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Hospital information systems—–Past, present, future☆

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Hospital information systems;
System architecture

Summary This article about the state of the art of hospital information systems and about future directions was written in 1984 by the late Peter Reichertz. It now serves as a companion paper to a paper with the same title, written by Reinhold Haux 20 years later (this issue). In that paper Reinhold Haux starts where Peter Reichertz ended. The original text of Peter Reichertz has been retyped and the figures redrawn. Possible errors may have resulted from this process.

1. Introduction

Hospital information systems have been in existence for almost two decades now. Therefore, it is possible to speak about their past. This contribution is intended to examine some of the features which we could observe during this evolution and intends to project some of the present observations into the future. However, the analysis will not be a formal one. Especially, it will not add new classifications and typologies to already existing ones like, e.g. the typology of Ball [1] according to the different stages of achievement and communication. Instead, some general aspects will be examined and some projections will be made out of the present stage as hospital information systems present themselves today.

It has to be noted that some of the features discussed for the future already have been seen in the past and have vanished in the present. They may come back in the future in a 'recycling' development as technology advances. Earlier ideas, which could not be implemented successfully due to lack of software and hardware techniques, may again be available tomorrow. Also, some features, which are described as features of tomorrow, can already be seen here and there in present systems of prototype character without being generally available.

Since earlier some contributions to the same topic have been made, it may be permitted to use some of the ideas expressed earlier resp. figures used elsewhere, (e.g [9—14]). As it happens, some observations and projections made in the past are still of value today. Therefore, the respective agreements and graphics may be allowed in this review for a more comprehensive picture.

In general, an analysis has to orient itself according to the axes:

- software and software technology;
- hardware and development of equipment;

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- system concept, e.g. the general approach and the architecture developed;
- environment and its changing aspects and
- system ecology as the new ecology evolving in an environment into which an information system is placed and which begins to react with people and organization which themselves have a strong influence on the development of the system as such resulting in a new ecological balance which differs from the old environment and, in most cases, also from the original system design.

However, contrary to previous analyses [11—14] the following reflections will not be grouped according to these axes though they will be dealt with under various aspects. Also it is not intended to make some programmatic statements with a fervent belief in all the good things technology can bring to medicine. But hopefully an analysis from a more remote standpoint may reveal one or the other global aspect of value.

2. General aspects

Information systems have to map the real environment into a formal representation, e.g. data base structures, through the bottleneck and restriction of data acquisition [10,13]. The information thus stored has to be processed and presented back to those who want to use the system. Therefore, the model given in Fig. 1 has the components of data base and base of methods for:

- acquisition of information;
- processing information and
- presentation of information [10,13].

Information systems do not have the right of existence out of themselves. They have to serve a purpose. The functions of such a system (see also [8]) can be described as:

1. reporting and regular collection and collating of data;
2. analysis, e.g. comparison and description of the evolution of data;
3. trend recognition as the result of the evaluation of continuous analyses;
4. prognoses in terms of projection of trends into the future;
5. problem identification and classification and
6. definition and selection of alternatives for action.

Hospital information systems very doubtlessly have reached the second level in this list of functions, though naturally in one or the other case, some functions of the higher levels may be already recognized. This means, however, even though quite successful solutions have been created, there is still a long way to go to surpass the mere logistics of data, as important as this function may be.

