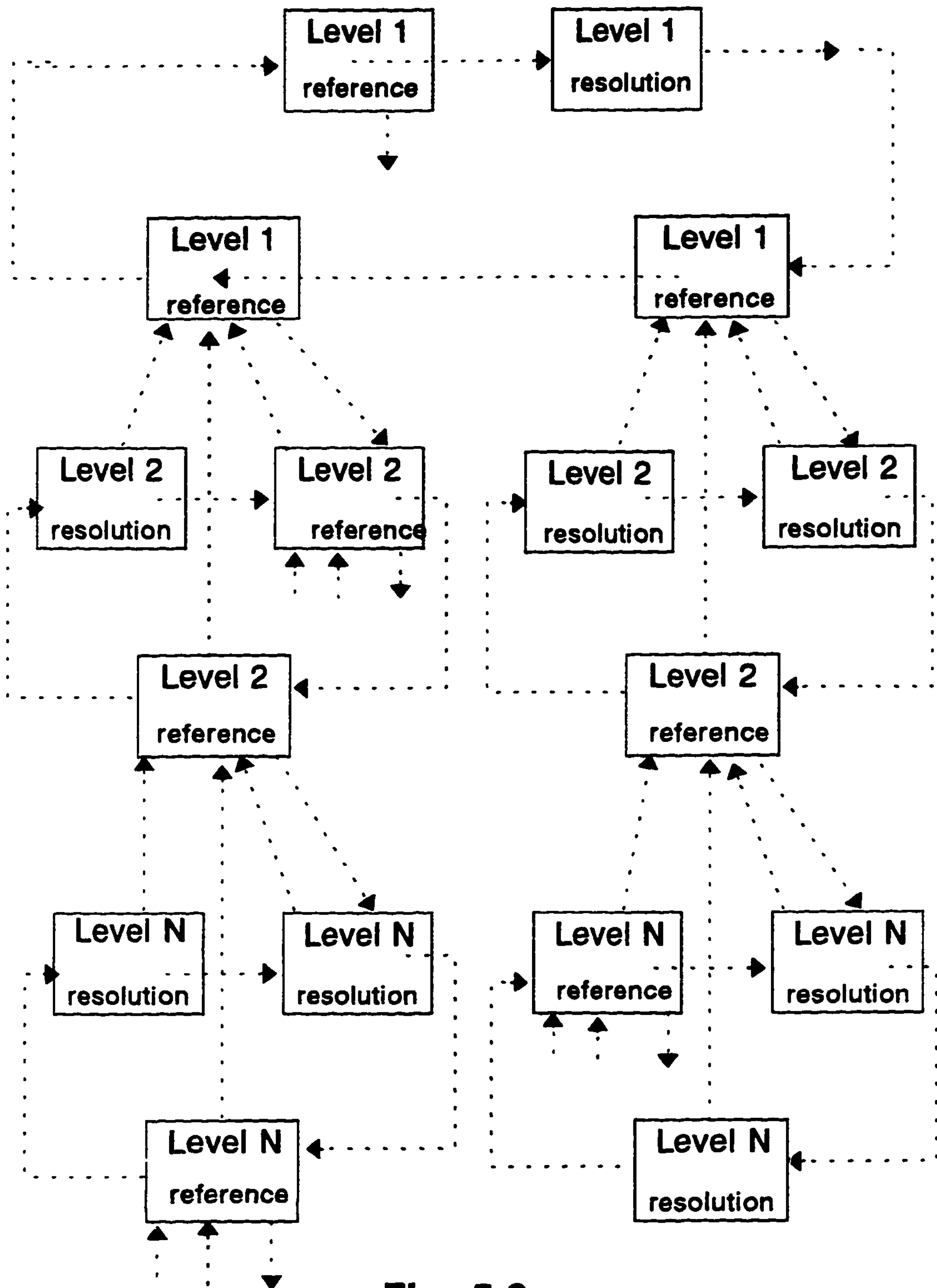


Fig. 5.2

Hierarchical Structure of Knowledge Bases

Hierarchical Linked Lists with Parallel Processing

Linked Lists are one of the basic data structures and have a few well-known modifications: Circular Linked Lists (CLL), Doubly Linked Lists (DLL), and combinations of the above. Linked Lists are regarded rather as implementation technique used in development of other data structures, such as graphs and trees. It is rarely considered as a data structure capable to satisfy the requirements of a full real-life application. This is due, mostly to the sequential nature of linked lists processing. Also, the structure of hierarchical linked lists may be considered too cumbersome.

On the other side, linked lists are one of the most generic, flexible, dynamic and versatile data structures. This allows the creation of generic simple algorithms to process them. Adding the parallel processing power to these algorithms may eliminate deficiency of sequential processing yet retain all the benefits of simple and generic algorithms.

The structure of the hierarchical linked list is presented on Fig. 5.2. On the top level we have a circular linked list, where each node, besides the data field, has a pointer to the next node on the same list, and also a pointer to the lower level linked list down the hierarchy.

Therefore each node has the following format:

Data Pointer Pointer

Assume for simplicity that there are n nodes in each LL. , and there are k levels in the whole structure. Then the total number of nodes S is:

$$S = n + n^2 + n^3 + \dots + n^k = \frac{n(n^k - 1)}{n - 1}$$

The average number of searched nodes in each LL. is $n / 2$. In the worst case scenario the number of searched nodes is n (all nodes have to be searched). The search time may be estimated as $O(nk)$.

Modifying Circular LL. to Circular DLL , and using the parallel search in two directions we can cut the searching time in half. To do that we have to add an additional pointer in each node. To add even more parallelism to the search algorithm and to cut the search time accordingly, we can make more than one entry point to each LL., and start the parallel search to both directions, as shown on Fig. 5.3

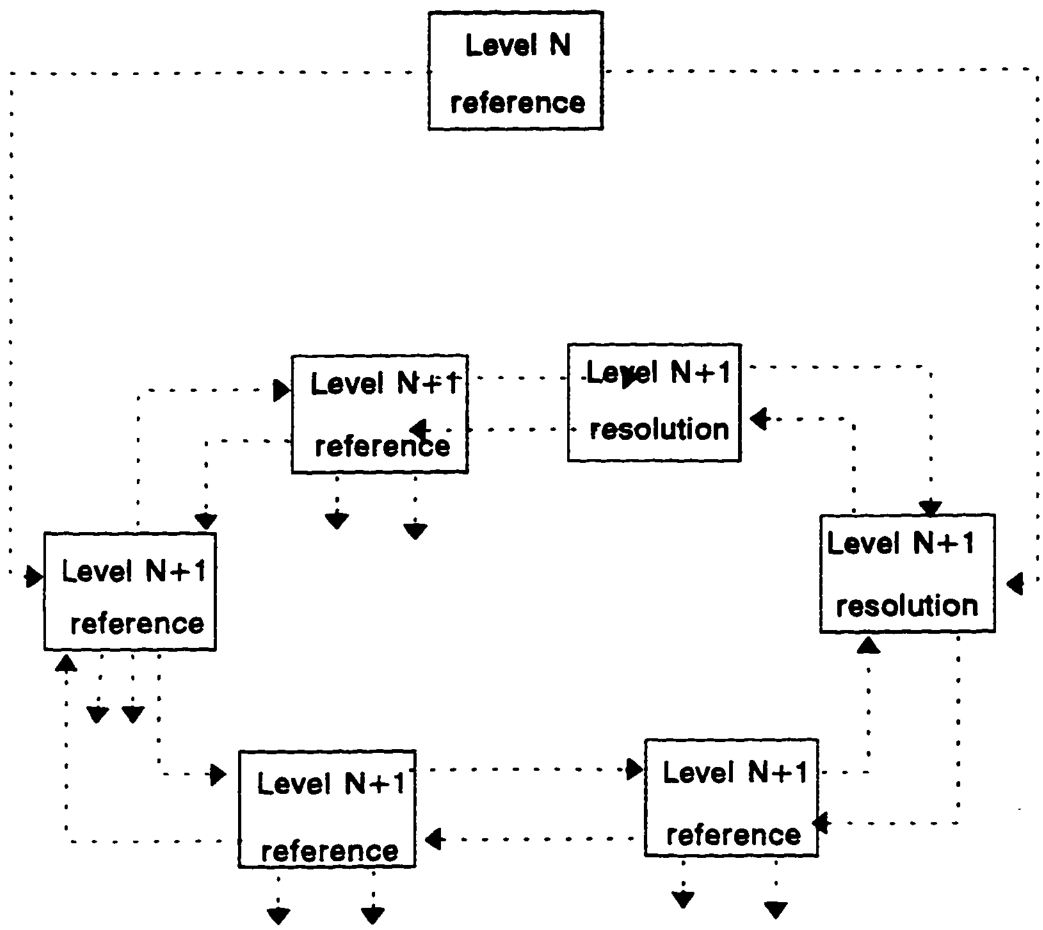


Fig 5.3
Hierarchical Structure of Knowledge Bases with Parallel Processing

5.3 SEARCH CRITERIA FOR QUERIES PROCESSING IN MEDICAL NETWORK

The knowledge-based medical network is designed in order to provide means of telecommunications between participating members of medical community. The major characteristic of this proposed network is that the inquiry sent to the network may not have the address of the party who is able to answer the question in the best possible way, i.e. the expert in the area of knowledge related to the query.

Therefore, the task of request processing in the medical network is performed in the following steps:

- accept the query, perform lexical, syntax and semantic analysis of it;
- find the expert member of the network capable to answer the question;
- interpret the question from the network query language into an expert's (database) language.

The more detailed analysis reveals the following subtasks involved in the development of request processing software:

- constructing entry query language for the knowledge-based medical network.
- selection of the expert search criteria;
- development of optimal search algorithm.
- building up the network structure supporting the optimal search algorithm;

The entry query language most likely should be build as a logical descriptive language. The construction of the full query language is definitely beyond the scope of the dissertation. The keywords/leximas in the format, corresponding to the next stage after lexical and syntax analysis, are accepted as the processing units of the query;

To formally define a search criterion for query processing in IMN let's introduce the following symbols:

S_E - an expert's specialization;

S_R - an attributed request specialty;

L_E - an expert's level of knowledge;

V_E - availability of an expert;

P_R - a position of a request sender within a network;

A_E - an expert's address;

D_R - distance limit for an expert's position relative to a request sender position.

The selection of the search criterion may be based on the following considerations:

Expert's E specialization S_E, level of knowledge L_E and position P_E are accepted as the parameters for search and selection. The ideal strategy would be to find an address A_E of an expert with the specialization matching to the request S_R, with the highest possible level of the expertise and the closest possible position to the position P_R of the party sending request.

It is obvious, that in general case this problem may not have any solution, as you cannot satisfy two requirements (min and max) simultaneously.

As one of the acceptable modifications we may consider the search of an expert with the qualification above certain level and location within certain distance $\mathbf{D}_{R}$, determined by request

$$A_E \quad \left| \begin{array}{l} L_E > L_R , \\ P_E - P_R < D_R , \\ S_E = S_R \end{array} \right. \qquad \{5.3.1\}$$

Let's introduce **C** - the cost of the resolution as a function of both expert's level and distance:

$$C = C (L_E , D_R) \qquad \{5.3.2\}$$

Then the most logical strategy would be to minimize the cost of the resolution, assuming that we deal with an expert not lower that a certain level specified by request. In this case the problem of finding an optimum criterion C may be formulated as follows:

$$A_E \quad \left| \begin{array}{l} C(L_E, P_E - P_R) \rightarrow \min, \\ L_E > L_R , \\ S_E = S_R \end{array} \right. \qquad \{5.3.3\}$$

Usage of a cost function C requires the knowledge of matrix $\mathbf{C}(\mathbf{L}_E, \mathbf{D}_R)$ values for all applicable $\mathbf{L}_E$ and $\mathbf{D}_R$. The estimation of $\mathbf{C}(\mathbf{L}_E, \mathbf{D}_R)$ may be a hard and tedious job. Another possible criterion may be based on the availability of an expert $\mathbf{V}_E$. In fact, this approach was used in the Data-Mail Electronic Consultation System at the Mount Sinai Medical Center, a pilot project for an intelligent LAN. The search algorithm is looking for a node with the following characteristics:

$$\mathbf{A}_E : \left| \begin{array}{l} \mathbf{V}_E \rightarrow \mathbf{max}, \\ \mathbf{L}_E > \mathbf{L}_R, \\ (\mathbf{P}_E - \mathbf{P}_R) < \mathbf{D}_R, \\ \mathbf{S}_E = \mathbf{S}_R \end{array} \right. \qquad \{5.3.4\}$$

The availability function $\mathbf{V}_E$ in the Data-Mail system is determined as a value opposite to an expert's work load $\mathbf{W}_E$, which in turn, is calculated as the number of pending patient's cases:

$$\mathbf{V}_E = \mathbf{W}_{MAX} - \mathbf{W}_E \qquad \{5.3.5\}$$

5.4 DEVELOPMENT OF INTERFACES TO USER'S DATABASES

The design, development and an implementation of an Intelligent Medical Network requires intensive data telecommunications between members of the network. In most cases the members are represented by computer information systems, and more precisely - by databases and future knowledge bases. In fact, the whole IMN may be considered as a distributive computing environment.

Distributed computing involves accessing multiple platforms and connecting workstations. Many of today's distributed computing approaches are based on the client / server architecture. There are different architectures in distributed processing. One of them is distributed database. The idea of distributed database is that the application can access data on remote sites the same way the application accesses data locally. A distributed database is a collection of multiple, logically interrelated databases, distributed over a computer network, with the distribution of data being transparent to the users. These multiple databases may have different structures and form a heterogeneous distributed database. The simple database may be implemented as a collection of files (flat, sequential, VSAM, etc.). More complex databases are based on hierarchical or network structures. The later developments include relational and object oriented databases.

With the development of heterogeneous distributed system, analysts and computer programmers often face the problem of creating a system of reloading information from one kind of internal database to database of another kind. The similar problem may appear when new database is merged into existing distributed system, and this newly accrued data, residing in database of certain type, has to be integrated with databases of different types. During the new software installation there is also an analogous problem of loading of initial data into the database. Usually a set of customized program should be written to accomplish such a task. Finally, the same problem appears in an automatic query processing by intelligent network. Here an inquiry is created by one member of the network according to a syntax required by a database utilized by this member. The query has to be understood by the intelligent network, transferred to an expert member of the network and translated into a format of the database utilized by an expert.

Semantical and Structural Data Conversion.

Converting data from one database structure to another involves several steps. First, semantically identical data elements in different databases have to be identified. In a medical and health care environment this goal can be achieved by the agreement of all participating parties to follow the standards proposed by American Medical Informatics Association. These standards were described earlier in this dissertation in chapter 3.

Assuming that all necessary data elements in participating databases are semantically in compliance with each other and AMIA standards, we may define the next step as a structural conversion of data. That may involve a transformation of data from let say flat-file structure, or relation database (tables) format into a hierarchical database format.

An additional step may be required to transmit a query from one member of a network to another. Even when dealing with the same type of data structure, a syntax translation may be required to transmit a query.

Different approaches may be used to link different databases. The common solution to solve all the above problems would be a universal utility or software package for loading and reloading information to a from database of an arbitrarily type and structure. Creation of a universal system to cover all above mentioned problems would be quite interesting theoretically and very useful in practice. While such project is an integral part of a full practical implementation of the Intelligent Medical Network, the elaborate analysis and design of a universal interface for medical databases is beyond the scope of this dissertation.

As examples of a smaller projects aimed at the same goal of building an interface between two databases with identical semantic data elements but different structure, real life projects are considered to illustrate possible solutions. One is a program generator designed for a structural data conversion. The other is a query editor which may serve as a syntax translator by Intelligent Peripheral within IMN. Also, a presentation of hierarchical structure by means of relational database is discussed.

Flat Files / Hierarchical database interface

As an example of structural data conversion system lets consider an interface between VSAM files and IDMS. This interface was designed and implemented as a project in the Empire Blue Cross and Blue Shield. Later this system was used to create programs for initial loading of data into test and production databases in Customer Information Resolution System within the same company.

I proposed a system of automatic generation of conversion programs, with recursive algorithm of generation based on a recursive representation of hierarchical structure of database.

This database may be presented by a tree, and elements of the tree may be defined recursively. Each vertex of the tree represent a certain type of record (a flat file) of database, where each edge represent a relationship between two records. If two records are connected, one is defined as a parent (owner - in terms of IDMS vocabulary), the other - as a child (or member of a set, according to the accepted IDMS terminology). This is a one-to-many Relationship. Between owner and its members may be different kinds of connection (mandatory, automatic, optional, manual), which determines whether member may be stored with or without being connected to an owner, and whether may be disconnected from the owner. Records in IDMS may be allowed to be stored with or without connection (if this is permitted by a definition of the type of connection). Database records may be retrieved by its logical key, by relative address within database (supplied by the system under the name "DB-KEY" when it stores the record), or by logical navigation over the tree. IDMS includes operators which allow to traverse either down the tree from owner to its members, or up - from member to owner. IDMS allows many different operations on its records, and different combinations between its record. Some of these operations were designed specifically for retrieval and update modes - to make operations in these modes faster and more convenient.

The interface uses only a subset of a full set of IDMS operators. Particularly, it limits the number of required operations under the database records to three.

These three basic kinds of operations / connections are as follows:

- Store and connect records of 1-level tree (i.e. owner record and its members - elements of the tree located one level down); This is a start-up operation, which allows to create a root node of a tree.
- Store one record and connect it to an existing record.). This operation allows a tree to grow by one level at a time. Consecutive application of this operation (store one record and connect it to existing record), permits building a hierarchical tree of a discretional height..
- Connect two existing records.

First two basic operations are necessary to create a hierarchical database structure. Totally hierarchical structure of any length and complexity may be created by using just two first operations. The third operation makes possible to have additional connections between elements of database, determined by a network structure. This operation (connect two existing records) is used when it is necessary to connect partial hierarchical subtrees within database structure. Therefore an directed graph may be created utilizing these three operations.

All files, used by Interface System have a certain format. Their records contain the data portion and prefix, where data portion corresponds to database records layouts, and prefix format is standard within interface system.

Prefix for each record contains the following information:

- K_O - logical key of the owner's record;

- K_R - logical key of the record itself:

- DBKey - relative address of the record within database, created by database.

When two records from two adjacent levels are processed, the correlation between them is like that:

K_O K_R DBKey DATA level i

⇓

K_O K_R DBKey DATA level i+1

When we create the records in a hierarchical tree from top to the bottom, the member's record on a certain step will become the parent's record on the next step.

On each step one of the three operations, described earlier, are used. First two levels of hierarchical tree are created using first operation (store owner and its members. Additional levels of database records hierarchy are created by using the second operations (Store and connect), and a more complex network-like structure can be created by using the third operation (Connect).

There are three types of programs used in the Interface system, which correspond to three types of operations on database records described earlier in this paper. Still, individual programs has to be written to process each individual record type within database. In this Interface system that problem have been solved by creating a program generator, which produces programs to store and connect all records in required database. Information necessary to generate a program includes type of operation on database records, database record name, type of connection and description of input files, from which data has to be reloaded to database. Interface System consists of three programs and three permanent files. Each file contains a prototype of a program associated with certain type of operation on database record. Main program (a scanner) is using parsing algorithm to tune a general program prototype into a program to process a specific database record. There are four different types of variables, which are used within this program and with input parameters, to identify different types of text conversion (i.e. replace, insert, delete and copy). Input to the main program is a file with generation parameters described earlier. Output is a created processing program in form of a source code.

The described approach works well for pure hierarchical database structure. It may also work for certain types of network structure, but not in a general case. Thus, the program for a situation where a member record has to be connected to two owner records simultaneously by the time it is stored cannot be generated by the Interface.

Relational / Hierarchical Databases Interfaces

The approach used to develop a flat-file / hierarchical database interface may be easily expanded to a relational database / hierarchical database conversion. This is justified by the fact, that a relational database may be presented by means of "external views", where the term "view" is reserved in SQL to mean, specifically, a named, derived table. Therefore in relational database we already have a binary relation between two entities, which was used as a base for building a recursive algorithm in our Interface. In fact, the similar course was taken in [145] to create an interface between hierarchical database (IMS) and relational database (DB2).

Presenting Hierarchical Structure with a Relational Database

The widespread applications of relational databases is based on the fact that it based on a complete theoretical foundation - normalization theory . In a relational schema the entire information content of the database is represented by means of a single data construct, namely the n-ary relation. A network database schema does not have such a complete theory as the normalization theory to assist with the design of a network schema. There are at least two essential data constructs in the network approach, and usually more [39]. A hierarchical structure may be considered as a restricted form of a network schema. Hierarchical databases have a definite disadvantage of being much more complex than relational.

On the other hand, hierarchies are obviously a natural way to model truly hierarchical structures from the real world. So from implementation point of view the best way of building a database for an intelligent network is to represent a hierarchical structure by means of a relational database.

A hierarchical structure is a tree and can be presented as a set of its edges, i.e. as a set of pairs ($K_{i,m}$. $K_{i+1,n}$), where *i* is a height (level) of a tree node, and *m* and *n* are sequential numbers of nodes within their levels. In a relational database environment a record contains 2 fields representing nodes of an edge. Lets call these fields PARENT and CHILD. The root does not have a parent node, so the identification of its parent is NULL and it can be identified by the following SQL statement:

```
SELECT CHILD WHERE PARENT = NULL
```

Identifying a root node as a child on a level 0 , i.e. $CHILD_0$, all nodes on the next levels may be found and processed recursively:

$$\text{SELECT ALL CHILD}_i \quad \text{WHERE PARENT} = \text{CHILD}_{i-1}$$

5.5 DATA PROTECTION AND SECURITY IN THE INTELLIGENT MEDICAL NETWORK

The security protection becomes one of the major issues in network administration. Recent wide-publicized cases of computer hackers. Mitnick and Levin exposed to the world the vulnerability of the telecommunication networks. These two cases represent two major reasons for computer hackers to break the security of networks: psychological and financial. Mitnick was able to obtain the private credit card information contained in a network. He did not used it, he did not profited from it - he demonstrated his ability to oversmart security experts . Eventually, he has lost. Levin was able to encode the passwords of some international clients of a major bank and was able to actually transfer several million dollars out of their bank accounts. Bank was able to recover everything but 400 million.

Administration of any telecommunication network consider security as one of the most serious areas of development. In case of medical and health care data privacy of collected information is necessary because of significant economic, psychological, and social harm that come to individuals when personal health information is disclosed . The goals of information security in health care can be stated as follows [38]:

1. To ensure the privacy of patients and the confidentiality of health data (prevention of unauthorized disclosure of information);

2. To ensure the integrity of health care data (prevention of unauthorized modification of information);

3. To ensure the availability of health data for authorized persons (prevention of unauthorized or unintended withholding of information or resources).

Basically, two protection mechanisms are involved: passwords and encryption of data.

Passwords

Usually, medical and health - care computer systems and networks use some form of password security for user authentication, and user - specific and role - specific menus may be used to implement further limitations on access. However, standard password access controls do not prevent insider threats and are not helpful when authentication has been compromised.

In addition, tight access control at the level of the type of user, computer application, or patient fails in critical ways in the health care environment. Sensitive data (i.e., mental health data or HIV status) are often among the most important items necessary to take care of a patient. This is the information that may need to be made available and shared among numerous health care providers and ancillary health personnel. Most often, numerous persons at multiple levels in multiple roles (medical students, residents, nurses, therapists, dietitians, social workers, administrators, consultant physicians, covering physicians, and a private or personal "attending" physician) are routinely involved in a patient's care, and it is difficult to predict which person in which role will validly need access to a person's health record at some particular time. For this reason, clinical systems have usually allowed all clinical personnel access to the computerized medical record of all patients in a hospital, and often to the records of patients not in the hospital as well (i.e., records of discharged patients or their ambulatory care, or both).

Encryption of data

There are many complicated and secure mathematical algorithms for encryption. Private -key, or "secret-key" encryption depends on a number or string of characters that is shared only between the communicating parties and is used by an encryption algorithm to encode and decode the message. The exact encryption algorithm need not be a secret. A main problem with private-key encryption protocols is that communicating parties must somehow securely share and use the "secret" key.

Public-key encryption is based on a mathematical technique that creates an "asymmetrical cryptosystem", that is, the keys to encode and decode a message are different but intimately linked, so that they are, in effect, functional inverses of each other and can only be used together. In public-key cryptography, one key is published, and the other remains private to a user. To send a secret message, the sender obtains the recipient's public key and uses it to scramble the message, which the recipient can decode with his or her private key. In addition, the creator of a message or document can "sign" it by encoding a piece or algorithmic "digest" of the document with his or her secret key, so that anyone can then verify the "signature" by decoding it with the signer's published key.

The New York State Community Health Management Information System (NYSCHMIS) Confidentiality and Data Security Policy says:

"All data collected into or handled through the repository and defined as 'deniable' (identifiable) ... shall be encrypted, both when being transmitted through the network or if written to a local system. Software and/or hardware shall be supplied with secure algorithms which will encrypt/decrypt all such sensitive data.

Privacy and Confidentiality in Health Care

Nevertheless, the encryption do not guarantee an absolute protection of transmitted data. Moreover, the cost of a machine capable of breaking a Data Encryption Standard of the US government (DES) key within 1 year (with an 8%) chance per month) was only $64,000 in 1995. [71].

What are the specifics of medical information and what kind of additional measures should medical communication networks utilize in addition to a regular methods of protection in other telecommunication network. Where do a danger come from? In an open forum communication network, the major concern may be an inappropriate content or meaning of some messages, transmitted by some individual. For financial telecommunication transactions there are two major problems: to protect some information (such as a credit card number) and to detect fraud transactions. Both kinds of such illegal activities are usually conveyed by small group of individuals. Unlike these situations, the major threat in medical networks may come not from some hackers' illegal activities, but from legal information queries made by insurance companies, investigations firms and so on. This is currently the major public concern regarding medical networks and availability and accessibility of medical information [33, 38, 71].

"If computerized medical information is not secure, people could be denied jobs and insurance" [79]. Health-care information regarding purely medical information should be available only to persons involved in the medical treatment of a patient. Administrative information regarding health-care should be available only to those who are professionally involved in the administration. [48].

Accordingly, the major protection actions in medical telecommunication networks are required not from technical, but from legal and administrative sides.

Legal Protection

On October 24, 1995, Senator Bennett of Utah (acting for himself and Senators Dole, Leahy, Kassebaum, Kennedy, Frist, Simon, Hatch, Gregg, Stevents, Jeffords, Kohl, Daschle, and Feingold) introduced SR-1360, the "Medical Records Confidentiality Act", a bill to ensure personal privacy with respect to medical records and health - care information. The Bennett - Leahy bill (as it is known) covers personally identifiable health data in electronic and paper form held by "health information trustees", including health care providers, health plans, health researchers, public health authorities, insurers, employers, and others. It gives patients the rights to inspect, copy and amend their records and requires patients to provide written authorization before disclosures can be made, with exceptions that include emergencies, legally mandated public health reporting, institutional review board (IRB)-approved research, and, with some safeguards, warrants, and subpoenas. The bill requires health information trustees to establish appropriate technical, policy, and physical safeguards for protected data, to publish their information practices, and to keep a record of some categories of disclosures. The bill includes stiff civil penalties for "substantial and material failure to comply" with the law and criminal penalties for wrongful disclosure of protected data. The criminal sanctions cover both those who disclose the data and those who knowingly receive them. There are severe penalties for violations involving commercial advantage, personal gain, or malicious harm.

Such a bill is always a compromise between extremes; a trade-off between absolute individual privacy and practical implementation, costs, and the public good.

Administrative measures of data protection

Administrative methods of medical data protection include, first of all, the development of data structure which is able to separate clinical and personal data. Moreover, within each type of data (clinical and personal) certain levels of privacy protection should be introduced. While clinical data of a patient may be available to a medical personnel in general, an access for each individual health care provider may be restricted to a specific area of a patient's medical and/or personal data. Additional authorization will be required for a personnel to obtain more patient's data.

Much more restrictive should be access to clinical data by outside parties, according to the "Bennett Bill" discussed earlier. Insurance companies may obtain a clinical information related to a specific claim only. In no way can they gain access to this kind of data to determine an insurance risk level of a potential client. All other parties, such as marketers, manufactures, specialized health care providers may obtain patient's clinical data on individual basis with a patient's of a legal guardian consent.

On the other hand, medical and health care researchers should gain access to anonymous patient's data. They do not need an exact patient's identification, and this information has to be withhold from them, or permitted on individual basis with additional authorization. In this case a combination of data password protection and encryption of data is required.

Altogether the following areas for which policy has to be developed are identified [71]:

User authentication - issues relating to the identification of a user to the system and the ways in which the system might know that a user is who they claim to be.

Physical security of data center sites - issues relating to the physical access to computer hardware; theft prevention; backup and disaster recovery; and the security of sensitive terminal locations, such as console or control, and of publicly accessible terminals.

Access control to system resources - issues of the physical devices and logical mechanisms, such as computer programs, that control access to system resources.

Data ownership - issues of who will own which data, the delegation of authority over data, and enunciation of the duties and responsibilities of data ownership.

Data protection policies - issues of minimally acceptable and consistent protections to be afforded by systems crossing organizational and functional boundaries, anticipated implementation barriers to those protections, and the punitive measures for organizational members abusing system privileges.

Building security into systems - issues of how to assure that security requirements are addressed in central and local participating systems, how to partition security responsibilities between central and local systems, and how to assure that security requirements remain satisfied as systems are modified or expanded.

Security of hard copy materials - issues of how to prevent security breaches from paper copies of sensitive electronic documents and data.

System integrity - issues related to defining user types and roles that serve to distinguish the functional needs and security levels of users.

User profiles - issues related to defining user types and roles that serve to distinguish the functional needs and security levels of users.

Legal and liability issues - issues relating to the uses and misuses of the system that involve potential liabilities of legal concerns for participating organizations, including protections under existing computer crime laws, liabilities when a record is compromised, and requirements for user penalties under union contracts.

Problem identification and resolution - issues of system audits and audibility, intrusion detection and notification of intrusions, and detection and notification mechanisms for other types of security problems.

Network security - issues relating to the security management of computer networks and the movement of data over such networks, including the security of bridges and routing equipment, the passing of authorization tokens, data encryption, electronic signatures, and nonrepudiation of messages.

Informed consent - issues related to the use of medical information collected about patients and obtaining consent from patients for desired and potential uses of medical data.

Education of users - issues related to the education of users regarding their responsibilities as system users and the risk conjured by their actions, including activities on the system and degrees of nonvigilance.

Even such limited efforts may achieve a reasonable level of privacy and data protection for patients and provide a general public with a sense of security, trust and protection. This will justify the financial expenses required to afford our goals to protect patient's rights.

6. OBJECT-ORIENTED MODEL OF A HEALTH CARE SYSTEM IN THE USA

The development of Application Functional Blocks of the Knowledge Module of an intelligent network is based on the same methodology as the development of Service Functional Blocks, namely - Object Oriented Analysis and Design.

. The model is expressed in terms of objects and relationships, dynamic control flow, and functional transformations.. In this chapter an analysis of a health care system is presented.

In a case of a knowledge - based complex medical network the elements of the system are the participating institutions and their knowledge bases. The results of an analysis may be presented in a form of a model, describing both major characteristics, parameters and attributes of elements and relationships between them. In this dissertation a model of a health care system in the USA is built based on the object - oriented analysis and design (OOA&D). The model is based on three steps, common for any Object-Oriented Model:

- Build an Object Model:
- Develop a Dynamic Model:
- Construct a Functional Model:

6.1 OBJECTS IN THE HEALTH CARE SYSTEM

The medical network may connect practically all major medical institutions of the US, a big number of medical offices, and quite a few related organizations, such as health insurance companies, Health Departments and Offices of Medical Examiners, Federal Drug Administration, National Health Foundation, pharmaceutical companies, manufacturers of medical equipment, etc. It will also interconnect numerous hospital and university LANs.

The knowledge base of the network may include a number of various databases, both existing and developed in future, which contain various objects, such as diagnosis and methods of diagnostics, treatments, patients history, billings and payments, personnel data and so on.

The potential members of the network for medical services, as represented by Fig. 6.1, may include among others:

- Hospitals and Nursing Homes;
- Medical and Dental Schools, Nursing Programs;
- Physicians and Medical Specialists offices;
- Pharmacies and Medical Labs;
- Insurance Companies;
- Health Officials offices;
- Private Research institutions;
- Manufactures.

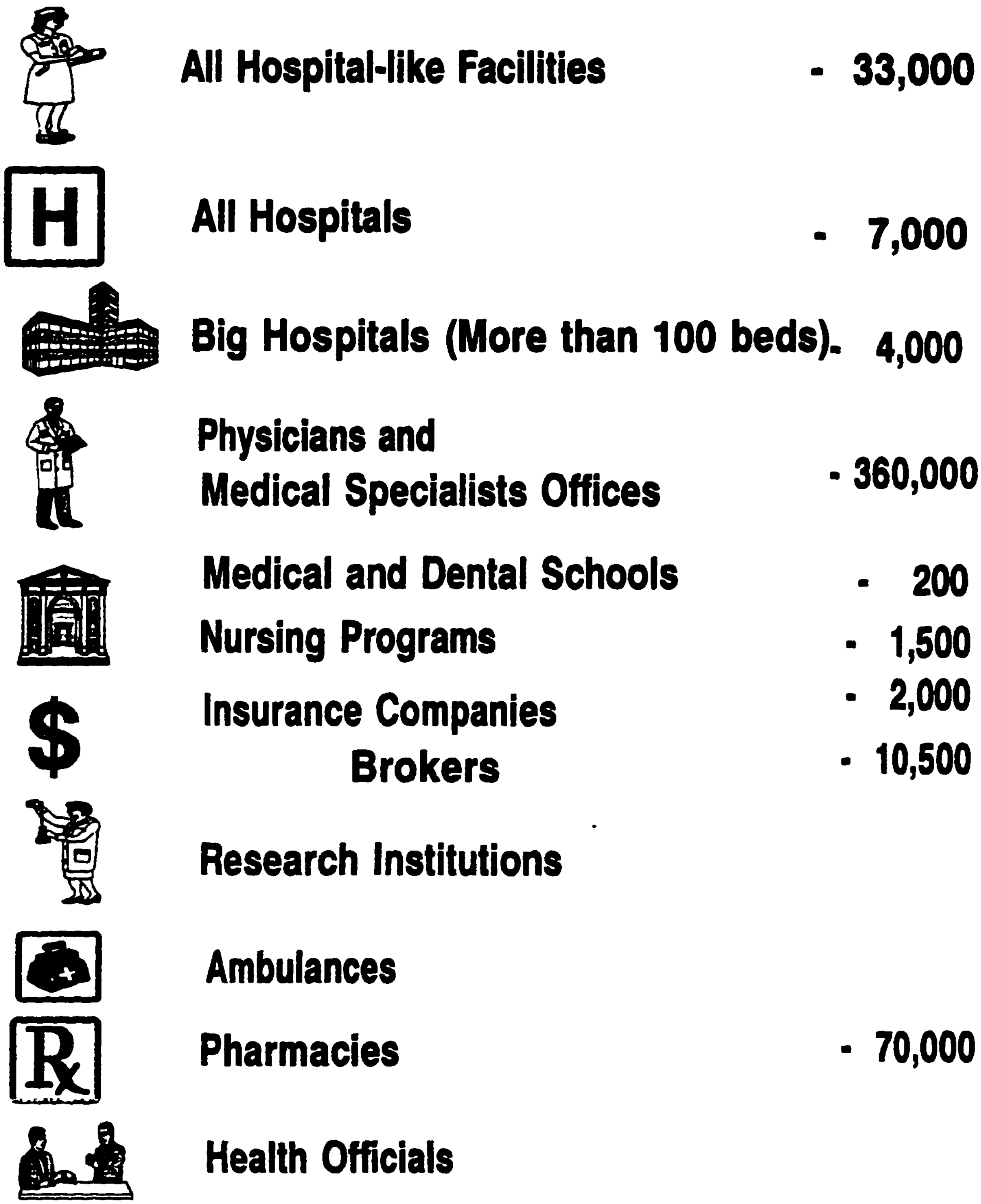


Fig. 6.1 Medical Network Participants

Medical Institutions.

According to the official data [141], there were 6,844 hospitals in the US in 1986 year, 3765 of them had more than 100 beds. The total number of hospitals in US is slightly but steady decreasing since 1975, as the number of bigger hospitals is on the rise: in 1975 there were total of 7,156 hospitals with 3,691 hospitals with more than 100 beds. The bigger hospitals are more likely to have a more advanced computer systems and to be interested in using a modern technology. The number of all hospital like facilities, including Nursing Homes is much higher: 32,600 (as of 1986). There are 142 Medical schools and 58 Dental schools in the US. In addition, there are about 1500 Nursing Programs. Out of the total number of 580,000 physicians in the US (this number includes those over 65 years old, inactive, etc.), 360,000 are considered active and office based. Although the number of medical offices differs from the number of physicians, due to partnership, multiple offices for one doctor, etc., an estimate of 200,000 - 300,000 seems to be reasonable.

Related organizations.

2000 Insurance Companies in the US offer health coverage policies, using 10,500 brokers. There were 556 HMO plans in 1991, and its number is increasing rapidly. Although no current estimate could be found, using newsletters and some articles one may conclude that each health insurance company had started at least one or two managed care networks. Therefore, at current time the number of HMO and Managed Care network may exceed the number of insurance companies. Among other related services, such as medical labs, ambulances and pharmacies, only the number of pharmacies in the USA - 70,000 - could be found. In addition there are Offices of Health Officials, with estimated number of few thousand, and also manufactures and private research institutions, whose numbers are hard to estimate. In the object model of the health care system we included only those types of participants of the medical network, who are directly related to providing a health care. Thus manufactures, research organizations and some other participants are excluded from the model.

Considering that many institutions may have more than one computerized information system, and therefore represent multiple access points to the network, the overall number of potential *Medical Network Access Points (MNAP)* may be found in a vicinity of 500,000.

According to their functional roles in providing medical care to patients, all participants in the medical network may be arranged in the following classes of objects:

- MEDICAL PROVIDER . This is the superclass with the following subclasses inheriting attributes and methods of superclass : HOSPITAL, PHYSICIAN, PHARMACY, MEDICAL LAB and SPECIAL SERVICES);
- MEDICAL KNOWLEDGE BASE superclass with subclasses of DIAGNOSIS and TREATMENT;
- CONSULTANT superclass, which includes subclasses of Medical Schools, Scientists and Health Officials;
- INSURANCE;

- and, of course, a class of PATIENT represents the central object in the whole structure.

These classes of the health care system in the USA are represented in Fig. 6.2, along with their associations, attributes and operators. Classes match to the members of the network, and associations correspond to processes within the system. All associations between classes in this chart are ternary, which reflects the complexity of a modern health care system. As follows from Fig. 6.2, we selected four independent processes among medical services.

The BILLING/PAYMENT process.

The process of billing and payment is at the present time the most elaborated in existing health care systems. It describes the relationships between object classes of PROVIDER, PATIENT and INSURANCE. Most of existing MIS in hospitals and insurance companies will fall into this category. The relationship between medical provider, patient and insurance should be modeled as a ternary association, since there are many-to-many relationship between medical provider and patient (each patient may visit different doctors and other types of medical providers, as well as each medical provider have more than one patient), and each medical provider - patient connection may be covered by more than one medical insurance coverage. The ternary association between classes of medical provider, patient and insurance can be modeled as a class of claim. Claims processing is a core of any insurance business. Claim may be used to formally define financial aspects of complex transactions between providers and patients. This is why claim is used as a link attribute in two other processes also shown in Fig 6.1. The billing / payment process has already been developed as a part of many managed care networks and is rather a purely business application. Although it is a very important unit of a global medical /health care network, it is not further elaborated in this dissertation since it does not have much of a scientific significance.

The CURE process

This process describes the main goal of the medical services - when the PATIENT is cured by a MEDICAL PROVIDER, utilizing available MEDICAL KNOWLEDGE. This, in fact is the core process in any health care or medical system. The ternary association represent a many - to - many relationships between a medical provider, a patient, and a medical knowledge described by diagnosis and treatment , i.e. the fact that a patient may be treated by the same doctor or institution for multiple disorders, or by different providers for a complex disease, and that various medical knowledge information may be utilized for different ailments, or different providers may refer to different segments and components of medical knowledge even when dealing with the same illness. The billing / payment process, described earlier, illustrates the financial aspect of the encounter between a medical provider and a patient, while a cure process describes a clinical meaning of the same relation.

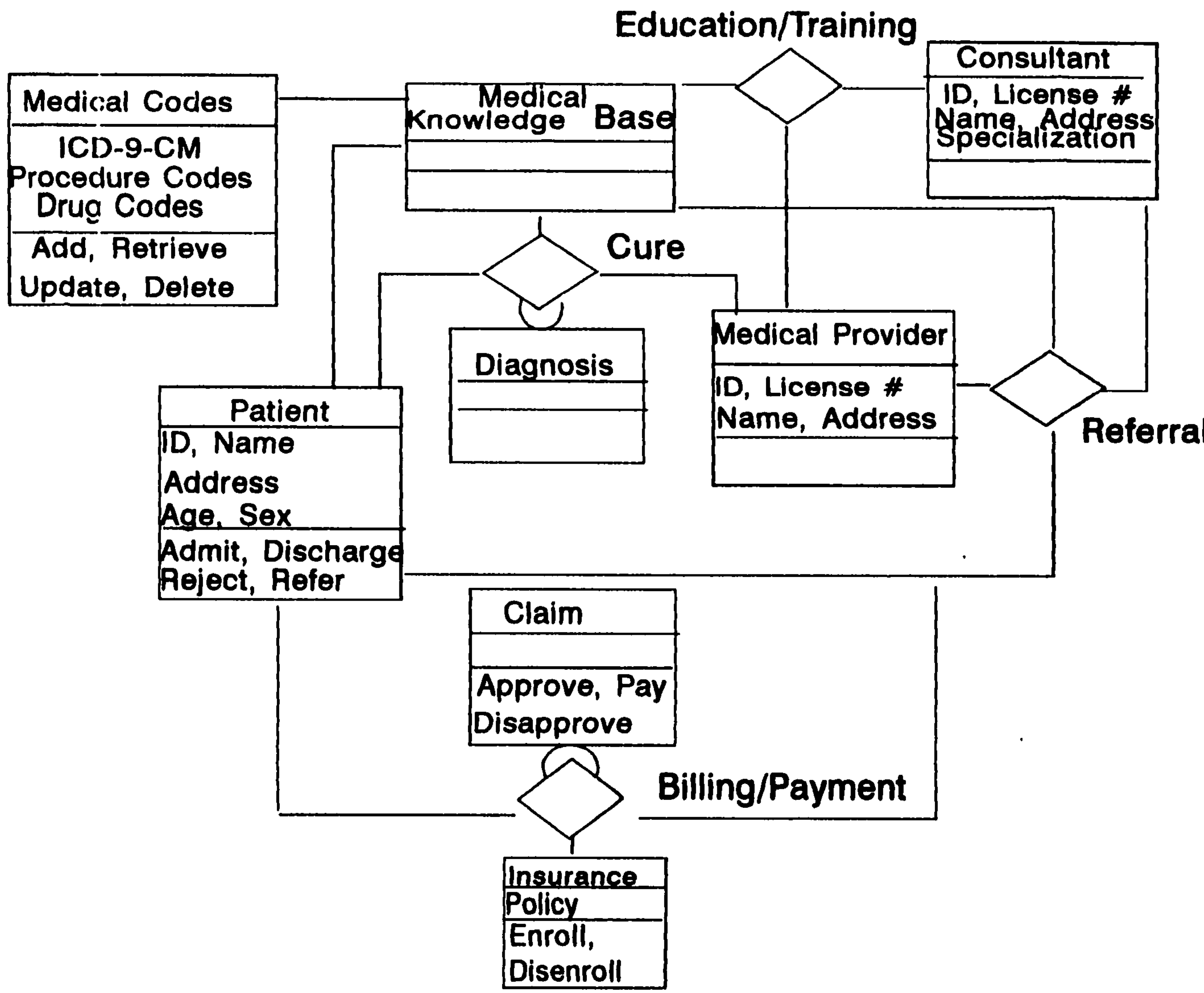


Fig. 6.2 Object Model of a Health Care System

The REFERRAL process

This process, which takes place between Medical Provider, Consultant and Patient with the help of a Knowledge Base may be considered as complementary to CURE process. But as medical and health care systems are increasingly moving toward managed care organization, the role of the REFERRAL process becomes more and more important. While being under general care of his/her primary physician (subclass of medical provider), a patient may be referred to a medical specialist (consultant) to answer specific medical questions. The problems associated with the referral are selecting a consultant, conveying the right information, organizing additional referral, if necessary, sending the answers back . In the referral process telecommunication becomes an important part of the process itself. Intelligent decisions have to be made concerning composing a message itself, selection of destination, tracking the request and sending an answer back to the original inquirer.

The EDUCATION/TRAINING process

Another ternary association between PROVIDER, CONSULTANT and MEDICAL KNOWLEDGE, represent the education/training process. As in a case of CURE process, the ternary association was chosen to represent the fact of many - to - many relationship between providers, consultants and medical knowledge. It is important to note, that educational system is, in turn, the knowledge-based system on its own. Therefore to fully describe the education / training process in a medical intelligent system we would have to have to show the way how the deal two knowledge-based systems interact with each other.