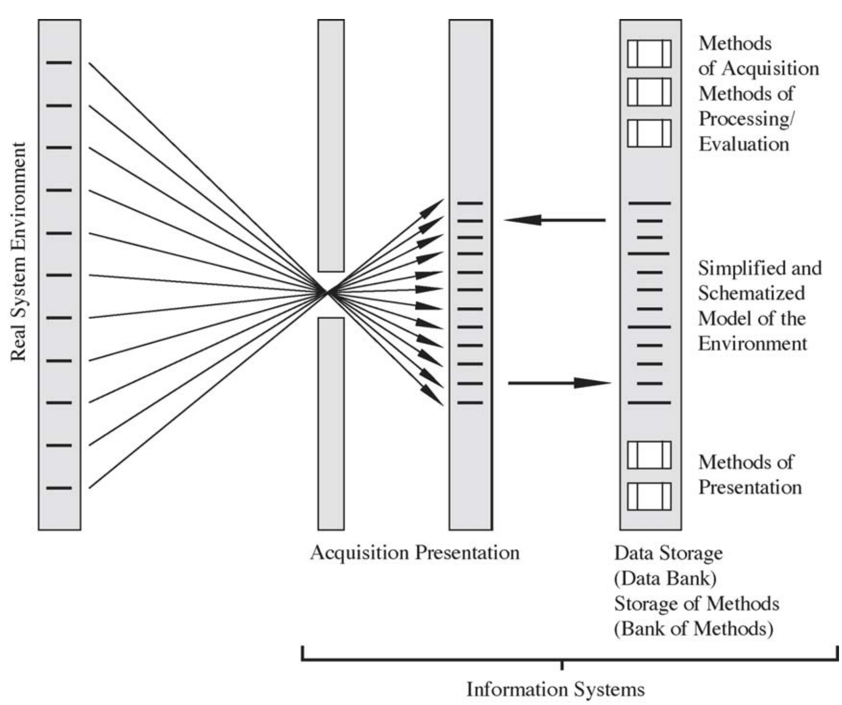

Fig. 1 Model of Information Systems (see [10,13]).

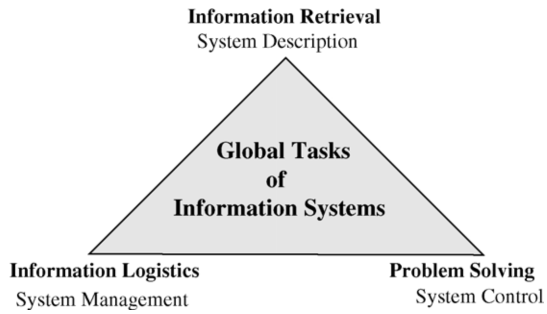

Fig. 2 Global tasks of information systems.

Fig. 2 attempts a more global approach in describing tasks of information systems:

(A) The most primitive, though necessary function is that of retrieval of information as it has been stored. This is the function of system description.
(B) If information is managed properly, it can be made available, whenever it is needed, where it is needed and in what presentation it is needed: the function of information logistics serves the system management.
(C) Future aspects go beyond system management to problem solving. This function of system control requires the further development of techniques just being experimented with. Expert systems and methods of artificial intelligence, hopefully combined with advanced statistical methods, have the potential to contribute to the solution of actual problems in the system environment. Here lies the future of information systems and there are great possibilities and needs within the hospital environment.

3. What has determined the development of systems in the hospital?

One has to bear in mind that hospital operations follow conflicting goals in terms of optimal use of resources and functions [9].

The system hospital has to be optimized as an 'industrial enterprise', minimizing cost resp. increasing efficiency.

On the other side, the system patient requires optimal attention and expects the use of all possible resources and highest technology in order to achieve the best results in re-establishing health or minimizing disease. Clearly, this does not necessarily go together with minimizing costs of hospital operations. Also time aspects of serving the 'system patient' do not necessarily coincide with planning aspects of hospital personnel and allocation of resources in laboratories and ancillary departments.

So far, the main thrust of hospital information systems has been lying in the area of optimization of hospital operations as such. Much remains to be done in optimizing care for the patient. Ultimately, this might also contribute to the efficiency of the hospital operations as such. But, this may remain wishful thinking. One has to face the problem that care optimization may generate additional cost. Hopefully information systems within the hospital may help to reconcile the conflicting goals.

In the 70's, systems concentrated more on the fiscal operations of a hospital and the administrative aspects. Gradually, interest is focussing on patient care, resp. the medical and nursing aspects (for the Federal Republic of Germany see [5,16]).

One aspect of providing better care for the patient is that of integrating all the information pertaining to his status and originating from various places and sources within the hospital. Interestingly enough, these integrating aspects could already be found in very early attempts, which failed due to insufficient hardware and software technology of the late sixties and early seventies (e.g. [4]).

Because if one examines how informatics technology 'penetrated' into the hospital, it can be seen that aspects of 'integrated files' [4,6] and logistics of patient care information was one of the major design criteria of early developments. What prevailed in the seventies however was providing support for administration on one side, or a specific laboratory operation on the other (see Fig. 3).

In 1978 [11] (also see [12,14]), I described the aspects of an actual information system within a

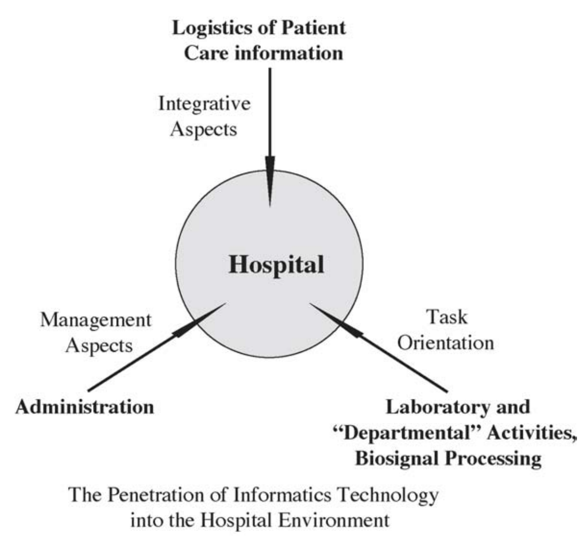

Fig. 3 The penetration of informatics technology [11,14].

specific health care environment to have resulted from three major hierarchies:

- The design objectives as the hierarchy determined by objective criteria and rational arguments for the construction of such systems being objectives of:
  - health care planning according to the local and regional requirements;
  - specific medical tasks, clinical trials and investigations;
  - patient care management and its improvement and
  - last, but very often not least, hospital management and optimization of hospital operations.
- The design 'drives' being the 'hidden' forces behind the objective criteria and very often providing the motivational aspects and emotional engagement for the pursuit of a certain way resp. systems aspect. These include:
  - the systems hierarchy resp. the attempt to achieve a certain structure;
  - the technology hierarchy resp. the influence of certain technology aspects and the belief in such;
  - the influence of the sociological hierarchy, e.g. the relationship between physicians and the nursing staff and
  - the utility hierarchy, e.g. the value placed upon the utilities as they are to be provided by the system (Fig. 4).
- Finally the design environment naturally has had strong influence on the actual development, be it through:
  - the aspects of finance and funding;
  - the structure of, e.g. the actual health delivery system;
  - the political environment with its priorities and preferences and
  - last, but not least, industry with its various influence zones, reaching from financial over systems to political aspects.

4. The present state

Accordingly, hospital information systems display different aspects according to the local and regional health care environment. Nonetheless, typical features have evolved, being dominated by the dualism of hospital goals namely to serve:

- the hospital management in order to optimize operations and
- the patient resp. to provide better possibilities for patient care and its management.

Fig. 5 tries to extract a conceptional schema from the various types of applications and their inter-relation (compare also [19]).