The superclass of MEDICAL CODES

The processes described above (Payment / Billing, Cure, and Education / Training) are not completely independent from each other. They all show connections between the same classes of Provider, Patient, Consultant and Medical Knowledge objects. Finally, the object - oriented model of the USA health care system, presented in this dissertation, uses ICD-9-CM Diagnostic, Procedure and External Causes of injury and poisoning Codes together with NDC Drug codes as universal identifiers of medical / clinical encounters and financial insurance transactions. Therefore, all classes of objects presented on the Fig. 6.2 are considered to be subclasses of a superclass MEDICAL CODES (ICD-9-CM / NDC).

- *Diagnostic codes*: The ICD-9-CM classification has three digit diagnostic codes with 1 or 2-digit optional subcodes. All possible 999 codes are utilized within system, and are broken down by 17 categories.
- *Procedure Codes*: Two supplementary classifications for medical procedures are included in ICD-9-CM:
- \- A V-supplementary classification of procedures, where each procedure may be identified by a two position code with 2 - position subcodes. So far 82 codes are utilized (V01 through V82);

- - An E-supplementary classification of external causes of injury and poisoning (codes E800 through E999).
- *Drugs Codes*: . The format of NDC ID number is 5-digit code, 3-digit subcode and 2-digit dosage/packaging size code. Therefore the full identification number for drugs is 10 digits long. This is enough to identify 10 billion of unique drug units

.

The PATIENT class of objects.

From the Health Care Services point of view, a Patient is nothing else but the Code of Disease, and as such, the class PATIENT is a subclass of MEDICAL CODES. Therefore the class PATIENT inherits the attributes CODE OF DISEASE and DRUG CODE from the class MEDICAL CODES. At the same time a patient is an element of the society. As such a social element it has attributes of ID (usually Social Security No), NAME, ADDRESS, AGE, SEX, etc. Yet, each patient is unique not only as an individual, but also as a bearer of his/her distinctive medical statistics. This statistic is a vital part of the universal Medical Codes of Diseases. Thus an attribute MEDICAL STATISTICS is added to the class PATIENT. The medical statistics of individual patients may be utilized when need for re-classification, modification and correction of Medical Codes occurs.

The CLAIM object class

Among the most common attributes of the CLAIM class of objects are type of a claim (Hospital, Medical, Drugs, Lab procedure, and others), basic information related to a patient, medical provider and insurance coverage, which allows to identify all three objects connected, information which identifies the event (diagnosis, procedure, charge, etc.) and also information which allows to exclude duplicate and falsified claims (i.e. date and cite of service)

6.2 THE CLASS OF MEDICAL PROVIDER

6.2.1 The MEDICAL PROVIDER abstract superclass.

The MEDICAL PROVIDER superclass includes subclasses of Hospitals, Physicians, Pharmacies, Medical Labs and other related services, such as rehabilitation or physical therapy. It is linked to the class of medical codes, because practically every transaction involving medical providers has to be formally expressed in terms of the accepted medical codes. The class of medical provider is an abstract class, since no direct instances of this class exists in a real life. All the subclasses (HOSPITAL, PHYSICIAN, PHARMACY, MEDICAL LAB, SPECIAL SERVICES) inherit the following attributes from the superclass MEDICAL PROVIDER: ID, NAME, ADDRESS, SPECIALIZATION. Identificator (ID) is defined in a superclasss medical provider as a license number. Subclasses may override this default definition with other type of identifier. The operations on MEDICAL PROVIDER superclass, also inherited by all subclasses, are: ADMIT, DISCHARGE, REJECT and REFER (a Patient).

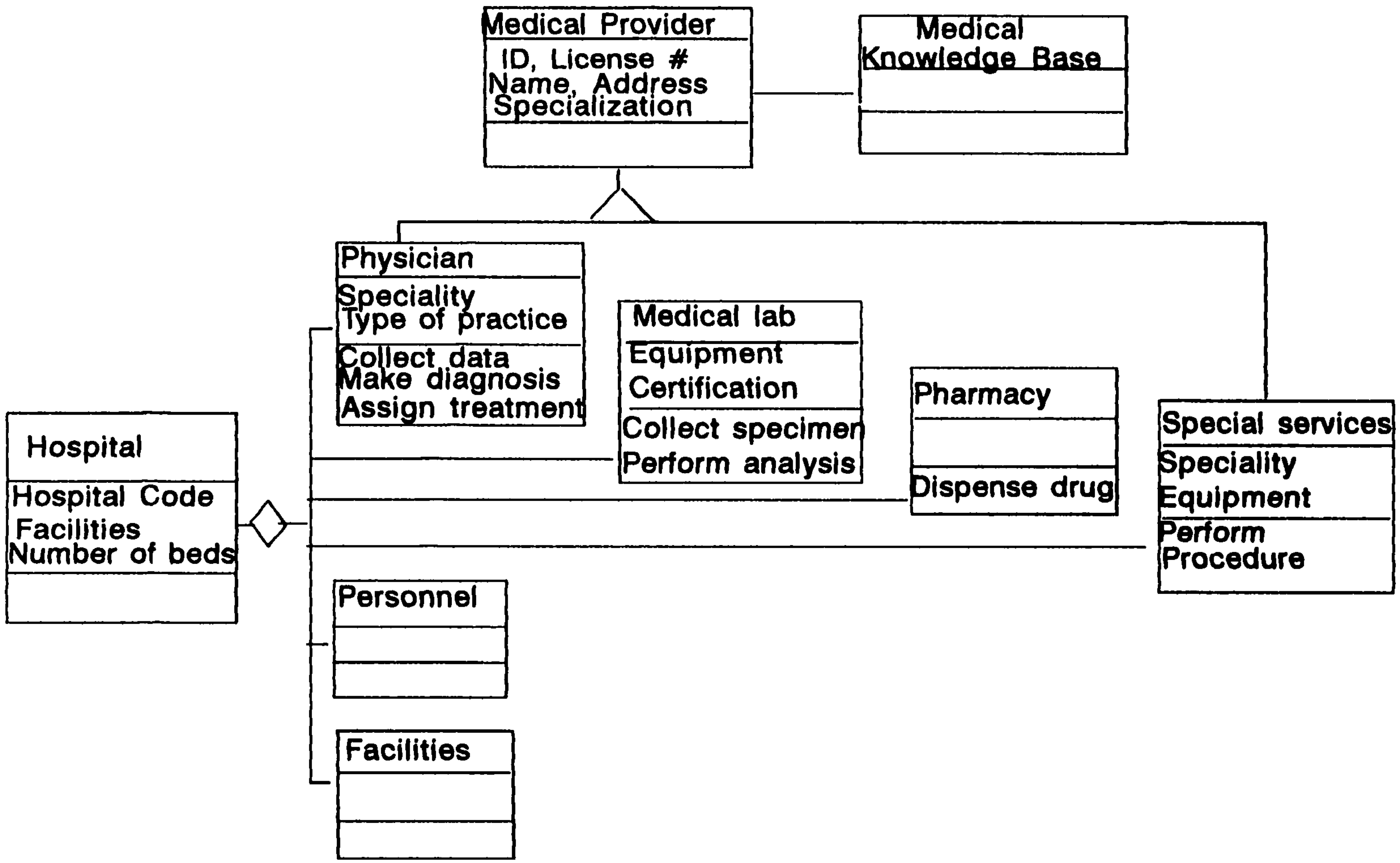


Fig. 6.3 Class of Medical Provider Object Model

All subclasses may override inherited attributes and operations, as well as they may add their own attributes and methods. The complex structure of MEDICAL PROVIDER object class is shown in Fig. 6.3.

6.2.2 The HOSPITAL class.

The most complex subclass in the superclass of medical provider is HOSPITAL. On one hand, being a subclass of medical provider, it inherits all the attributes (Id, name, address, specialization) and methods (admit, discharge, reject and refer). In addition, hospital has such attributes as hospital code, types of hospital facilities, codes for programs and approvals, types of special services, numbers for employees total number of beds,, number of beds for nursing home and rehabilitation programs, outpatient visits [62]. On the other hand, it is an aggregation of all other subclasses of medical provider (physician, pharmacy, medical lab and special services), human personnel and facilities (subclasses PERSONNEL and FACILITIES). An aggregation is a strong form of association in which an aggregate object (hospital, in this case) is made of components (all other subclasses of medical provider class and other supporting services).

6.2.3 Subclass PHYSICIAN.

These classes, besides being possibly aggregated as hospital components, may also function as independent units. In addition to having inherited attributes and operations from superclass MEDICAL PROVIDER, each subclass may also have its own attributes and operations or override inherited characteristics with its own parameters. Particularly, as was mentioned earlier, class of physician may use an Universal Physician Identifier Number (UPIN) by the Health Care Financing Administration or the prescribers' code being developed by the National Council of Prescription Drug Programs, Inc. (NCPDP) in collaboration with American Medical Association. Additional attributes for the PHYSICIAN class, as used in the Directory of Physicians [45], include Physician primary and secondary specialty, type of practice, American Specialty Board and so on. Operations added for a class of physician are COLLECT DATA, MAKE DIAGNOSIS and MAKE A PRESCRIPTION.

6.2.4 Subclasses PHARMACY, MEDICAL LAB, SPECIAL SERVICES.

The MEDICAL LAB class has attributes EQUIPMENT and CERTIFICATION, and operations COLLECT SPECIMENS and PERFORM ANALYSIS. For the PHARMACY class we added operations DISPENSE DRUG, and for the SPECIAL SERVICES class - attributes SPECIALTY and EQUIPMENT and operation PERFORM PROCEDURE.

6.3 KNOWLEDGE BASE OF THE HEALTH CARE SYSTEM

6.3.1 Medical Codes aggregate class

Medical Knowledge Base class is a subclass of MEDICAL CODES, which, in turn, is an aggregation of classes of ICD-9-CM codes, Procedure Codes and Drug Codes NDC. Widely adopted by insurance companies, hospitals and physicians, these code classifications are presented in our design as one class MEDICAL CODES, where all other objects in the system have associations with it, or are subclasses of this class. The more detailed analysis should attribute each subclass of the medical knowledge base class to the appropriate class of medical codes aggregate class. In this dissertation, however, all related connections are assigned to the aggregated class of medical codes, without a differentiation.

6.3.2 MEDICAL KNOWLEDGE BASE superclass.

The MEDICAL KNOWLEDGE BASE (MKB) is a subclass of MEDICAL CODES. It inherits the attributes of CODE OF DISEASE, CODE OF PROCEDURES and DRUG CODE .

According to the definition of knowledge, presented earlier in chapter 1, data are the individual items made available to the analysts, information is a set of data with some interpretation or value added, and knowledge is a set of rules, formulas, or heuristics used to create information from data and information. Therefore, a medical knowledge base class may be presented by an aggregation of classes DATA, RULES and INFORMATION. The links between data, rules and information correspond to this definition, as rules describe the conversion of data and/or information into a new information (Fig. 6.4).

6.3.3 Class of MEDICAL DATA

MEDICAL DATA class is comprised of subclasses of patient's personal data (Name, age, Id, address, etc.), patient's physical data (weight, height, anatomical abnormalities), physician's observations on a patient, and results of medical analysis. (Fig. 6.4). The duration of a period when these data are valid may significantly vary from a lifetime span (for Id, Name) or long-term (address, height for adults, etc.) to a very short period. For example, a set of data for 10-20 parameters is registered every 15 seconds during a surgery.

6.3.4 Class of MEDICAL INFORMATION

Class of MEDICAL INFORMATION is comprised of DIAGNOSIS and TREATMENT subclasses, as presented on Fig. 6.4 .

Class DIAGNOSIS is fully characterized by the inherited attribute CODE OF DISEASE, and has the only operation MAKE. As diagnosis is made based on patient's symptoms and the results of analysis, the class DIAGNOSIS is an aggregation of subclasses ANALYSIS and SYMPTOM. Analysis may be represented by a number item, corresponding to the type of procedure related to obtaining an analysis. As for symptoms, no formal classification is developed yet, and the value of the attribute will include the text with verbal description of a symptom.

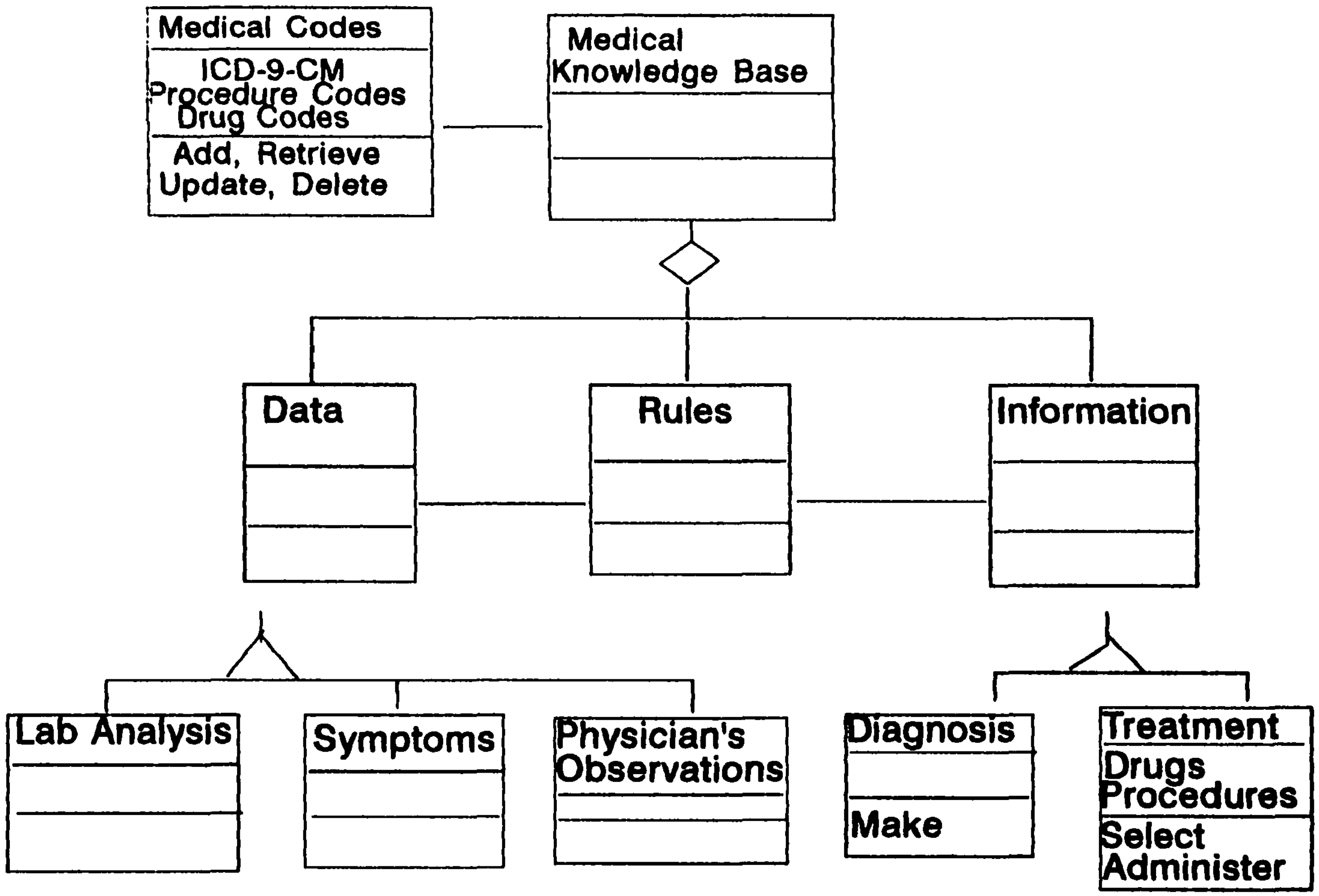


Fig. 6.4 Class of Medical Knowledge Base Object Model

The TREATMENT is a generalization of 2 subclasses - MEDICAL PROCEDURE and DRUG. We introduced 2 operations on TREATMENT: SELECT and ADMINISTER. The PROCEDURE class has such attributes as PROCEDURE CODE and EQUIPMENT. The PROCEDURE CODE attribute is represented by officially adopted code. Government agencies and some private companies use their own internal classifications for an utilized equipment. There is no nationally adopted universal system for the equipment codes. Development of the STANDARD MEDICAL EQUIPMENT CODES may be one of the task which has to be resolved when the network for medical services is created.

The class of Medical Procedure may be further subdivided into subclasses of Therapeutical Procedure, Physical Therapy, Surgery and Rehabilitation Procedure (Fig. 6.5). Each of these subclasses may, in turn, be further subdivided into relevant subclasses. This process may be continued until object models of all atomic medical subprocedures will be built. The dissertation illustrates this process by using subprocedure surgery as an example (Fig 6.6). The class of surgical procedure is further subdivided into subclasses of Pre-operating Procedure, Anesthesia, Operation, and Post-operating Care. Finally, an object Anesthesia is presented on Fig. 6.7, as a lowest level of a medical procedure breakdown.

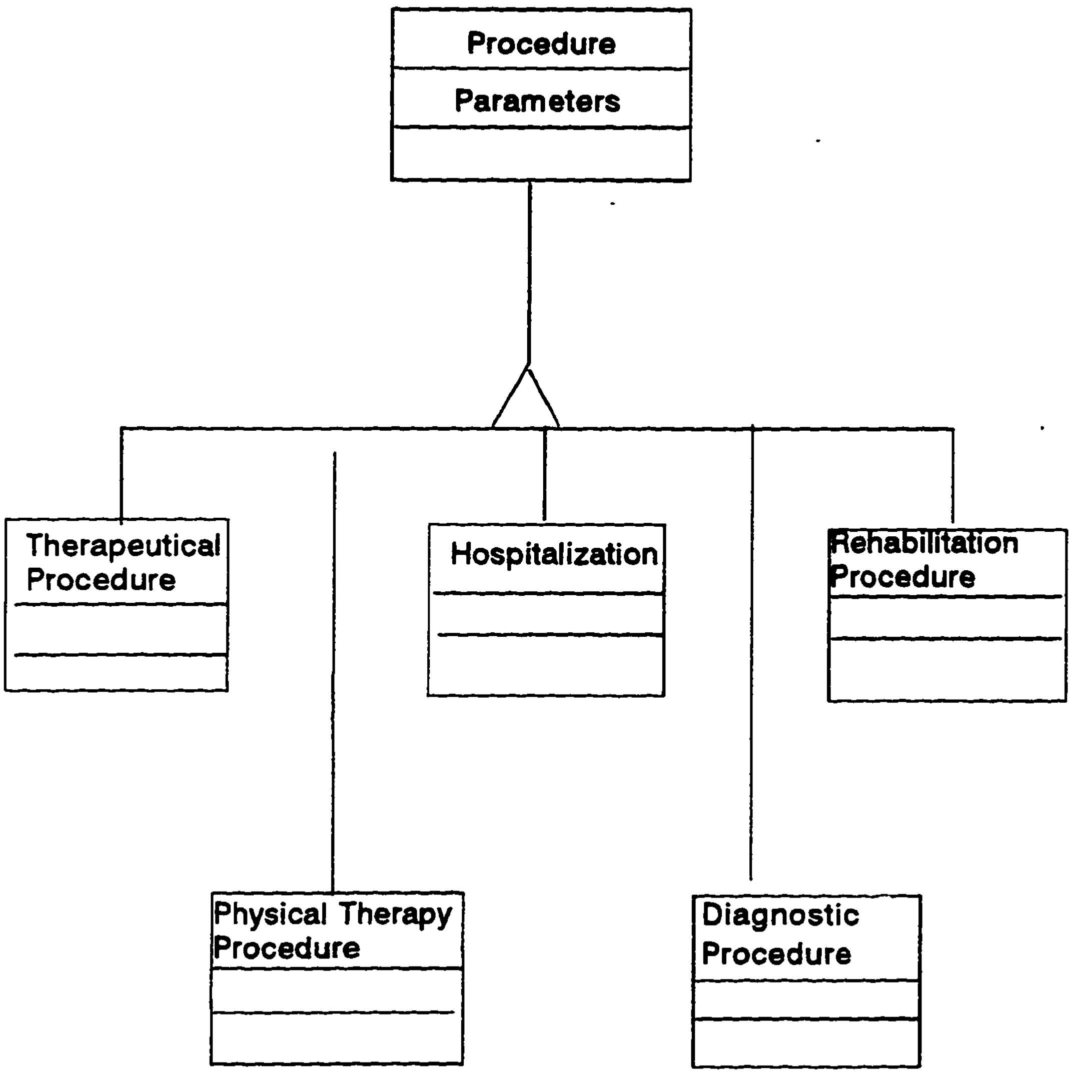


Fig. 6.5

Class of Medical Procedure Object Model

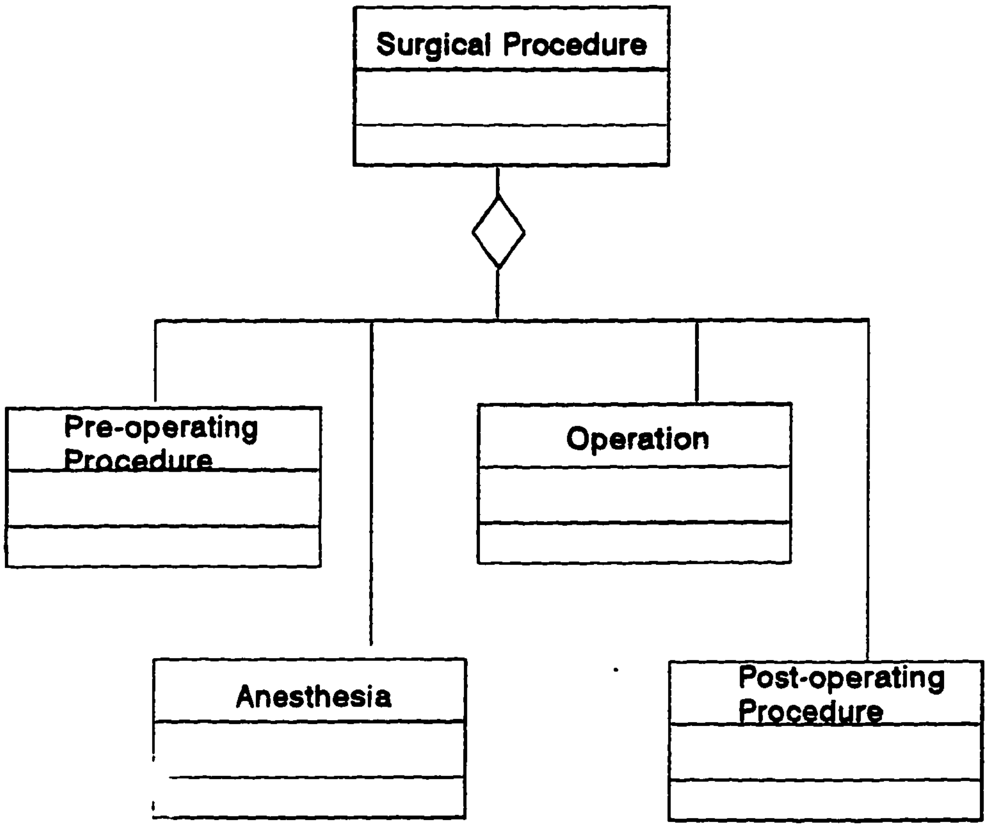


Fig. 6.6 Subclass of Surgery Object Model

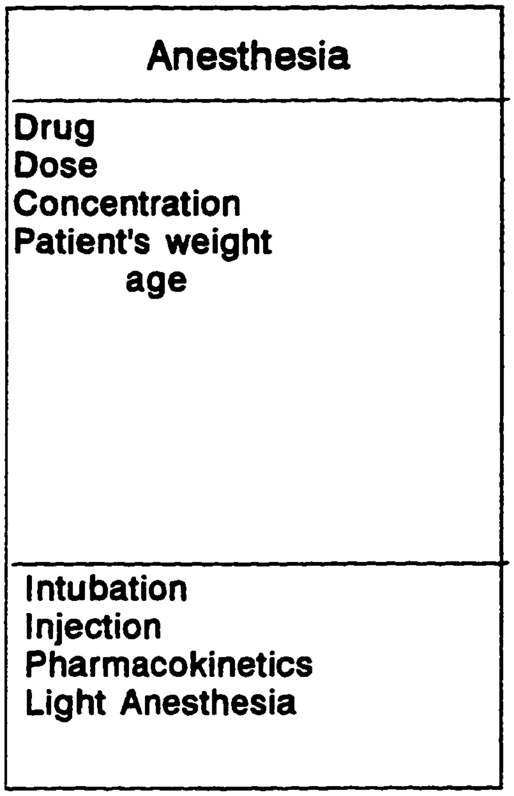


Fig. 6.7

Subclass of Anesthesia Object Model

6.3.5 Class of MEDICAL RULES.

Medical rules are descriptions of processes to convert medical data (patient symptoms, analysis results and physician's observations into medical diagnoses and treatments. For a long period in history medical reasoning, which constitutes most of medical rules, was a process based on description and intuition as much as on analytical reasoning. During last decades, with widespread use of computers and artificial intelligence methods, medical rules in forms of expert systems, statistical models, simulation models and so on started to appear. This subclasses of medical rules were described in greater detail in chapter 1.

6.4 DYNAMIC MODEL OF A HEALTH CARE SYSTEM

State Diagrams

An object model describes the possible patterns of objects, attributes, and links that can exist in a system. [107]. The attribute values and links held by an object are called its state. Over time, the objects stimulate each other, resulting in a series of changes to their states. An individual stimulus from one object to another is an event. The response to an event depends on the state of the object receiving it, and can include a change of state or the sending of another event to the original sender or to a third object. The pattern of events, states, and state transitions for a given class can be abstracted and represented as a state diagram. A state diagram is a net of states and events, just as object diagram is a net of classes and relationships. The dynamic model consists of multiple state diagrams, one state diagram for each class with important dynamic behavior, and shows the pattern of activity for an entire system. Each state machine executes concurrently and can change state independently. The state diagrams for the various classes combine into a single dynamic model via shared events.

Every event is an unique occurrence, which can be grouped together into event classes and be given a name to each event class to indicate common structure and behavior. This structure is hierarchical. One event may logically precede or follow another, or the two events may be unrelated. Two events that are causally unrelated are said to be concurrent; they have no effect on each other. If the communications delay between two locations exceeds the difference in event times, then the events must be concurrent. because they cannot influence each other Even if the physical locations and time frames of the two events are not distant, events are considered to be concurrent, if they do not affect each other.

Scenarios

A scenario is a sequence of events that occurs during one particular execution of a system. The scope of a scenario can vary; it may include all events in the system, or it may include only those events impinging on or generated by certain objects in the system. A scenario can be the historical record of existing a system or a thought experiment of executing a proposed system. Each event transmits information from one object to another. Therefore the next step after writing a scenario is to identify the sender and receiver objects of each event. The sequence of events and the objects exchanging events can both be shown in an event trace diagram.

A state is an abstraction of the attribute values and links of an object. Set of values are grouped together into a state according to properties that affect the gross behavior of the object. A state specifies the response of the object to input events. The response of an object to an event may include an action or a change of state by the object. A state corresponds to the interval between two events received by an object. Events represent points in time, states represent intervals of time.

A state diagram relates events and states. When an event is received, the next state depends on the current state as well as the event; a change of the state caused by an event is called a transition. A state diagram is a graph whose nodes are states and whose directed arcs are transitions labeled by event names. The state diagram specifies the state sequence caused by an event sequence. If an object is in a state and an event labeling one of its transitions occurs, the object enters the state on the target end of the transition. A state diagram describes the behavior of a single class of objects. Since all instances of a class have the same behavior (by definition), they all share the same state diagram, as they all share the same class features. But as each object has its object attribute values, so too each object has its own state, the result of the unique sequence of events that it has received. Each object is independent of other objects and proceeds at its own pace.

Dynamic Model

The dynamic model is a collection of state diagrams that interact with each other via shared events. An object model represents the static structure of a system, while a dynamic model represents the control structure of a system. A state diagram, like an object class, is a pattern; it describes an entire, possibly infinite, range of sequences. A scenario is to a dynamic model as an instance diagram is to an object model.

The dynamic model describes different states of the system, and events and processes which causes the system to change state. In this model of medical services for a patient, the states of the system are associated with the states of a patient. Any person may be in a healthy condition, be latently sick, or have a specific disease. The disease may be in acute or in chronic forms. This states and processes of changing them in a system are represented by Fig. 6. 8.

A Lifetime Scenario

The scenario for a lifetime of a typical person representing a patent may be described as following. Initially a patient is in a healthy state. Then he or she may happened to be in a latent state. Sooner or later a patient's condition will be changed to an acute form or a chronic condition of a disease. After a treatment (or without it) this acute condition is cured and a sick person may be returned into a healthy state. A patient with a chronic disease may stay in this condition for the whole life or may eventually return to a healthy condition.

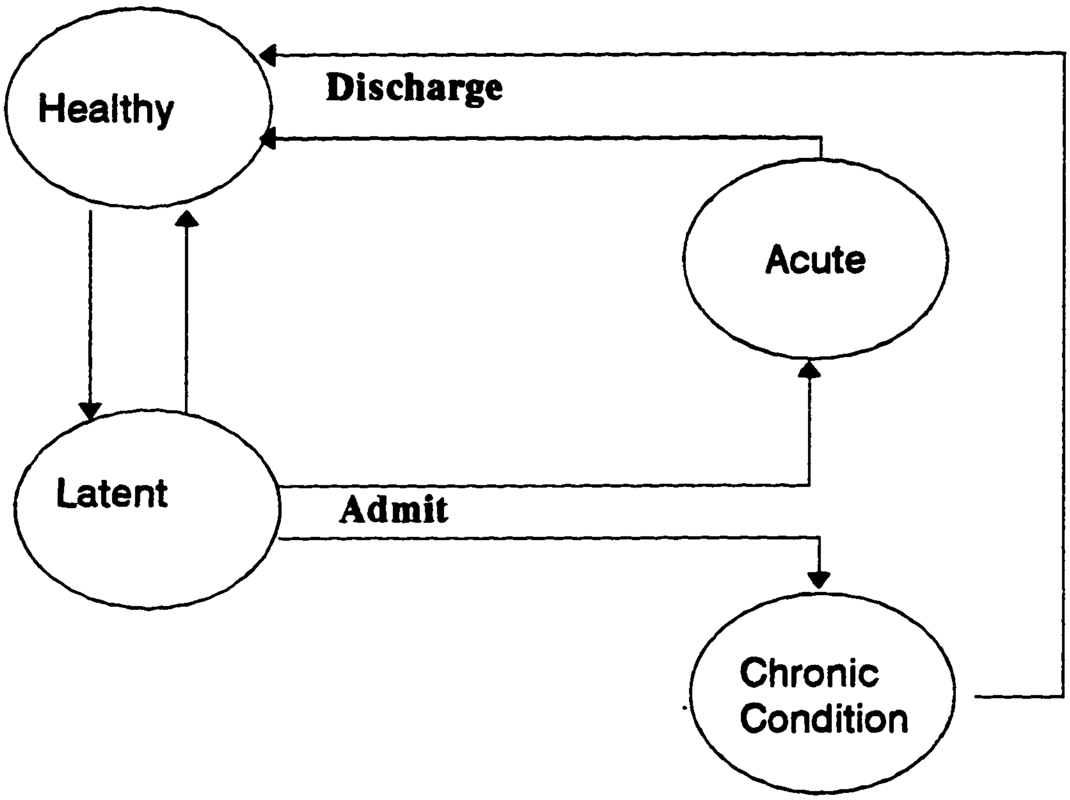


Fig. 6.8
Dynamic Model of Object Patient in a Health Care System

This chart describes a patient condition for each disease (medical diagnosis) independently, so each person may have more than one dynamic diagram representing his / her condition. On each diagram a patient may be found in a different state.

Healthy and Latent States

The event of transition from a healthy state to a latent disease is usually unnoticed, and its time may be approximately estimated later, usually by a physician during a physical examination. Both the healthy and the latent states are usually out of observation by a health care professionals. Nevertheless, a patient may be occasionally observed and treated while being in a healthy or a latent stage - for example when having physical, annual screening or vaccination. In terms of this model, the whole purpose of screenings or physical examinations may be set up to discover latent stages of certain diseases and to provide a care and appropriate treatment for a sick person. One of the goals of a preventive branch of a health care system is to minimize the duration of a latent period of a disease, while one of a possible component of a criteria of evaluation of a quality of a health care system may be the average length of a latent period among the population.

An Acute State

The event of transition of a patient from a latent to an acute state is usually coincided with his / her admission by a health care provider. During an acute and a remission stages a patient is under control of a health care system.

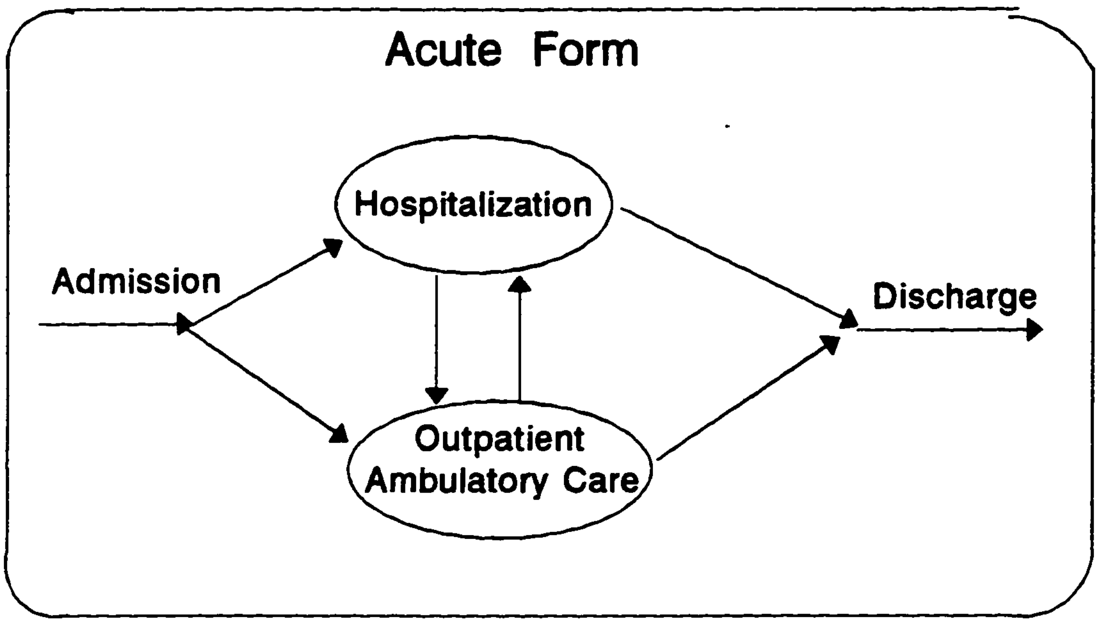


Fig. 6.9

Subdiagram of Acute Form of a Disease

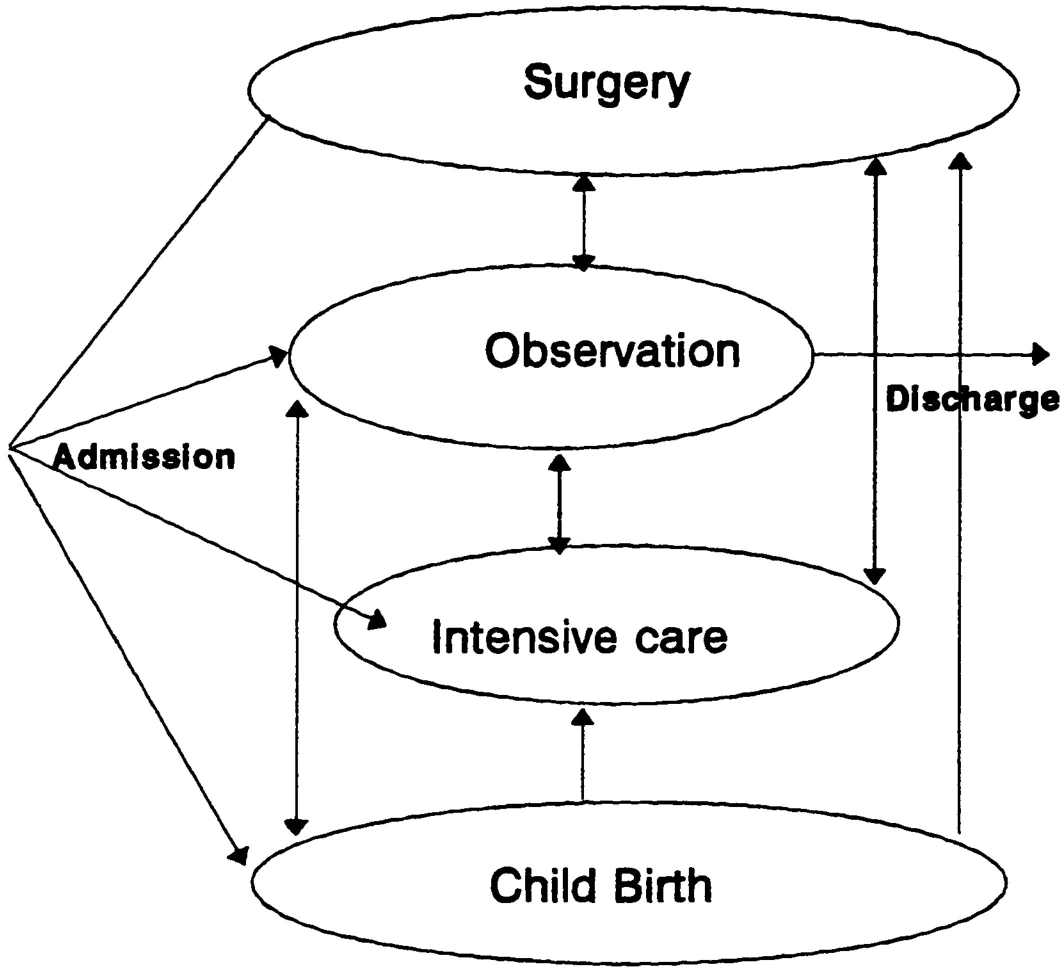


Fig. 6.10 Subdiagram of Hospitalization

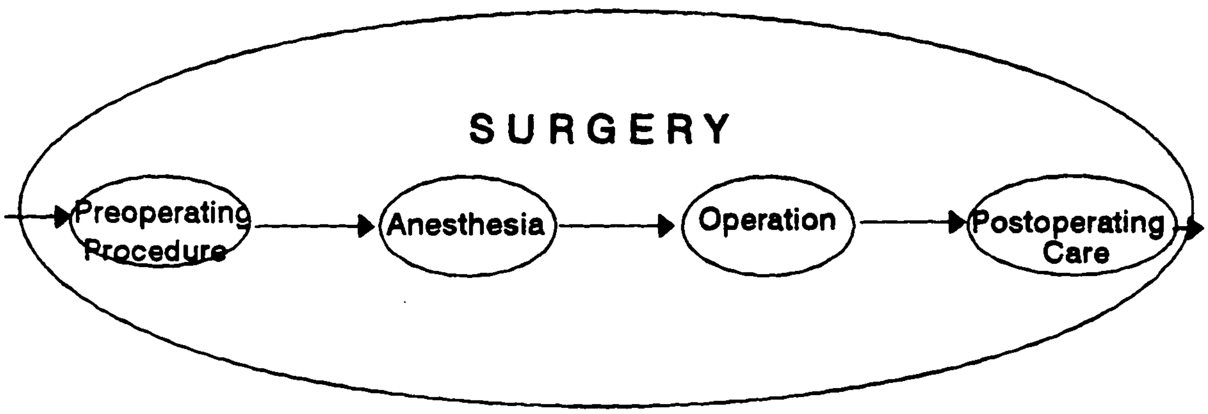


Fig. 6.11

Subdiagram of Surgery

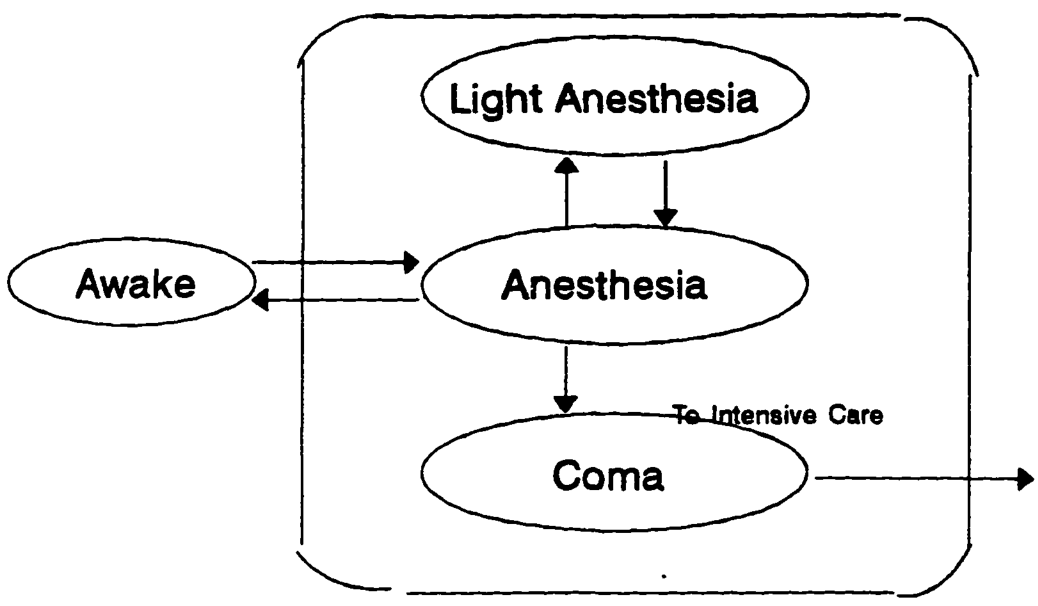


Fig. 6.12

Subdiagram of Anesthesia State

The acute stage of a disease may, in turn, be broken down into sub-stages of hospitalization and outpatient / ambulatory office care (Fig 6.9). Hospitalization may or may not involve surgery, intensive care and some special procedures. Surgery includes pre-operation, anesthesiology, operation and post-operation states.

Each of these stages may be further detailed and divided into micro-stages. In fact, anesthesiology alone is a very complex process, which includes different states of a patient's condition, events, and actions of a medical personnel based on perplex rules of reasoning.

The subdiagrams of states of Hospitalization, Surgery and Anesthesiology are presented in Figs. 6.10 - 6.12.

A Chronic Condition

In a chronic condition a state of a patient alternates between Exacerbation and Remission. Its diagram is presented on Fig. 6.13. Exacerbation stage may be compared with an acute condition, and may be described by using a model analogous to an subdiagram of an acute state. A remission state is confined to outpatient / ambulatory services. The function of these services is to extend a duration of this remission period and, if possible, to return a patient into a healthy stage. Outpatient / ambulatory services may include states of drug treatment, physical therapy, social services, other kinds of therapy. The subdiagram of a remission state is presented on Fig. 6.14

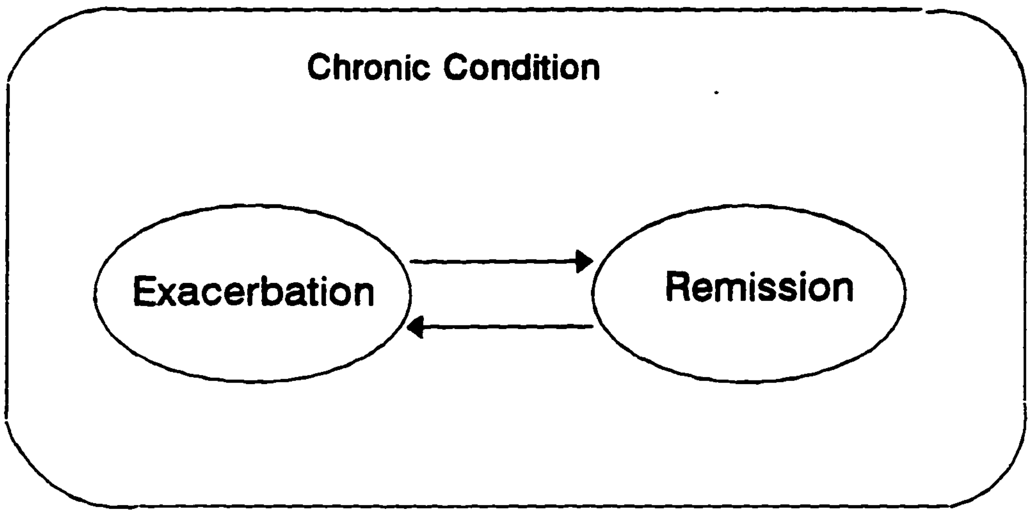


Fig. 6.13

Subdiagram for Chronic Condition

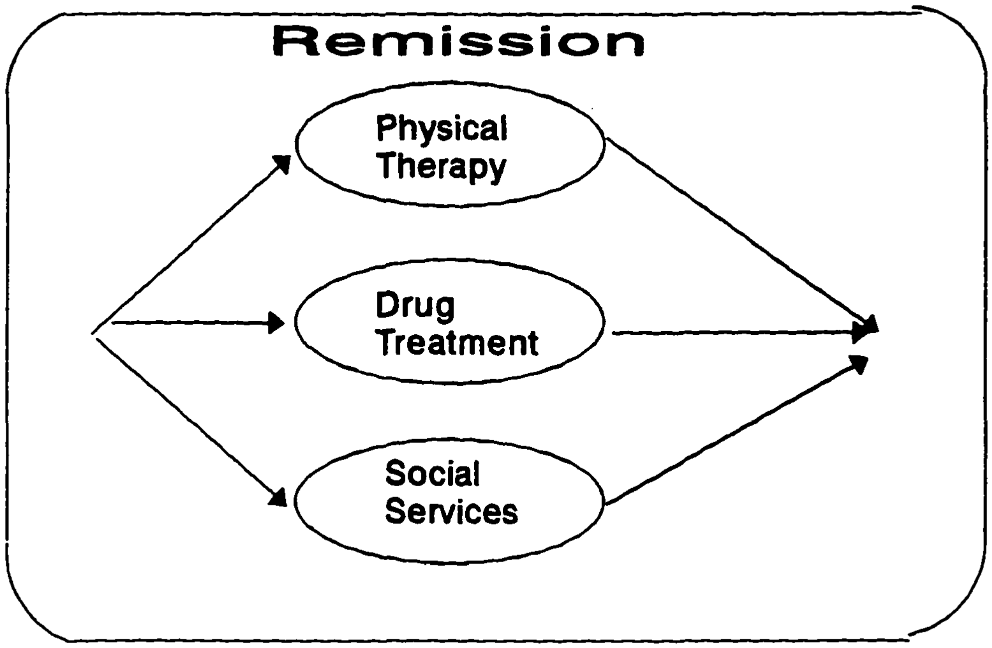


Fig. 6.14

Subdiagram of Remission State

6.5 FUNCTIONAL MODEL OF THE HEALTH CARE SYSTEM

The functional model describes the data transformation within a system. This is the third and final part of the complete object oriented model. The functional model specifies what happens, the dynamic model specifies when it happens, and the object model specifies what it happens to. The functional model shows how an output data or information are derived from input values, without regard for the order in which the values are transformed. The functional model consists of multiple data flow diagrams which show the flow of values from external inputs, through operations and internal data stores, to external outputs. The functional model also includes constraints among values within an object model. The functional model specifies the results of a data conversion without specifying how or when they are converted.