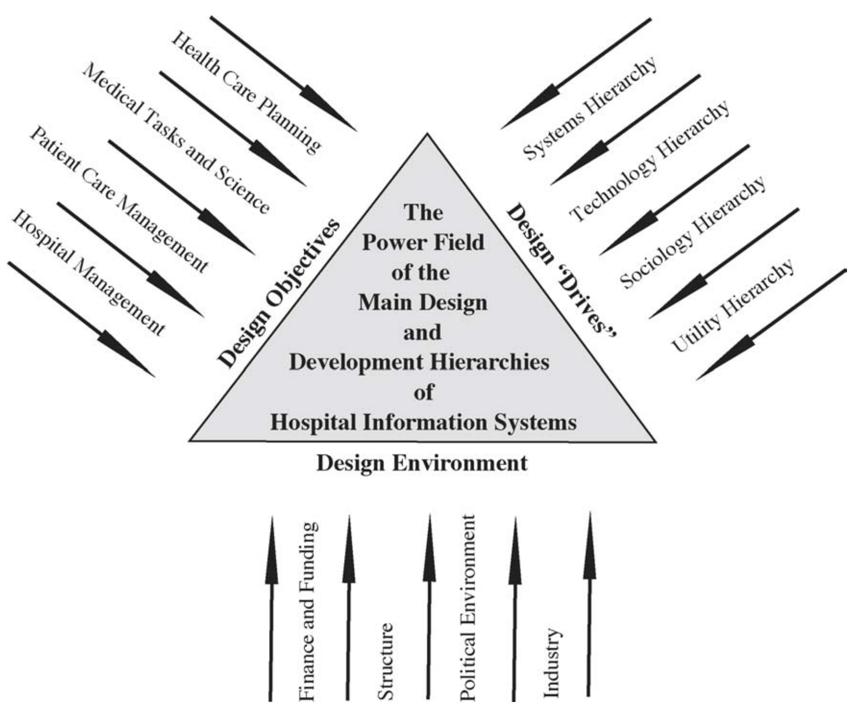

Fig. 4 The major hierarchies of system development (taken from [11—14]).

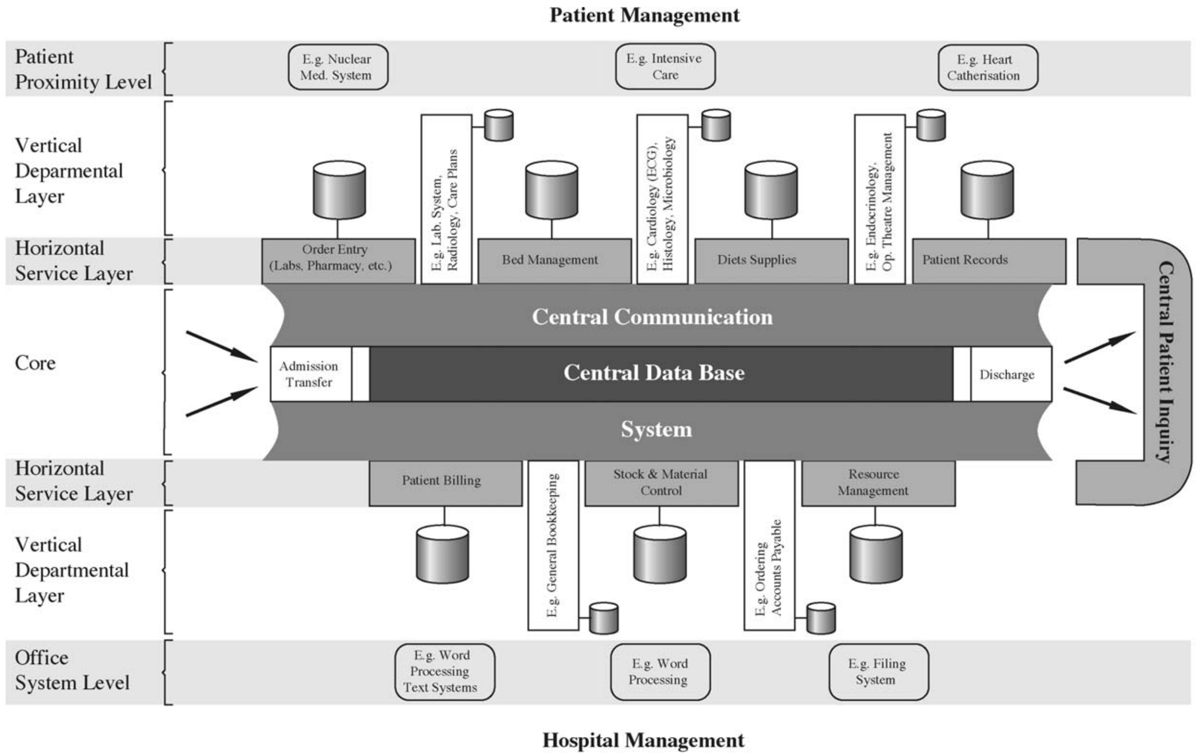

Fig. 5 Conceptual model of hospital information systems.

4.1. The core of hospital information systems

The center of information systems and the levels, as they developed both in pioneer installations and in the gradually evolving industrial software, is a central data structure and a means for communication. The patient 'enters' the system through the admission, transfer and discharge functions of the core and leaves the system, at least partially, through this main port.