The functional model consists of multiple data flow diagrams which specify the meaning of operations and constraints. A data flow diagram shows the functional relationships of the values transformed by a system, including input values, output values, and internal data stores. A data flow diagram is a graph showing the flow of data values from their sources in objects through processes that convert them to their destinations in other objects. A data flow diagram contains processes that transform data, data flows that move data, actor objects that produce and consume data, and data store objects that store data passively.

As was mentioned earlier, we have outlined three major processes in the Medical Services System: Education/Training, Cure and Billing/Payment, corresponding to the three major subsystems. Education/Training subsystem may as well belong to an

Educational Intelligent network, with Knowledge Module supplied by the Medical Services System. Therefore Education/Training units may in a future utilize the basic Medical Knowledge Processing modules, adapted for educational needs. We have to keep in mind this possibility while developing Medical System Objects and Processes, making them as flexible and versatile as possible.

Billing/Payment subsystem is a typical example of administrative system. During its design and development we have to integrate existing hospital, insurance, university MIS's into one network, which will require dynamic interface systems.

The Cure process between PHYSICIAN, PATIENT and MEDICAL KNOWLEDGE BASE is the core of the Medical Intelligent System. It will eventually be broken down on subprocesses with one thing common for all of them - all these processes have the MEDICAL KNOWLEDGE BASE as one of their sources of input data. By this reason we may address the functional blocks which perform these processes as Medical Knowledge Processors (MKPs).

The description of the CURE process

Fig. 6.15 is the functional model of a health care system. It corresponds to the Data Flow diagram for the CURE process. It includes classes of a MEDICAL PROVIDER and a Patient, major processes, which correspond to these classes operators or methods, and Medical Diagnosis data store for an information exchange.

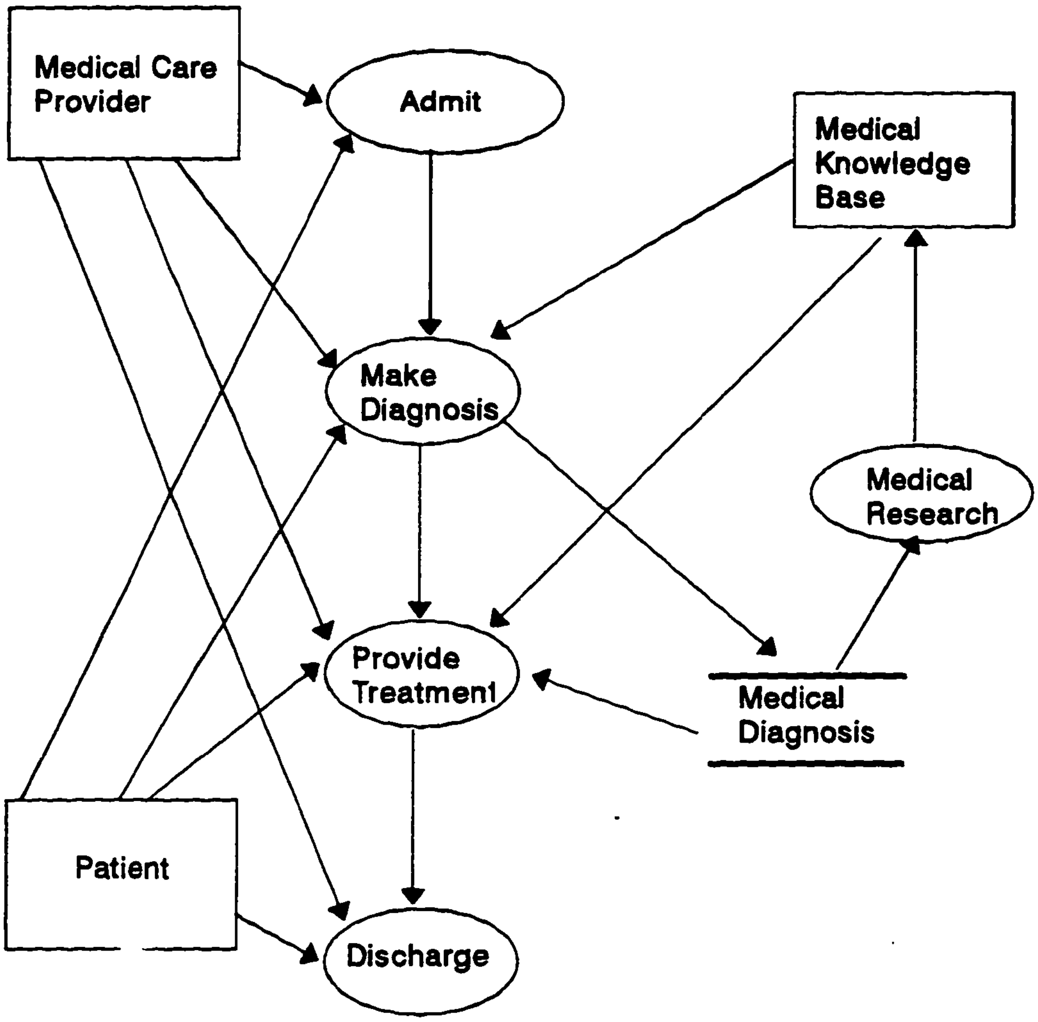


Fig. 6.15

Functional Model of a Health Care System

The processes included in this diagram are Admit, Make Diagnosis. Provide Treatment and Discharge. The processes Make Diagnosis and Provide Treatment in this chart are supported by the MEDICAL KNOWLEDGE BASE object. All processes on this diagram match the operations on subclasses of objects in the MEDICAL PROVIDER class. The class of Medical Diagnosis, is a result of Make Diagnosis process and is an input to a Provide Treatment process. Therefore Medical Diagnosis is represented by a data store object. Medical Research is a process which maintain and updates the Medical Knowledge Base object.

Each process possibly defines a functional node in the Knowledge Module of the Intelligent Medical System. During further analysis and design each process will be broken down into more specific subprocesses and operations, and some classes of objects will be divided into more detailed subclasses.

For example, the Make Diagnosis process may be expanded as represented by Fig. 6.16. The initial interaction between PHYSICIAN and PATIENT may be broken down to subprocesses of COLLECT DATA, COLLECT SPECIMENS, PERFORM ANALYSIS. All these processes in this chart are supported by the MEDICAL KNOWLEDGE BASE object. In order to clarify the relationships between objects in the diagram, the links between the medical knowledge base and all other objects are not shown. Nevertheless these connections exist and has to be accounted in the detailed analysis of each object and subprocess.

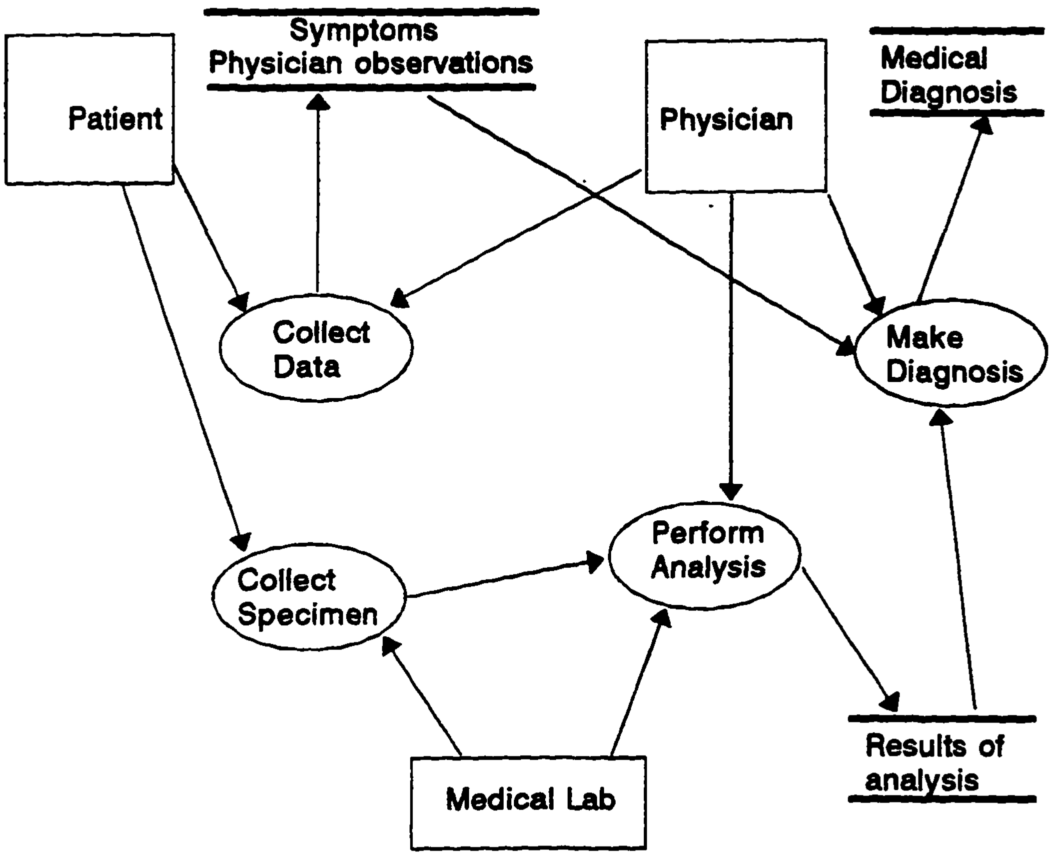


Fig 6.16
Expansion of Make Diagnosis Process

The MEDICAL LAB object participates in the COLLECT SPECIMENS and PERFORM ANALYSIS processes. PHYSICIAN then can MAKE a DIAGNOSIS, using the result of analyses, patient observation and all available MEDICAL KNOWLEDGE. This is, probably, the process which will require the most elaborate future analysis. All processes on this diagram match the operations on subclasses of objects in the MEDICAL PROVIDER class, except such operations as ADMIT, REJECT and DISCHARGE . In fact, Fig. 6.15 represents everything that happens to a PATIENT after he has been admitted, and before being discharged by a MEDICAL PROVIDER.

The expansion of Treatment process is presented on Fig. 6.17. After the diagnosis is made, a PHYSICIAN can MAKE a PRESCRIPTION and/or REFER to SPECIAL SERVICES. or another provider. Accordingly, based on received information, PHARMACY may DISPENSE a DRUG, and SPECIAL SERVICES object may PERFORM PROCEDURE on a PATIENT. Once again, all these processes in the chart are supported by the MEDICAL KNOWLEDGE BASE object, but the links between the medical knowledge base and all other objects are not shown. The feedback of the CURE process to a PATIENT may result in registered diagnosis, prescribed drugs and performed procedures.

The further possible detailization of a process to the next level of description is demonstrated by an expansion of a Perform Procedure process (Fig. 6.18). The types of procedures performed on a patient may include Therapeutical procedures, Physical Therapy, Surgery and Rehabilitation Procedure. (Fig. 6.18). The most complex, surgery procedure, consists, in turn, from Preoperating procedure, Anesthesia, surgical operation itself and Postoperating Care. The expansion of Anesthesia process is presented by Fig. 6.19. Such subprocesses as Intubation and Injection may be considered as the lowest level processes, each represented by a specific Functional Block in a Knowledge Module of an Intelligent Medical Network.

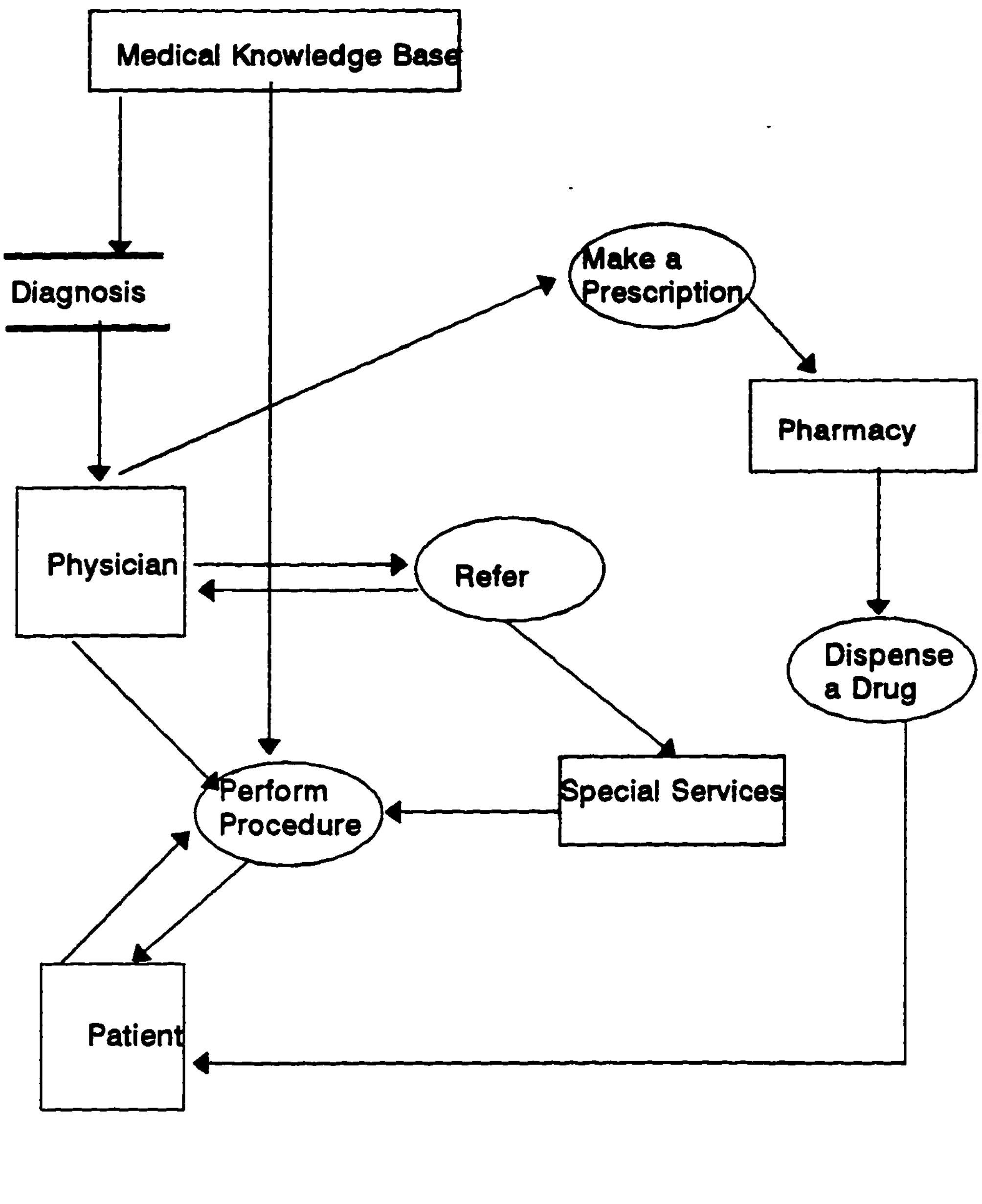


Fig. 6.17 Expansion of a Treatment Process

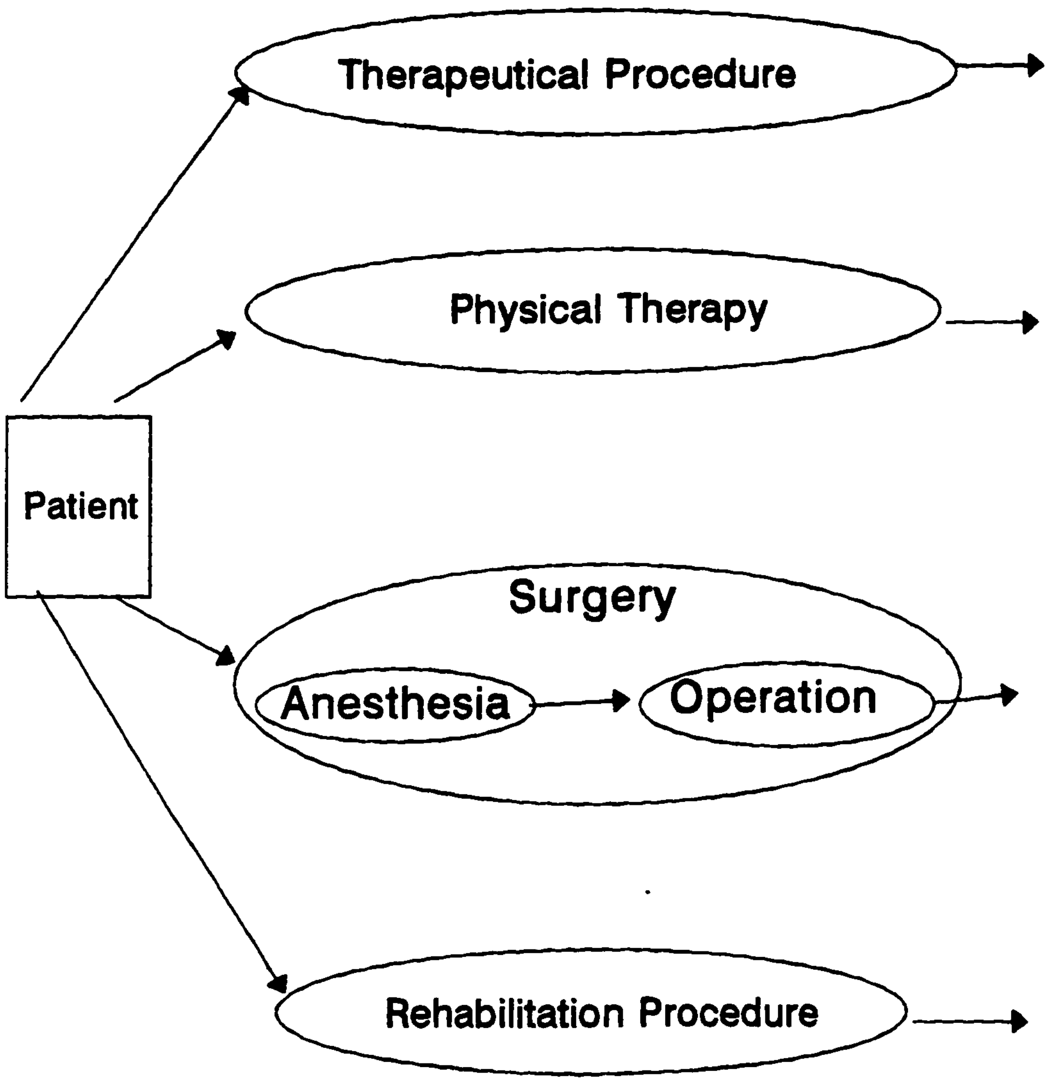


Fig. 6.18

Expansion of Perform Procedure Process

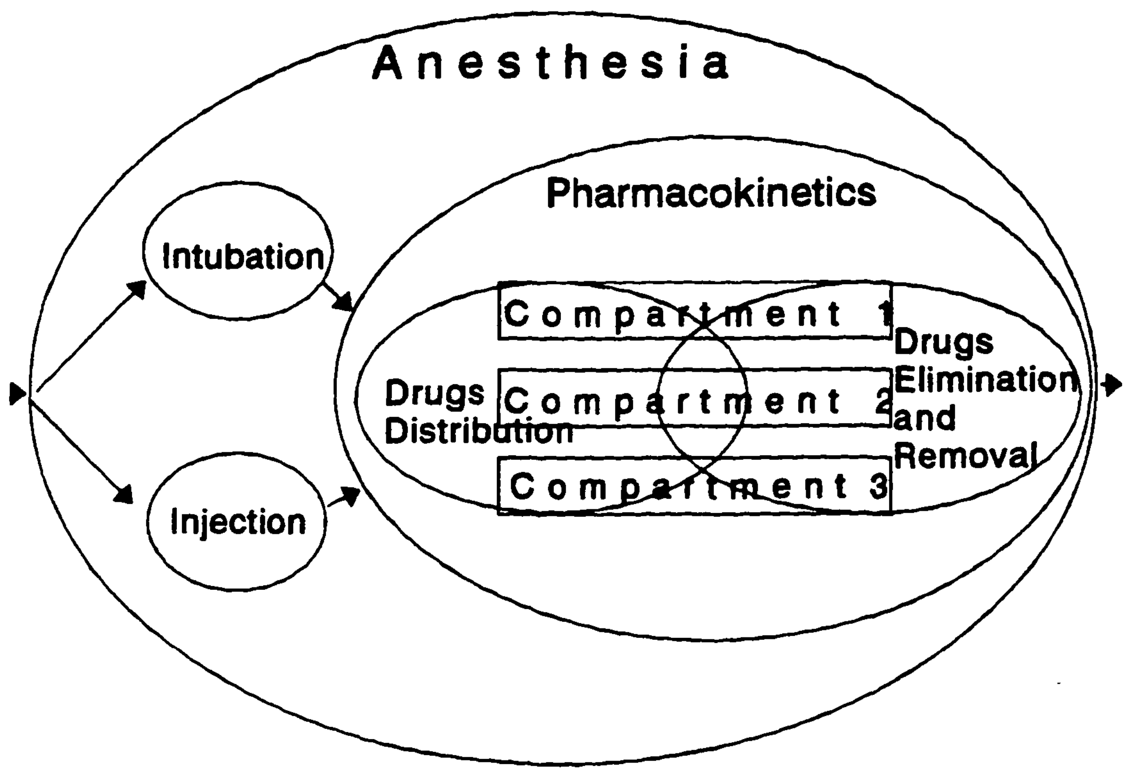


Fig. 6.19

Expansion of Anesthesia Process

7. IMPLEMENTATION OF THE INTELLIGENT MEDICAL NETWORK

The architecture of medical intelligent telecommunication network and set of algorithms for Service and Application Functional Blocks were implemented in Data-Mail - an electronic consultation system which has been developed at the Mount Sinai Medical Center, NY.