Some solutions have opted for a more distributed construction of data bases; nonetheless central ordering principles have to be kept to achieve the necessary integration of information and the distribution to the various points where it is needed, be it in the area of hospital management or in the field of care provision (Fig. 6).

This central data base is serving the central operational purposes of the hospital in the context of its dual goals. The data base structures may be straightforward, or more complex in a data bank, which certainly is to be preferred because of the various requirements and access procedures resp. combinations. Also a chronological hierarchy may have to be developed in regard to mass storage concerning archiving of data, abstracting and maintaining central summaries.

Preferably, hospitals have only one communication system. In history however, it has been necessary to keep old communication systems and to combine them with newer ones. This applies more to installations that have had to 'marry' older approaches with newer ones. Industrial systems, as being offered, certainly will be based on only one data base manager and communication system.

4.2. The horizontal service layers

The horizontal service layers (see also [19]) span departments both in patient care and hospital management and provide the means for daily operations. They have a broad interface with the core, both in regard to communication and to the data base structures.

Consequently, the data exchange between these systems and the core is high in volume and in frequency.

According to the dualistic structure of hospital information systems, the service layers can be found both in hospital management and patient management. Fig. 7 gives a prototype example for the possible modules in hospital management. The list of modules and functions is neither exhaustive nor absolute; in reality more functions or others may be present according to the actual health

Common Date Base System

The data base system is the most important part of the core of an hospital information system. It may or may not be a single data base; preferentially there will be several data bases according to the functional characteristics and with varying time characteristics concerning the storage of a data (from episodal to permanent). In case there is more than one data base, a logical connection has to be made between the varying parts. The data base needs the horizontal systems and contains summaries or key data from and for vertical systems and other sources.

A/D/T-System

The admission, discharge and transfer system provides entry and exit points for patients and determines their location within the system. Main functions are:

- To examine, whether the patient has already been in the hospital and to assure a unique identification number also enabling record linkage.
- To initialize the data parts necessary for the various horizontal and, if necessary, departmental systems and administrative structures.
- To produce identification devices and forms necessary to process admission or discharge with the external environment.

The Communication System

The communication system provides the on-line connection between the users and the various application systems respectively the common data structures.

Fig. 6 Core of hospital information systems.

Patient Oriented Administration

- Charge Capture
  (as far as not yet provided from the horizontal laver of patient care)
- Patient Billing

Finance and Bookkeeping

- Journal(s)
- Accounts receivable
- Accounts payable
- Investments
- Fixed assets
- General ledger and balance

Material and Disposition

- General stock control
- Pharmacy administration
- Blood bank administration
- Purchases and dietary requirements

Personnel Information Systems

- Payroll
- Personnel administration

Organization

- Personnel scheduling
- Bed control and management

Fig. 7 Horizontal service layer of hospital management.

care environment. One application may span different functions and vice versa the modules may be broken down according to more subfunctions. Typically, however, these systems require additional service data structures, according to their own constraints to function properly and efficiently. Very often, patients carry more than one identification number, e.g. a medical record unit number, or, as in many instances in the Federal Republic of Germany, a personal data related ID-number and additional account, claim or policy numbers for a stay within the hospital, e.g. to associate the data with a certain billing procedure. However, also here the broad contact with the central communication and data base system is necessary and exercised.

Unfortunately, according to the specific tasks of administration, there is a strong tendency to separate these service layers from the common approach within hospitals. This is not only deplorable regarding the necessary additional resources and redundant storage, but an integrated view is only possible if administrative data are derived from medical actions. Vice versa medical actions can be reviewed and correlated to administrative functions and consequences. Despite the dualistic aspect of the operations in hospitals, the hospital as a whole has a common goal to give maximum service to the patient with optimal procedures, while maintaining high quality of medical care. This common goal can only be reached through a common approach.