7.1 DATA-MAIL ELECTRONIC CONSULTATION SYSTEM AT MOUNT SINAI MEDICAL CENTER

Application Aspect

The purpose of Data-Mail is to enable the rapid and accurate exchange of information between general medicine physicians and consultants. From the application standpoint this system facilitates the targeted delivery of information in a managed care environment for its medical practices. The patient's Primary Care Physician has a greater responsibility for care decisions. If physicians are to provide cost effective quality medical care they must have complete, current, and comprehensive medical information from consultants before making treatment decisions. Consultant requests and consultant reports must be accessible to the primary care physician.

The existing consultation reporting system at the Mount Sinai Medical Center is a paper based process using handwritten multi-part forms. Physicians at the Medical Center are spread across several different buildings. Referring physicians write referrals by hand. Referrals are then logged, sorted, and distributed to the consultant's offices. The paper referral requests are held at the consultant's office until the patient is seen. The consultant then writes a progress note in the patient's chart (which may not leave the clinic) and a consultation report on the consultation request form. Any other documentation (e.g. lab results) is attached to the form and sent back to the referring physician. This process is cumbersome and labor intensive, and often generate illegible carbon copies.

The Data-Mail system will replace this manual paper based process with electronic mail communication. The e-mail messages are generated with the help of application software modules, and are sent to destinations determined by the communication software.

Technical Design Aspect

The Data-Mail system is built in accordance with the general architecture of an intelligent telecommunication system developed earlier in this dissertation. Its main subsystems correspond to the main modules of IN2 (Switching and Telecommunication Modules, Knowledge Module with Application and Service Functional Blocks, Administrative Module, Intelligent Peripheral).

The design of Application Functional Blocks is based on the Object-Oriented Model of the Health Care System, described in Chapter 6 of this dissertation. Application Functional Blocks include such objects as Patient, Health Care Provider (Physician, Lab, Special Services), Procedure, Medication, such processes as Refer, Make Diagnosis, Treatment and so on. Service Functional Modules represent three standard operations of query processing in intelligent telecommunication system: request formatting, request processing and response formatting. Database search and retrieval functions are performed by the universal Request Processing Unit (RPU). These functions and algorithms were defined in chapters 4 and 5 of the dissertation.

Implementation Aspect

The Data-Mail Electronic Consultation system is developed as a pilot project. The Mount Sinai is in the early design stage of developing an electronic medical record and information sharing system for the Outpatient environment. The initial implementation is with the General Medicine Practice (Internal Medicine Associates) and the Gastroenterology Practice of the Mount Sinai Medical Center. The General Medicine Practice sees an average of 2,000 to 3,000 patients per month and requests 300 to 400 consults per month. Requests for Gastroenterology consults overall average about 35 per month. The Data-Mail is a pilot project to be incorporated into this information system. This pilot project connects the Internal Medicine Associates Practice with Gastroenterology for the purpose of exchanging referrals and Endoscopy reports. The ultimate goal is to create a universal programming software where new applications are added simply by expanding vocabulary loaded into built-in system databases.

7.2 THE ARCHITECTURE OF THE DATA-MAIL ELECTRONIC CONSULTATION SYSTEM

The Data-Mail Electronic Consultation System at Mount Sinai Medical Center is an example of an intelligent LAN. It was designed in accordance with the general architecture of an Intelligent Medical Network and its Knowledge Module, presented on Figures 2.2. and 4.6 The main components of the Data-Mail System are:

- ***Consultant:*** a front-end user interaction subsystem. This subsystem corresponds to the Intelligent Peripheral Unit of an Intelligent Telecommunication System. It may serve as an example of the IP software, developed specifically for a medical application.
- ***Requester:*** an application subsystem. It corresponds to the Application Functional Blocks of the Knowledge Module of an Intelligent Telecommunication System.
- ***Omni-Desk:*** a control subsystem. This subsystem represents the Service Functional Blocks of the Knowledge Module of an Intelligent Telecommunication System.
- ***CCVBX***: an electronic mail subsystem. This subsystem takes place of the Switching and Communication Modules in an Intelligent Telecommunication System.
- ***Maintenance:*** a database support subsystem. This is an Administrative Module in terms of Intelligent Networks vocabulary.

The architecture of the Data-Mail Electronic Consultation System is presented on Fig. 7.1. Here all subsystems are presented by solid line blocks, while dotted line blocks show their correspondence to an Intelligent Network architectural modules.

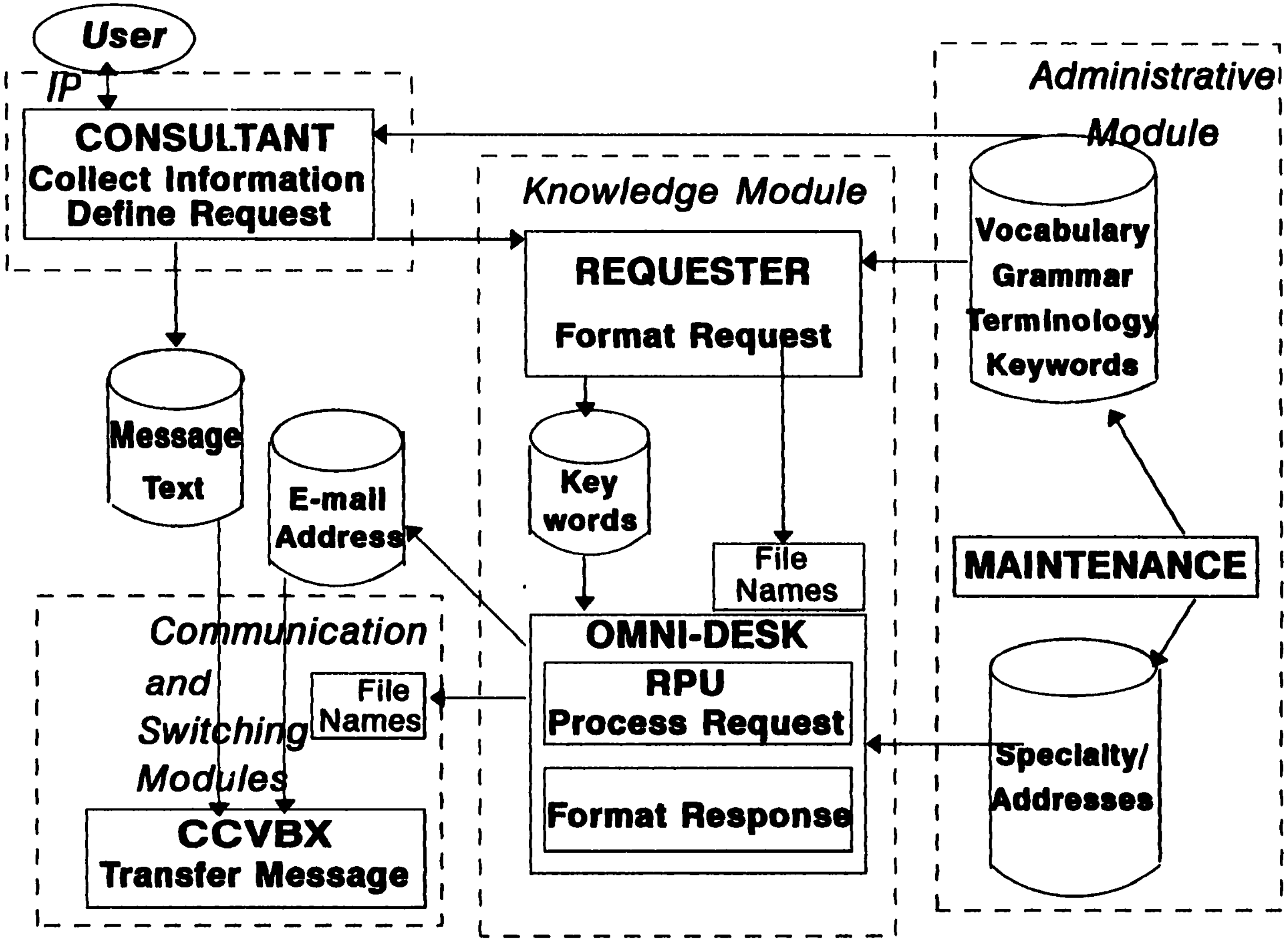


Fig. 7.1 Architecture of Data-Mail Electronic Consultation System

User corresponds directly with the front-end *Consultant* module. The *Consultant* provides guidance for an user to formulate his/her query in terms of vocabulary and terminology recognizable by the Data-Mail system. Therefore the *Consultant* has to communicate with the systems database, and retrieve Vocabulary and Grammar data. The *Consultant* creates a text of a message to be transferred through an electronic mail subsystem. This message is stored in the form of temporary file, which will be later available to the e-mail communication subsystem. After the message is built, the control is yielded to the *Requester* subsystem.

The *Requester* module analyzes the content of the message, and refers to the systems database dictionary. Using the inner-system terminology the *Requester* builds the formal request. This request is a list of keywords related to the message received. The message may contain several independent queries, and for every query a separate list of related keywords is built. Each list is stored in a temporary file of keywords (actually, a table in a relational database), which is transferred as a parameter to the *Omni-Desk* subsystem.

The function of the *Omni-Desk* subsystem is to determine the e-mail addresses of all required recipients for each particular query. Using master index file, the *Omni-Desk* module accesses individual lists of keywords. For each keyword list *Omni-Desk* locates related e-mail addresses in the Specialty/Addresses database. This is a two-step process. On the first step the Request Processing Unit (RPU) of *Omni-Desk* module creates a set of available e-mail addresses pertinent for each specified list of keywords. On the second step the minimal subset of e-mail addresses is selected. The minimal subset includes a minimum number of recipients for each message which may perform all necessary operations (make an analysis, provide a treatment, etc.). The list of applicable e-mail addresses is conveyed to the *CCVBX* module together with the name of the file which contains the text of the message to be transferred.

The *CCVBX* subsystems accepts both the text of the message and the list of related addresses and submits the message to all e-mail addresses.

The *Maintenance* subsystems ensures that all information in internal system databases is up-to-date, in a correct format. Like any large-scale complex system, an internal database contains a number of redundant data. The *Maintenance* subsystem ensures than there is no contradiction and/or inconsistency in the data.

7.3 ANALYSIS AND DESIGN OF DATA-MAIL ELECTRONIC CONSULTATION SUBSYSTEMS

7.3.1 CONSULTANT Front-end Subsystem

The *Consultant* subsystems is a front-end interactive software designed to communicate with an end-user, to help him/her to retrieve necessary information from internal system database, to guide a user through the variety of available options and to help him/her to formulate the text of a message to be sent over LAN.

The functions of the *Consultant* subsystem, therefore are as follows:

- To present to a user a list of options and define all steps necessary to complete a transaction of sending a message regarding a medical referral over Data-Mail system;

- To provide a user with an opportunity to enter certain information on each step by prompting and supplying him/her with an information relevant to the step.
- To create a text of a medical referral message to be sent over LAN. This message text is composed based on the information entered by a user on each step.

The overall configuration of the *Consultant* subsystem is build as a hierarchical structure of menu-driven screens with drop-down lists of available options. The information is retrieved from the internal system database according to the selected options and displayed on the screen in the form of options available on the next step. These steps are constructed in accordance with the Object Model of a Health Care System and include the following object classes:

7.3.2 REQUESTER Application Subsystem

The function of the *Requester* subsystem is to build a formal request accompanying a text of a medical referral message. The control to this subsystem is transferred from the *Consultant* subsystem. Actually, the *Requester* subsystem operates as a subprocedure of the *Consultant* subsystem, and is called almost each time an information is selected by a user on a front-end interactive communication screen.

Input to the *Requester* subsystem is the same as input to a message composition block of the *Consultant* subsystem. Based on the same information the *Consultant* subsystem creates a full English text of a message while a *Requester* subsystem builds a temporary file of keywords related to the message. The keyword file is organized in a hierarchical format convenient for processing by a recursive algorithm of *the Request*

Processing Unit, which was described earlier in this dissertation in Chapter 6. It is necessary to note that a user is not limited to a specific order in which he or she has to enter non-dependent pieces of information. For example, information related to family history may be entered either before or after current medications, or may be not entered at all. Nevertheless, the request keyword file is built in a certain order, representing a specific hierarchical structure. Each independent piece of information entered by a user is represented by a chain of keywords, which, in turn, identify a subtle of a full search tree contained in the internal system database.

The temporary file of keywords is the output of the *Requester* subsystem, which then yields the control to the *Omni-Desk* control system.

7.3.3 OMNI-DESK Control Subsystem

The Omni-Desk subsystem determines the actual e-mail addresses where the medical referral message will be sent. In doing so the Omni-Desk subsystem ensures that there is at least one valid address for the message to be sent, and that there is no duplication, contradiction or controversy between addresses when there are more than one related e-mail address found.

The e-mail addresses related to a medical referral message include Medical Records Department, Labs, Medical Specialist Consultant (for original referral) or Primary Physician (for send-back referrals). There are possible duplications within each group of e-mail addresses. There are three types of Medical Records, and each message should be directed to the appropriate one. A medical referral message has to be sent to the correct type of Laboratory. And only one Medical Consultant may me selected from the group of available specialists.

Create Addresses List Module (the Search Module)

At the first step the *Omni-Desk* subsystem searches the internal system database using the provided message keywords. This modules utilized the search strategy developed for a universal *Request Processing Unit*, and may be considered as an implementation of the service FB.

The search module reads a keyword with the highest level of hierarchy (0) and starts the search with the root of the search tree. The root node refers to a default system database table name. The table contains the keywords of the first level together with the reference type indicator (another database "D", another table "T", local reference within the same table ("L") or direct address reference "A"). On any hierarchical level there may be only one non-address reference (of types "D", "T", or "L"), and any number (including zero) of direct address references. The search is performed with an implementation of the recursive algorithm of the *Request Processing Unit*. The references of types "D" and "T" are considered to be the external requests, while the references of type "L" are internal requests. The reference of type "A" is a request resolution.

By the end of the search there has to be at least one address found for each keyword chain. This kind of a database integrity is guaranteed by the Maintenance subsystem. As a general rule there may be multiple e-mail addresses found for each keyword chain. There also may me duplicate e-mail addresses found for different keyword chains. A temporary file containing list of these related e-mail addresses found in a search database is the output of the Search Module. The control is then passed to the Select Module of the *Omni-Desk* subsystem.

Optimize Addresses List Module (the Select Module)

The function of the Select Module of the Omni-Desk subsystem is to find a minimal subset of a set of all available e-mail addresses related to the medical referral message. The minimization is done in steps and according to rule - based algorithm.

An input to the Select Module is the temporary file of e-mail addresses. In a general case this file contains multiple e-mail addresses with possible duplications. Every e-mail address corresponds to a certain participant in the Data-Mail system. Each of these participants may be characterized by certain attributes, such as type (Medical Records, Laboratory, Medical Specialist, Primary Physician), requirements (mandatory or optional), participation (member of managed-care network, or out-of-network), subspecialties (for Medical Specialists only), and current load of medical cases. These data are contained in the Participant's Profile, which is a part of the internal system database. The Select Module refers to the Participant's Profile for each e-mail address found in the input temporary file.

At the first step all duplicate e-mail addresses found in the temporary input file are eliminated. At the second step all mandatory addresses are identified and are included into output e-mail addresses file. The mandatory addresses are those of the Medical Records

Department, Labs, primary care physicians, and also those Medical Specialists who currently are involved in the care of this particular patient. At the third step a logical algorithm of eliminating of all unnecessary optional e-mail addresses is utilized. An e-mail address of an Medical Specialist is eliminated from the file if his/her subspecialty is covered by any of the mandatory e-mail addresses. Among the remaining addresses the out-of-network participants are excluded if their subspecialties are covered by members of the network. And finally, if there are still multiple addresses for a subspecialty, the participant with the least current load is selected. These selected e-mail addresses are included in an output file which is transferred along with the control to the communication subsystem.

7.3.4 CCVBX Communication Subsystem

The transmission of message over LAN is performed utilizing the standard e-mail package Lotus cc:Mail. CCVBX represents an interface between application software and cc:Mail system. The names of files containing e-mail addresses and a message text are transferred to CCVBX as parameters. CCVBX then initiates a cc:Mail execution and physical transmission of the message to given e-mail addresses.

7.3.5 Maintenance Subsystem

The Maintenance subsystem corresponds to the Administrative Module of an Intelligent Telecommunication system. The Maintenance subsystem performs various housekeeping functions for the Data-Mail Electronic Consultation System. Its primary goal is to guarantee the integrity of the internal database of the Data-Mail system. Although the basic functions performed by the Maintenance subsystem: Add, Update and Delete - are typical for any record keeping system, the underlying processing must confirm to certain rules. All data presented to a user as available options must have their equivalent keywords within the database. All keywords with the lowest hierarchy level must have at least one direct address reference. All e-mail addresses used as reference must have a matching entry in the Participants Profile table. At least one entry should exist for each participant's type.

7.4 DATA USED BY DATA-MAIL ELECTRONIC CONSULTATION SYSTEM

The internal system database contains the data representing the hierarchical structures (trees), and can be considered as a forest. The data is saved as a collection of node pairs (vertices), corresponding to edges of the tree. There are three independent data collections (trees) within the internal database, each associated with a specific subsystem of the Data-Mail system.

Data used in the *Consultant* subsystem

The data associated with the *Consultant* subsystem represent information available to user. It contains patients data and medical knowledge base. Although all the data are organized as hierarchical structure, it is presented in the form of relational database (tables). The mechanism of conversion hierarchical structures into relational and vice versa was described in chapter 6 of this dissertation.

In terms of object model of a health care system all the data associated with the *Consultant* subsystem correspond to object classes of *Patient and Medical Knowledge Base* with subclasses of *Medical Diagnosis, Treatment, Medication* (Drugs*), Medical Symptoms, Indications, Findings, Procedures.* In addition, this part of the database contains data which is used to create a message test in a proper English format, and is referred to as vocabulary and grammar.

The Patient data is carried in the table named "Referral". The Medical Knowledge is presented by tables "Terminology" and "Report_List". The building blocks for composing a message test may be found in tables "Vocabulary" and "Phrases". The format (design) of these database tables and the actual data used in the Data-Mail system are included in the Appendix B.

Data used by the *Requester* subsystem

For each message to be processed by the Data-Mail system the Requester subsystem receives keywords from the Consultant subsystem, one pair at the time, and create a temporary file in form of a relational database table, which contains the full path of user-selected options for the search tree of e-mail addresses.

Each row in the table has a unique entry number, keyword name, and reference to the parent node entry number. Duplicate entries are not allowed in the table. Since user obtains options for selections starting with the root of the options tree, the keywords also arrive to the Requester subsystem in the top-down order. A user may traverse a tree in each direction, up and down, returning back to add an additional entry. User's selections form subtree of arbitrary complexity. The function of the Requester subsystem is to create a full path for each leaf node selected. The full path originate at the root of the tree. Upon receiving new keyword as an input, the Requester subsystem will skip duplicate entries, but each new entry is guaranteed to have its parent already entered into the table. The reference to the parent's entry number is established for each new node added into the table.

The format of the "Key_Words" table is shown in the Appendix B of the dissertation.

Data used by *Omni-Desk* subsystem

An input to the Omni-Desk subsystem is the "Key_Word" table, created by the Requester subsystem. This table is a set of full path of keywords used in an "OmniDesk" table, which contains e-mail addresses attributed to keywords. The "OmniDesk" table represent another hierarchical structure (a tree), which relates keywords to e-mail addresses. Using data from the "Key_Words" table as a navigation tool, the Search Module of the Omni-Desk subsystem traverse the address tree, and locate the set of e-mail addresses relevant to each option selected by a user. These e-mail addresses are placed into temporary database table "AddressList".

The Select Module of the Omni-Desk subsystem uses the "AddressList" table as an input. It refers to the "Profile" table to find an additional information regarding each e-mail address found in the "AddressList" table. For e-mail address of each participant the "Profile" table contains the participant's type (Department of Medical Records, Laboratory, Medical Specialist, Primary Physician), requirements (mandatory or optional), participation (member of managed-care network, or out-of-network), subspecialties (for Medical Specialists only), and current load of medical cases. Based on this information, the Select Module chooses the minimal set of necessary e-mail addresses.

7.5 HARDWARE, SYSTEM SOFTWARE AND NETWORK SOFTWARE USED IN DATA-MAIL ELECTRONIC CONSULTATION SYSTEM

The Data-Mail system at Mount Sinai Medical Center is developed for a distributive network-based environment. Offices are spread across several different buildings. Practically all department make their own independent decisions concerning purchasing hardware and software. Many departments have established their own autonomous departmental LANs.

At the same time computers in virtually all offices at the Mount Sinai Medical Center are connected through a common institution-wide network, which is supported by the department of Information Services. The network utilizes a multi-platform hardware, where certain parts of network located in some buildings are based on ETHERNET standard platform, while another component of network located in different buildings are based on IBM Token-Ring protocol.

The accepted standard for hardware is a PC compatible Intel-based workstation with 486 processor (Pentium for newer machines), although there is still a number of 386 machines. The network includes about 50 file servers.

The standard Operating System is Windows 3.1. The conversion to Windows-95 is planning in a future, but currently this version is not supported yet. The network software is Novell Netware 3.12 LAN. The Mount Sinai Medical Center internal electronic-mail system is based on the Lotus cc:Mail software package.

The application software programs for the Data-Mail system are written using Visual Basic and C/C++ programming languages. The data are stored in the Microsoft Access database as well as in regular computer files.

7.6 SUMMARY

Data-Mail electronic consultation - an intelligent medical network was created using this dissertation as a theoretical basis. Development of a Data-Mail system have proved correctness of the approach selected in the dissertation.

- According to the approved plan of the dissertation, potential members of the medical intelligent network were identified. All participants of the Data-Mail electronic consultation system : *Physicians* (general medicine and specialists), *Medical labs*, *Pharmacy*, *Administration* were defined as objects in the Object-Oriented model of a health care system;
- The architecture Data-Mail system completely corresponds to the architecture of knowledge-based intelligent medical network, elaborated in the dissertation. The *Consultant* subsystem performs the functions of Intelligent Peripheral. The *Requester* and *Omni-Desk* subsystems correspond accordingly to Application and Service

Functional Blocks of the Knowledge Module, and *CCVBX* subsystem represent Switching and Communication Modules.

- The recursive communication algorithms for queries processing was designed and utilized in the Mount Sinai intelligent medical LAN.
- Types of possible requests in an intelligent medical network were categorized in the dissertation, and the particular kind "*Specialist's Referral and Consultation*" was implemented in the Data-Mail.
- Main components of the knowledge base of a medical network were identified and described in detail in the general model. Entire information contained in internal database of Data-Mail correspond to the classes *Treatment*, *Procedure*, *Diagnosis*, *Medication*, and *Physician's observations* with subclasses *Indication*, *Finding*, *Examination*, *Recommendation*.
- The specific medical database was developed in agreement with the initial design, including the database hierarchical structure, informational elements and data formats.
- Set of computer programs was written according to the general design of software modules presented in the dissertation.

CONCLUSION

The research presented in this dissertation lead to the development of an intelligent network-based system for medical and health care application.

The results obtained may be summarized as follows:

- General architecture of knowledge-based telecommunication systems, introduced by AT&T Bell Laboratories was redesigned in a such a way that it is appropriate to application-oriented networks. Functions and structure of knowledge module of such systems were specified.
- Analysis of query processing by a knowledge-based intelligent network was performed. Based on this analysis an object-oriented model of an intelligent telecommunication system was designed . A universal algorithm of query processing by an intelligent network was developed. Such important pieces as various database interfaces, search criteria and data security were discussed.
- A health care system was analyzed. Potential participants of medical network were identified and the dimension of network was estimated. Types of possible queries were specified. Identification and codification systems for the medical network were selected, based on existing knowledge base of medical informatics. As a result, a full object-oriented model of a health care system was built.
- Prototype software modules for the network were developed and incorporated into the Data-Mail Electronic Consultation System at the Mount Sinai Medical Center.

APPENDIX A

Standard Medical Codes

Table 1 ■

Suggested Code Systems for Some Subject Domains

Subject Matter	Preferred Code System	Description–Justification
Drugs	WHO drug record codes	Supported and maintained by the World Health Organization. Includes all drugs marketed internationally—an advantage to U.S. pharmaceutical manufacturers. Includes links to a hierarchical indications code (ATC) and to the American Chemical Society chemical codes for the drugs. We propose that it be added as an identifier to all drugs manufactured in the United States.
Drugs	NDC	Produced by the FDA and applied to all packages. Widely used, but not as comprehensive as the WHO codes and has no internal structure. We propose that it continue to be supported, and that the choice of use of WHO or NDC would depend upon the application.
Diagnoses	ICD9-CM	Would continue to be used where required by law and international treaty.
Diagnoses	SNOMED III	A much richer diagnostic structure than ICD9, and has a mapping to ICD9-CM.
Symptoms and findings + modifiers	SNOMED III	A quite rich catalogue of symptoms and findings.
Microbes and etiologies	SNOMED III	A rich catalogue of microbes and other etiologies.
Anatomic locations	SNOMED III	A very rich hierarchical definition of body locations.
Patient observations	ASTM (1384 & 1238-91, app A)	Provides codes for common clinical variables such as temperature, pulse, intake and output, the major components of history and physical
Patient outcome variables	Medical Outcomes Institute	A set of codes that defines all of the outcome variables used by a consortium of 30 large group practices.
Units of measure, ISO + units	ASTM 1238-91	Defines the ISO single-case abbreviations as the codes for units of measure and extends to units not covered by ISO.
ECG machine diagnoses	CEN PT007	A quite comprehensive set of codes (abbreviations) and descriptions for ECG diagnoses published as a pre-standard by CEN TC251 based on a collaboration with most of the ECG cart makers.

Table 2 ■

Other Subject Domains

Subject Matter	Preferred Code System	Description–Justification
Devices	To be established	Classifications for all major kinds of devices, Universal Medical Device Nomenclature System, available from Emergency Care Research Institute (ECRI), and the Classifications Names for Medical Devices and in Vitro Diagnostic Products, available from the FDA.
Diagnostic study identifiers (e.g., blood glucose, chest x-ray, cardiac MUGA)	To be established	This is a sorely needed category with available alternatives for some diagnostic procedures. In the United States, CPT4 defines most diagnostic procedures for professional billing. It is already in use so could be used as a first approximation. However, it creates codes for combined procedures in a non-uniform and inelegant manner. It lacks codes for most special serologic tests. It does not have codes for the observations that are components of some batteries (e.g., differential count, urinalyses—but those can be obtained from ASTM 1239-91, Appendix A). A possible choice for laboratory testing only is Euclides. At present it is a multiaxial code and may be difficult to adapt to existing laboratory systems. It is very elegant and complete, however. ASTM E31.12 is working on an alternative that is compatible with Euclides codes. SNOMED has developed but not yet published codes for diagnostic procedures.
Procedure codes	To be established	The same can be said about CPT4 here as above. CPT4 does have the advantage of current production usage. ICD-9 procedure codes are a bit more elegant (if three different procedures are performed they are not combined, but reported as separate atomic codes). SNOMED III is coming out with new codes. ICCS has a proprietary, but widely used, set of procedure codes. The READ codes include procedure codes.

Sources for Standards and Code Systems

ACR-NEMA	National Electrical Manufacturers Association, 2101 L St. NW, Washington, DC
ASC X12	X12 DISA, 1800 Diagonal Road, Suite 355, Alexandria, VA
ASTM	American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA
CEN PT007	European Committee for Standardization Central Secretariat: rue de Stassart 36, B-1050, Brussels, Belgium
ECRI	Emergency Care Research Institute, 5200 Butler Pike, Plymouth Meeting, PA
EUCLIDES TC251	Euclides Foundation International, Excelsiorlaan 4A, B-1930 Zaventem, Belgium
HL7	Health Level Seven, 900 Victors Way, Ann Arbor, MI
ICD9-CM	Commission on Professional and Hospital Activities, 1968 Green Road, Ann Arbor, MI [includes all procedures and diagnostic tests]
IEEE MIB and MEDIX	IEEE Standards Dept., 445 Hoes Lane, Piscataway, NJ
Medical Outcomes Institute	2001 Killebrew Drive, Suite 122, Bloomington, MN
NCPDP	National Council for Prescription Drug Programs, 4201 North 24th Street, Phoenix, AZ
NDC	National Drug Code Director, FDA, Rockville, MD
SNOMED III	American College of Pathology, 5202 Old Orchard Road, Skokie, IL
WHO drug codes	INTDIS, P.O. Box 26, S-751 03 Uppsala, Sweden

APPENDIX B

Software Listings

FRONTEND.FRM - 1

```
Dim DbDefault, TblDefault As String
Dim Key_Db As database, Key_Tbl As String
Dim keyInput, LevelUpInput


Sub Create_Keyword_Table (ReportNum, Word, WordUp)
Dim WorkRecs As dynaset, NewRec As dynaset, RefRec As dynaset

    CreateSQL = "Select * from " & Key_Tbl & " Where Report_Num
    SQLText = CreateSQL

    Set WorkRecs = Key_Db.CreateDynaset(SQLText)

    If Not WorkRecs.EOF Then
        WorkRecs.MoveLast
    End If

    CreateSQL = "KeyWord_Value = " & "'" & Word & "'"
    SQLText = CreateSQL
    WorkRecs.Filter = SQLText
    Set NewRec = WorkRecs.CreateDynaset()
    If NewRec.EOF Then
        TempEntry_Num = WorkRecs.RecordCount + 1
'         TempReport_Num = ReportNum
'         TempKeyword_Value = Word
        If WordUp = " " Then
            TempRefKey_Num = 0
        Else
            CreateSQL = "KeyWord_Value = " & "'" & WordUp & "'"
            SQLText = CreateSQL
            WorkRecs.Filter = SQLText
            Set RefRec = WorkRecs.CreateDynaset()
            If Not RefRec.EOF Then
                RefRec.MoveLast
            End If
            If RefRec.RecordCount = 1 Then
                TempRefKey_Num = RefRec("Entry_Num")
            Else
                ReportNum = 0
                Exit Sub
            End If
        End If
        WorkRecs.AddNew

        WorkRecs("Report_Num") = ReportNum
        WorkRecs("Entry_Num") = TempEntry_Num
        WorkRecs("Keyword_Value") = Word
        WorkRecs("RefKey_Num") = TempRefKey_Num
        WorkRecs.Update

    End If
```

FRONTEND.FRM - 2

```
End Sub

Sub Command2_Click ()
End
End Sub

Sub Form_Load ()
    Text1 = " Report Number "
    DbDefault = "d:\intemail\newdata\newgi.mdb"
    TblDefault = "Key_Words"
    Set Key_Db = OpenDatabase(DbDefault)
    Key_Tbl = TblDefault
End Sub
```

OMNICALL.FRM - 1

```
'Dim DbDefault, TblDefault, AdFileName, TblName  As String
Dim TblName    As String
Dim Omni_DB As DataBase, Key_DB As DataBase

Const DbDefault = "d:\intemail\NewData\Newgi.mdb"
Const TblDefault = "OmniDesk"
Const KeyDbDefault = "d:\intemail\NewData\Newgi.mdb"
Const KeyTblDefault = "Key_Words"

Const KeywordFile = "c:\intemail\newdata\test.txt"
Const AddressFile = "d:\intemail\newdata\adfile.txt"
Const AdFileName = "d:\intemail\newdata\adfile"

Sub OmniFind (KeyTerm, Response)
Dim WorkRecs As Dynaset, AdRecs As Dynaset, RefRecs As Dynaset
Dim RecNum As Integer, SQLText, TempString  As String

    CreateSQL = "Select * from " & TblName & " Where  Term_Ke
eyTerm & "'"
    SQLText = CreateSQL

    Set WorkRecs = Omni_DB.CreateDynaset(SQLText)
'    Set RefRecs = WorkRecs.Clone()

    WorkRecs.Filter = "Ref_Type = 'A' "
    Set AdRecs = WorkRecs.CreateDynaset()
    If Not AdRecs.EOF Then
        AdRecs.MoveFirst
    End If
    Do Until AdRecs.EOF
        Write #4, AdRecs("Ref_Address")
        AdRecs.MoveNext
    Loop
    WorkRecs.Filter = "Ref_Type <> 'A' "
    Set RefRecs = WorkRecs.CreateDynaset()

    If Not RefRecs.EOF Then
        RefRecs.MoveLast
    End If
    If RefRecs.RecordCount = 1 Then
        If RefRecs("Ref_type") = "D" Then
'            Close Omni_DB
            TempString = RefRecs("Ref_Address")
            Set Omni_DB = OpenDatabase(Ref_Address)
            TblName = TblDefault
            Call OmniFind(KeyTerm, Response)
        Else
            If RefRecs("Ref_Type") = "T" Then
                TblName = RefRecs("Ref_Address")
                Call OmniFind(KeyTerm, Response)
            Else
```

OMNICALL.FRM - 2

```
        If RefRecs.RecordCount > 1 Then
            TempCount = 0
            RefRecs.MoveFirst
            Do Until RefRecs.EOF
                If RefRecs("Ref_Type") <> "L" Then
                    TempCount = TempCount + 1
                End If
                RefRecs.MoveNext
            Loop
            If TempCount = 0 Then
                Input #3, KeyTerm
                Call OmniFind(KeyTerm, Response)
            Else
                Response = "Multiple non local References"
                Exit Sub
            End If
        Else
            If RefRecs.RecordCount = 0 Then
                If AdRecs.RecordCount > 0 Then
                    Response = "OK"
                Else
                    Response = "No Address"
                End If
            Else
                Response = "Negative Number of Records"
            End If
        End If
    End If
End Sub

 Sub OmniKeyFind (PswString, Response)
Dim WorkRecs As Dynaset, AdRecs As Dynaset, RefRecs As Dynaset
Dim RecNum As Integer, SQLText, TempString   As String

 '   If PswString <> "" Then
    TemPos = InStr(1, PswString, ",")
    If TemPos = 0 Then
        KeyTerm = PswString
    Else
        KeyTerm = Left(PswString, TemPos - 1)
    End If
     PswString = Right(PswString, Len(PswString) - TemPos)
    CreateSQL = "Select * from " & TblName & " Where  Term_Keywc
eyTerm & "'"
    SQLText = CreateSQL

    Set WorkRecs = Omni_DB.CreateDynaset(SQLText)
    WorkRecs.Filter = "Ref_Type = 'A' "
    Set AdRecs = WorkRecs.CreateDynaset()
    If Not AdRecs.EOF Then
        AdRecs.MoveFirst
    End If
    Do Until AdRecs.EOF
```

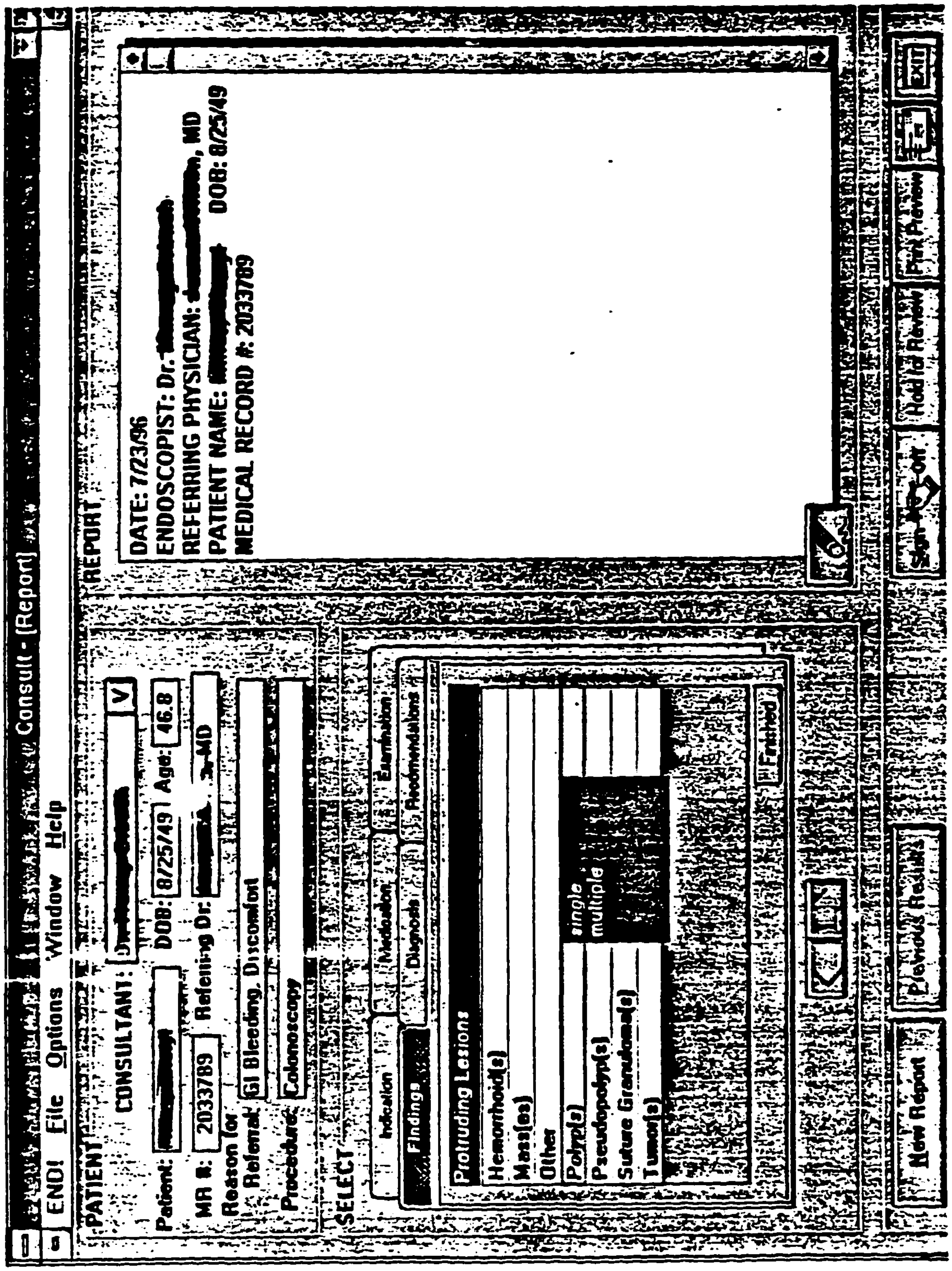
```
    End If
    If RefRecs.RecordCount = 1 Then
        If RefRecs("Ref_type") = "D" Then
             Close Omni_DB
            TempString = RefRecs("Ref_Address")
            Set Omni_DB = OpenDatabase(TempString)
            TblName = TblDefault
            Call OmniKeyFind(PswString, Response)
        Else
            If RefRecs("Ref_Type") = "T" Then
                TblName = RefRecs("Ref_Address")
                Call OmniKeyFind(PswString, Response)
            Else
                If RefRecs("Ref_Type") = "L" Then
                    TemPos = InStr(1, PswString, ",")
                    PswString = Right(PswString, Len(PswString)
                   Call OmniKeyFind(PswString, Response)
                Else
                    Response = "Unknown Reference Type"
                    Exit Sub
                End If
            End If
       End If
    Else
        If RefRecs.RecordCount > 1 Then
            TempCount = 0
            RefRecs.MoveFirst
            Do Until RefRecs.EOF
                If RefRecs("Ref_Type") <> "L" Then
                    TempCount = TempCount + 1
                End If
                RefRecs.MoveNext
            Loop
            If TempCount = 0 Then
                TemPos = InStr(1, PswString, ",")
                If TemPos <> 0 Then
                    PswString = Right(PswString, Len(PswString)
                    Call OmniKeyFind(PswString, Response)
                End If
            Else
                Response = "Multiple non local References"
                Exit Sub
            End If
        Else
            If RefRecs.RecordCount = 0 Then
                If AdRecs.RecordCount > 0 Then
                    Response = "OK"
                Else
                    Response = "No Address"
                End If
            Else
                Response = "Negative Number of Records"
            End If
        End If
```

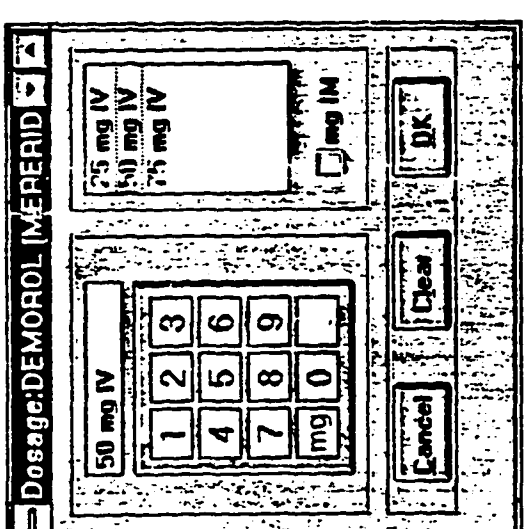
OMNICALL.FRM - 4

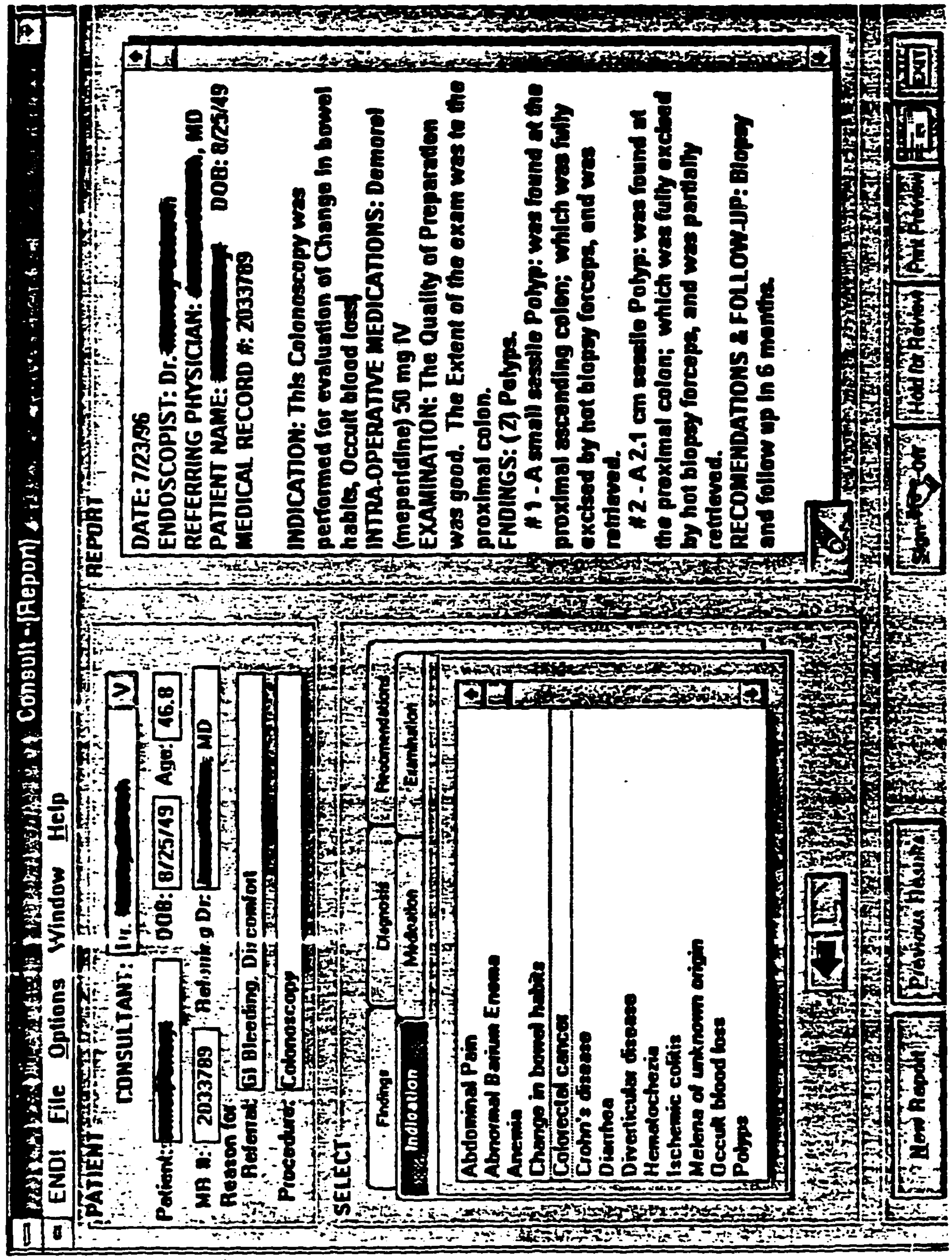
```
    KeyTblName = KeyTblDefault
    CreateSQL1 = "Select * from " & KeyTblName
    CreateSQL2 = " where Report_Num = " & ReportNum
    CreateSQL3 = " and RefKey_Num = " & RefNum
    SQLText = CreateSQL1 & CreateSQL2 & CreateSQL3
    Set KeyRecs = Key_DB.CreateDynaset(SQLText)
    If KeyRecs.EOF Then
        TblName = TblDefault
        Response = ""
        PString = PasswordString
        Call OmniKeyFind(PString, Response)
    Else
        KeyRecs.MoveFirst
        While Not KeyRecs.EOF
            If PasswordString = "" Then
'                PasswordString = KeyRecs("Keyword_Value")
                PString = KeyRecs("Keyword_Value")
            Else
'                PasswordString = PasswordString & "," & KeyRecs(
)
                PString = PasswordString & "," & KeyRecs("Keyworc
            End If
            RefNum = KeyRecs("Entry_Num")
'             Call OmniKeyStart(ReportNum, ByVal RefNum, ByVal Pas
            Call OmniKeyStart(ReportNum, ByVal RefNum, ByVal PStı
            KeyRecs.MoveNext
        Wend
    End If
End Sub

Sub OmniStart (KeywordFile, AddressFile)
Dim AddNum As Integer

    Open KeywordFile For Input As 1
    Open AddressFile For Output As 2
    AddNum = 0

    While Not EOF(1)
        Input #1, FileNameK
        Open FileNameK For Input As 3
        Input #3, KeyTerm
        FileNameA = AdFileName & AddNum & ".txt"
        Open FileNameA For Output As 4
        Set Omni_DB = OpenDatabase(DbDefault)
        TblName = TblDefault
        Response = ""
        Call OmniFind(KeyTerm, Response)
        If Response = "OK" Then
            Write #2, FileNameA
        End If
        Close 4
        Omni_DB.Close
        AddNum = AddNum + 1
```