Fulfilling a basic prerequisite for modern accounting procedures, systems addressing themselves predominantly to these functions were developed by industry in the sixties and found their way into the hospital in the industrialized countries. For the Federal Republic, e.g. a recent survey revealed that approximately 85% of all hospitals have contact with edp-systems in one way or the other [5,16]. Of those hospitals having more than 250 beds this figure can be specified with 97%. Mostly these applications lie in the area of business and management. Thus, it is naturally, that more comprehensive systems start from here providing data entry for business administration, planning and other chores of management.

Fig. 8 is the analogy to Fig. 6 for the 'patient care world' of the horizontal service layer. The same as for Fig. 7 has to be said here in regard to comprehensiveness and grouping of the systems described. Typical for these systems is, like for hospital management, that they span services and departments and provide a general tool for the scheduling and processing of patient care. Typical is also, that most of the procedures planned or supported are able to provide basic information for cost accounting and billing, when they are properly constructed and the necessary information is captured and transferred to the service layer of hospital management. This makes the integrative aspects obvious.

More sophisticated approaches may, e.g. combine reporting systems (for instance like in radiology) with abstracting and coding systems for the further classification of the care procedure or the diagnostic-therapeutic classification or process. The same holds true for surgical pathology and histology.

As indicated in Fig. 5, the horizontal layers communicate broadly with the central data base. Nonetheless, own storage structures are developed for performance, safety and optimal storage. In principle, the functions described may be implemented in separate hardware structures, provided that resp. software guarantees the necessary integration and communication.

Order-Entry and Result Reporting Systems

Systems to interact with laboratories, radiology, micro-biology and other ancillary departments to initiate investigations concerning the patient and making provisions for receiving the results. Ideally, charges will be generated from these systems automatically for charge capture systems for billing and in the future for cost identification and cost accounting. (Linkage with horizontal service layer of hospital management).

Patient Care Planning and Scheduling Systems

Provide planning and scheduling of patient care:

- scheduling systems for the transportation of patients for the various examinations and interventions resp. treatments such as radiology examinations, physical therapy, etc.,
- operation theatre planning,
- pre-admission and out-patient scheduling and
- nursing care systems as they are developing for planning and delivery of nursing care according to general and specific plans and principles.

Dietary/Kitchen Control

In the simplest form to order the meal, in more advanced stages to provide selection between menus or possibilities to compose the meal according to components available with respective linkage to the patient's care plan.

Therapy System

In the simplest form as pharmacy system to order and administer drugs to the patient, in more advanced types to test for interaction or contra-indication. Systems may also provide initial counselling for therapy selection.

Material Supply

These systems allow for the ordering of specific material for medical treatment. Blood e.g. may be ordered here or through a more advanced therapy system.

Medical Records Control Systems

For the management and localization of medical records and to ensure documentation and abstracting according to given rules and codes.

Fig. 8 The horizontal layer of patient management objectives.

Departmental Systems

To serve the activities within a department and to:

- control,
- support and
- report. The activities within a department such as clinical chemistry, radiology, micro-biology, neuro-physiology etc., but also special clinical units in regard to:
  - administration,
  - activities planning and control
  - documentation and
  - scientific evaluation.

Fig. 9 Vertical layer of departmental systems in patient care.

4.3. The vertical departmental layers

The vertical departmental layers (see also [19]) in Fig. 5 support the functions of a department or a subsystem with the hospital. In hospital management, these systems process accumulated patient data, communicate with the outside in regard to supply and finance etc.

In patient care, this vertical layer serves the medical departments and services as described in Fig. 9.

It is typical, that here the necessity for own data structures increases resp. the exchange with the central data base of the core decreases, resp. develops towards defined interfaces and parameters.

Special Purpose-System in Patient's Proximity

These systems include special management systems like those for:

- Heart catheterization.
- Automatic ECG or EEG analysis.
- Ultrasound.
- Computer tomography.
- Nuclear magnetic resonance.
- Nuclear medical examinations etc.

Systems for Intensive Care

- Of various kinds (postoperative care, cardiac or neurological care, etc.).

Expert Systems

For:

- Diagnostic support and procedures.
- Therapy and selection of therapeutical methods.

Pictorial Systems

For the manipulation and presentation of pictorial data and, esp. in the future, 3 D-representations and picture synthesis.

Fig. 10 Systems of the patient proximity level.