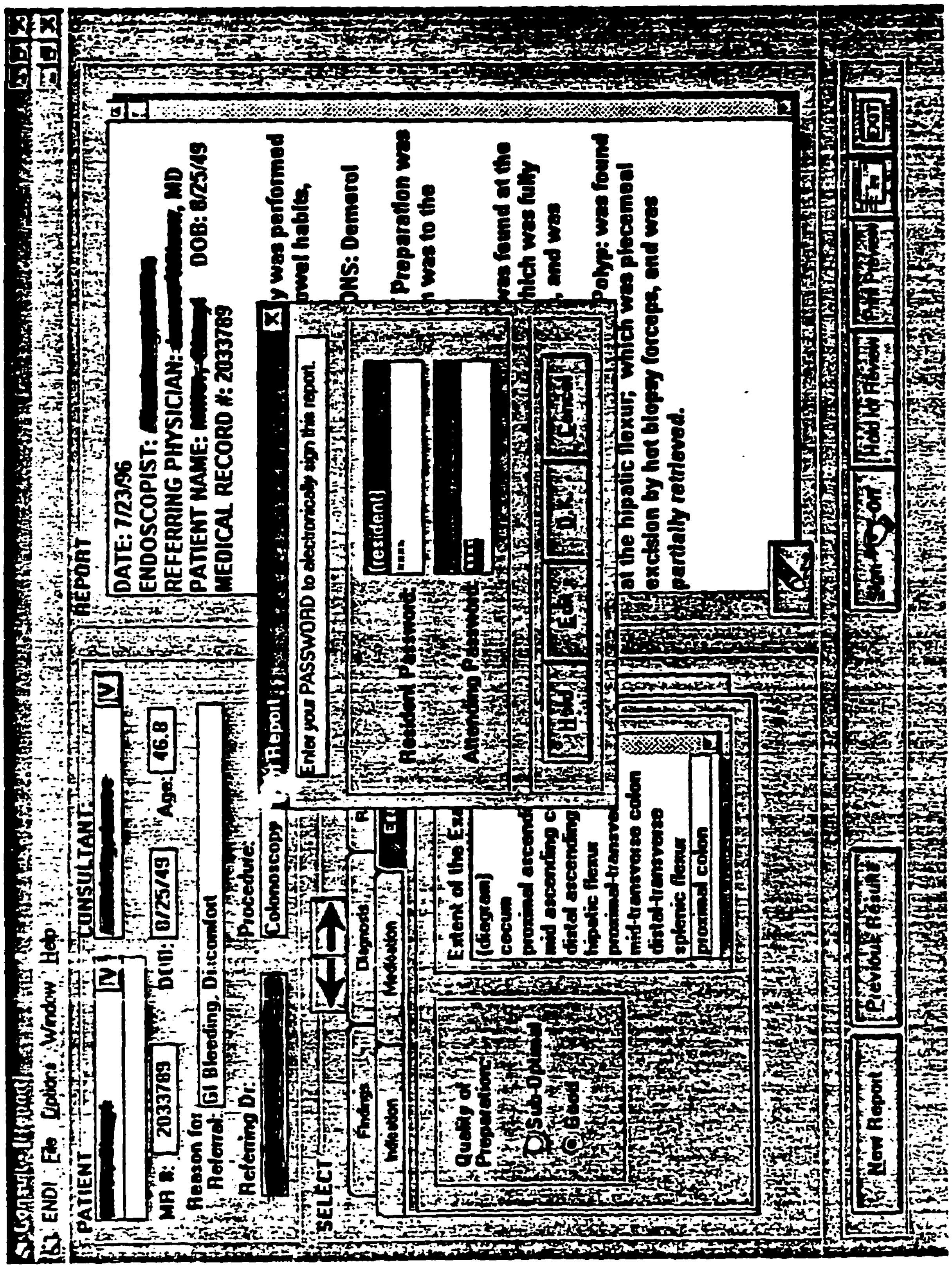
OMNICALL.FRM - 5

```
'Dim KeywordFile, AddressFile As String

' DbDefault = "C:\intemail\NewData\Newgi.mdb"
' TblDefault = "OmniDesk"
' KeywordFile = "c:\intemail\newdata\test.txt"
' AddressFile = "c:\intemail\newdata\adfile.txt"
' AdFileName = "c:\intemail\newdata\adfile"
' Call OmniStart(KeywordFile, AddressFile)

    Set Key_DB = OpenDatabase(KeyDbDefault)
    Set Omni_DB = OpenDatabase(DbDefault)
    ReportNumber = 3
    Level = 0
    KeyStr = ""
'    Open AddressFile For Output As 2
    FileNameA = AdFileName & ReportNumber & ".txt"
    Open FileNameA For Output As 4
    Call OmniKeyStart(ReportNumber, Level, ByVal KeyStr)
'    _Close 2
    Close 4
    End
End Sub
```


Consult - [Report]
END! File Options Window Help
PATIENT
CONSULTANT: [redacted]
Patient: [redacted]
DOB: 8/25/49
Age: 46.8
MR #: 2033789
Referring Dr: [redacted] MD
Reason for Referral: GI Bleeding, Discomfort
Procedure: Colonoscopy
SELECT
Indication
Medication
Examination
Findings
Diagnosis
Recommendations
Protruding Lesions
Hemorrhoid(s)
Mass(es)
Other
Polyp(s)
Pseudopolyp(s)
Suture Granuloma(s)
Tumor(s)
single
multiple
Finished
REPORT
DATE: 7/23/96
ENDOSCOPIST: Dr. [redacted]
REFERRING PHYSICIAN: [redacted], MD
PATIENT NAME: [redacted] DOB: 8/25/49
MEDICAL RECORD #: 2033789
New Report
Previous Results
Sign-off
Hold for Review
Print Preview
EXIT


Dosage:DEMOROL [MEPERID
50 mg IV
25 mg IV
50 mg IV
75 mg IV
mg IM
Cancel
Clear
OK


END! File Options Window Help
PATIENT
CONSULTANT: Dr. [redacted]
Patient: [redacted]
DOB: 8/25/49 Age: 46.8
MR #: 2033789 Referring Dr: [redacted], MD
Reason for Referral: GI Bleeding, Discomfort
Procedure: Colonoscopy
SELECT
REPORT
DATE: 7/23/96
ENDOSCOPIST: Dr. [redacted]
REFERRING PHYSICIAN: [redacted], MD
PATIENT NAME: [redacted] DOB: 8/25/49
MEDICAL RECORD #: 2033789
INDICATION: This Colonoscopy was performed for evaluation of Change in bowel habits, Occult blood loss.
INTRA-OPERATIVE MEDICATIONS: Demerol (meperidine) 50 mg IV
EXAMINATION: The Quality of Preparation was good. The Extent of the exam was to the proximal colon.
FINDINGS: (2) Polyps.
#1 - A small sessile Polyp: was found at the proximal ascending colon; which was fully excised by hot biopsy forceps, and was retrieved.
#2 - A 2.1 cm sessile Polyp: was found at the proximal colon; which was fully excised by hot biopsy forceps, and was partially retrieved.
RECOMENDATIONS & FOLLOW-UP: Biopsy and follow up in 6 months.
New Report
Previous Results
Sign-Off
Hold for Review
Print Preview
EXIT


ENDI File Options Window Help
PATIENT
CONSULTANT
REPORT
MR #: 2033789
DOB: 8/25/49
Age: 46.8
Reason for Referral: GI Bleeding, Discomfort
Referring Dr.:
Procedure:
Colonoscopy
DATE: 7/23/96
ENDOSCOPIST: [redacted]
REFERRING PHYSICIAN: [redacted], MD
PATIENT NAME: [redacted] DOB: 8/25/49
MEDICAL RECORD #: 2033789
Enter your PASSWORD to electronically sign this report.
Resident Password:
Attending Password:
O.K.
Cancel
New Report
Previous Result
Exit

ItemNumber	Description	Area	ICD9/CPT	Catagory
1	Abni BE			Indication
2	Abni Flex Sig/Polyp			Indication
3	Prior Polyp			Indication
4	Prior Colon Ca			Indication
5	(+) FOBT			Indication
6	Rectal Bleeding			Indication
7	Surviellance UC			Indication
8	Surviellance CD			Indication
9	Change Bowel Habits			Indication
10	(+) Family History			Indication
11	Endoscop Consult			Indication
12	Prev CF Unsuccessful			Indication
13	Prev CF Polyp not removed			Indication
14	No reason			Indication
15	Other			Indication
0	Demerol			Medication
0	Valium			Medication
0	Versed			Medication
0	Narcan			Medication
0	Other			Medication
20	Present			Diverticular Diseas
21	Massed			Diverticular Diseas
22	Infected			Diverticular Diseas
23	Red Folds			Diverticular Diseas
24	Prior India Ink			Other
25	AVM			
0	Abnormal X-ray	Esophagus	793.4	
0	Abnormal X-ray	Stomach	793.4	
0	Abnormal X-ray	Duodenum	793.4	
0	Abnormal X-ray	Small Bowel	793.4	
0	Abnormal X-ray	Pancreas Common	793.4	
0	Abnormal X-ray	Colon	793.4	
0	AVM, Arteriovenous malformation	Esophagus	569.84	
0	AVM, Arteriovenous malformation	Stomach	569.84	
0	AVM, Arteriovenous malformation	Duodenum	569.84	
0	AVM, Arteriovenous malformation	Small Bowel	569.84	
0	AVM, Arteriovenous malformation	Pancreas Common	569.84	
0	AVM, Arteriovenous malformation	Colon	569.84	
0	Cancer	Esophagus	150.9	
0	Cancer	Stomach	151.9	
0	Cancer	Duodenum	152.0	
0	Cancer	Small Bowel	152.9	
0	Cancer	Pancreas Common	157.9/156.9	
0	Cancer	Colon	153.9	
0	Crohn's Disease	Esophagus	555.9	
0	Crohn's Disease	Stomach	555.9	
0	Crohn's Disease	Duodenum	555.0	
0	Crohn's Disease	Small Bowel	555.0	
0	Crohn's Disease	Pancreas Common	555.9	
0	Crohn's Disease	Colon	555.1	
0	Diverticular Disease	Esophagus	530.6	
0	Diverticular Disease	Stomach	537.1	
0	Diverticular Disease	Duodenum	562.00	
0	Diverticular Disease	Small Bowel	562.00	
0	Diverticular Disease	Pancreas Common	751.69	
0	Diverticular Disease	Colon	752.10	
0	Foreign Body	Esophagus	93.1	
0	Foreign Body	Stomach	935.2	
0	Foreign Body	Duodenum	936	
0	Foreign Body	Small Bowel	936	

WordType	GrammerPart
name	pronoun
name	pronoun
name	pronoun
name	pronoun
name	pronoun

ItemNumber	Description	Area	ICD9/CPT	Catagory
0	Foreign Body	Pancreas Common	936	
0	Foreign Body	Colon	936	
0	GI Bleeding, Acute	Esophagus	578.9	
0	GI Bleeding, Acute	Stomach	578.9	
0	GI Bleeding, Acute	Duodenum	578.9	
0	GI Bleeding, Acute	Small Bowel	578.9	
0	GI Bleeding, Acute	Pancreas Common	578.9	
0	GI Bleeding, Acute	Colon	578.9	
0	Neoplasm Malignant	Esophagus	150.9	
0	Neoplasm Malignant	Stomach	151.9	
0	Neoplasm Malignant	Duodenum	152.0	
0	Neoplasm Malignant	Small Bowel	152.9	
0	Neoplasm Malignant	Pancreas Common	152.9	
0	Neoplasm Malignant	Colon	153.9	
0	Polyp (1-2)	Esophagus	211.0	
0	Polyp (1-2)	Stomach	211.1	
0	Polyp (1-2)	Duodenum	211.2	
0	Polyp (1-2)	Small Bowel	211.2	
0	Polyp (1-2)	Pancreas Common	211.6	
0	Polyp (1-2)	Colon	211.3	
0	Polyp (multiple)	Esophagus	211.0	
0	Polyp (multiple)	Stomach	211.1	
0	Polyp (multiple)	Duodenum	211.2	
0	Polyp (multiple)	Small Bowel	211.2	
0	Polyp (multiple)	Pancreas Common	211.6	
0	Polyp (multiple)	Colon	211.3	

Heading	Description
Complaint	Abdominal Pain
Complaint	Constipation
Complaint	Diarhea
Complaint	Heartburn
Complaint	Rectal Bleeding
Indication	(+) Family History
Indication	(+) FOBT
Indication	ABNL BE
Indication	ABNL Flex Sig/Polyp
Indication	Change Bowel Habits
Indication	Endoscopy Consult
Indication	Other
Indication	Prev CF Polyp not removed
Indication	Previous CF Unsuccessful
Indication	Prior Colon Ca
Indication	Prior Polyp
Indication	Rectal Bleeding
Indication	Surviellance CD
Indication	Surviellance UC
Medication	Asulphadine
Medication	Demerol
Medication	Lomotil
Medication	Narcan
Medication	Pepcid
Medication	Tagamet
Medication	Valium
Medication	Versed
Medication	Zantac
Procedure	Barium Swallow
Procedure	Colonoscopy
Procedure	ERCP
Procedure	Esphogeal Motility Study
Procedure	Gastroscopy
Procedure	Lower GI Series
Procedure	Sigmoidoscopy
Procedure	Upper GI Series
Diagnosis	Diagnosis 1
Diagnosis	Diagnosis 2
Diagnosis	Diagnosis 3
Diagnosis	Diagnosis 4
Diagnosis	Diagnosis 5
Diagnosis	Diagnosis 6
Finding	Protruding Lesions
Finding	Excavated Lesions
Finding	Mucosa
Finding	Normal Lumen
FollowUp	Stitz Baths B.I.D.
FollowUp	Proctofoam
FollowUp	Follow Up Biopsy Results
FollowUp	Colonoscopy within 1 Year
Complication	Complication

TermType	Term	Attribute	AttributeValue	EntryType	Site
Protruding Lesions	Polyp	Number	count	input,count	
Protruding Lesions	Polyp	Size	mm	input,mm	
Protruding Lesions	Polyp	Sessile Pedicle	Sessile	select,2,1	
Protruding Lesions	Polyp	Pedunculated Pedi	Pedunculated	select,2,2	
Protruding Lesions	Polyp	Bleeding		select,YN	
Protruding Lesions	Tumor	Small	Small	mixed,3,1	
Protruding Lesions	Tumor	Medium	Medium	mixed,3,2	
Protruding Lesions	Tumor	Large	Large	mixed,3,3	
Protruding Lesions	Tumor	Length	cm	input,cm	
Protruding Lesions	Tumor	Submucosal	Submucosal	select,5,1	
Protruding Lesions	Tumor	Fungating	Fungating	select,5,2	
Protruding Lesions	Tumor	Ulcerated	Ulcerated	select,5,3	
Protruding Lesions	Tumor	Infiltrative	Infiltrative	select,5,4	
Protruding Lesions	Tumor	Frond-like/Villous	Frond-like/Villous	select,5,5	
Protruding Lesions	Tumor	Partial Obstructing	Partial	select,2,1	
Protruding Lesions	Tumor	Complete Obstruct	Complete	select,2,2	
Protruding Lesions	Hemorrhoids	Bleeding		select,YN	
Protruding Lesions	Suture Granuloma	Single	Single	mixed,2,1	
Protruding Lesions	Suture Granuloma	Multiple	Few	mixed,2,2	
Excavated Lesions	Erosion	Number			
Excavated Lesions	Erosion	Localized Extensio			
Excavated Lesions	Erosion	Segmental Extensi			
Excavated Lesions	Erosion	Bleeding			
Excavated Lesions	Aphtha	Number			
Excavated Lesions	Aphtha	Localized Extensio			
Excavated Lesions	Aphtha	Segmental Extensi			
Excavated Lesions	Aphtha	Bleeding			
Excavated Lesions	Ulcer	Number			
Excavated Lesions	Ulcer	Size			
Excavated Lesions	Ulcer	Bleeding			
Normal Lumen	Dilated				
Normal Lumen	Stenosis	Benign Intrinsic			
Normal Lumen	Stenosis	Malignant Intrinsic			
Normal Lumen	Haustrations	Normal			
Normal Lumen	Haustrations	Decreased			
Mucosa	Vascular Pattern	Localized			
Mucosa	Vascular Pattern	Segmental			
Mucosa	Vascular Pattern	Diffuse			
Mucosa	Erythmatous (hype				
Mucosa	Congested (edema				
Mucosa	Granular				
Mucosa	Friable				
Mucosa	Petechiae				
Mucosa	Psuedomembrane				
Mucosa	Melanosis				

PHRASES

5/10/96

ItemNumber	Phrase	Type
1	The patient:	seen
4	A prescription was given	prescription
2	was seen	

ItemNumber	Description	Area	ICD9/CPT	Catagory
1	Abni BE			Indication
2	Abni Flex Sig/Polyp			Indication
3	Prior Polyp			Indication
4	Prior Colon Ca			Indication
5	(+) FOBT			Indication
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8	Surviellance CD			Indication
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13	Prev CF Polyp not removed			Indication
14	No reason			Indication
15	Other			Indication
0	Demerol			Medication
0	Valium			Medication
0	Versed			Medication
0	Narcan			Medication
0	Other			Medication
20	Present			Diverticular Diseas
21	Massed			Diverticular Diseas
22	Infected			Diverticular Diseas
23	Red Folds			Diverticular Diseas
24	Prior India Ink			Other
25	AVM			
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0	Abnormal X-ray	Stomach	793.4	
0	Abnormal X-ray	Duodenum	793.4	
0	Abnormal X-ray	Small Bowel	793.4	
0	Abnormal X-ray	Pancreas Common	793.4	
0	Abnormal X-ray	Colon	793.4	
0	AVM, Arteriovenous malformation	Esophagus	569.84	
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0	AVM, Arteriovenous malformation	Pancreas Common	569.84	
0	AVM, Arteriovenous malformation	Colon	569.84	
0	Cancer	Esophagus	150.9	
0	Cancer	Stomach	151.9	
0	Cancer	Duodenum	152.0	
0	Cancer	Small Bowel	152.9	
0	Cancer	Pancreas Common	157.9/156.9	
0	Cancer	Colon	153.9	
0	Crohn's Disease	Esophagus	555.9	
0	Crohn's Disease	Stomach	555.9	
0	Crohn's Disease	Duodenum	555.0	
0	Crohn's Disease	Small Bowel	555.0	
0	Crohn's Disease	Pancreas Common	555.9	
0	Crohn's Disease	Colon	555.1	
0	Diverticular Disease	Esophagus	530.6	
0	Diverticular Disease	Stomach	537.1	
0	Diverticular Disease	Duodenum	562.00	
0	Diverticular Disease	Small Bowel	562.00	
0	Diverticular Disease	Pancreas Common	751.69	
0	Diverticular Disease	Colon	752.10	
0	Foreign Body	Esophagus	93.1	
0	Foreign Body	Stomach	935.2	
0	Foreign Body	Duodenum	936	
0	Foreign Body	Small Bowel	936	

WordType	GrammerPart
name	pronoun
name	pronoun
name	pronoun
name	pronoun
name	pronoun

ItemNumber	Description	Area	ICD9/CPT	Category
0	Foreign Body	Pancreas Common	936	
0	Foreign Body	Colon	936	
0	GI Bleeding, Acute	Esophagus	578.9	
0	GI Bleeding, Acute	Stomach	578.9	
0	GI Bleeding, Acute	Duodenum	578.9	
0	GI Bleeding, Acute	Small Bowel	578.9	
0	GI Bleeding, Acute	Pancreas Common	578.9	
0	GI Bleeding, Acute	Colon	578.9	
0	Neoplasm Malignant	Esophagus	150.9	
0	Neoplasm Malignant	Stomach	151.9	
0	Neoplasm Malignant	Duodenum	152.0	
0	Neoplasm Malignant	Small Bowel	152.9	
0	Neoplasm Malignant	Pancreas Common	152.9	
0	Neoplasm Malignant	Colon	153.9	
0	Polyp (1-2)	Esophagus	211.0	
0	Polyp (1-2)	Stomach	211.1	
0	Polyp (1-2)	Duodenum	211.2	
0	Polyp (1-2)	Small Bowel	211.2	
0	Polyp (1-2)	Pancreas Common	211.6	
0	Polyp (1-2)	Colon	211.3	
0	Polyp (multiple)	Esophagus	211.0	
0	Polyp (multiple)	Stomach	211.1	
0	Polyp (multiple)	Duodenum	211.2	
0	Polyp (multiple)	Small Bowel	211.2	
0	Polyp (multiple)	Pancreas Common	211.6	
0	Polyp (multiple)	Colon	211.3	

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