4.4. The level of independent systems

Like in the universe, far-away from the core, independent structures develop like own galaxies. Fig. 5 describes these as patient proximity systems for patient management and as office systems for the 'world' of hospital management. These applications have increased dramatically with the advent of PCs. In principle, a communication with the core is not necessary, though communication may be advantageous.

Such 'satellites' or 'new galaxies' are described in Fig. 10. The development in the future will lie in the area of expert and pictorial systems. But still great research and development is necessary before they will become tools for routine use (see also [15]).

5. Principles and problems of communication

This development of structural layers serves the necessity to provide adequate utility to the various structures and objectives. However, the more complex the system grows, the smaller will be the possibility for changes and dynamic development. This is especially true for the necessary integrating aspects. Communication becomes a problem, when information has to be presented where it is needed and when it is needed. Synchronization and integrity of the various data pools is necessary for proper functioning and in order to avoid repetitive data capture and update.

Fig. 11 gives a general model of the relationship between complexity and flexibility. Flexibility, however, is also required in regard to the necessary changes resulting from the advances in medicine and the social changes reflected in new proce-

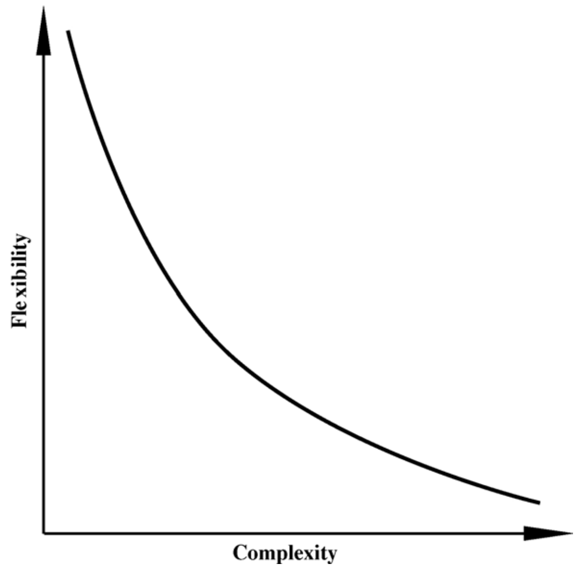

Fig. 11 The relationship between complexity and flexibility.

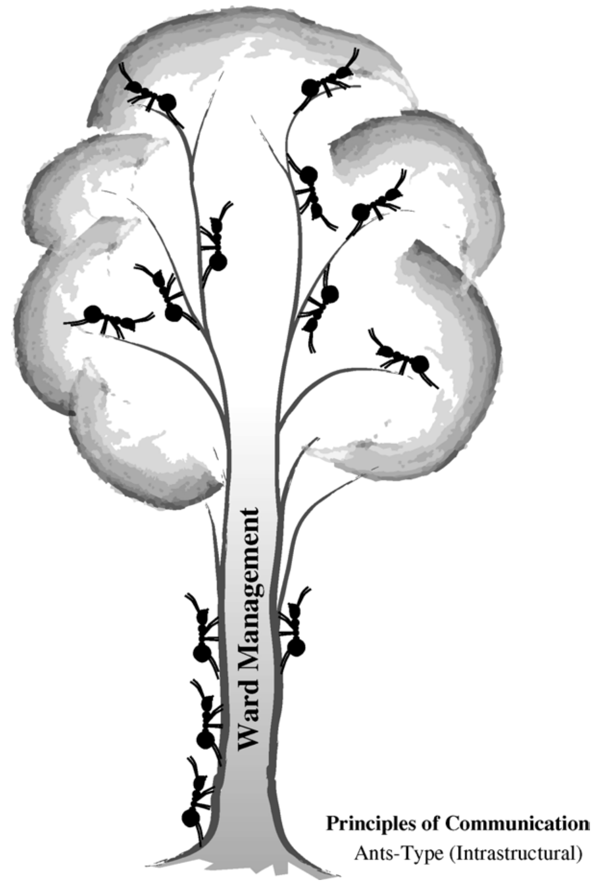

Fig. 12 Principle of communication: ants type.

dures for accounting, costing, restrictions and other events of influence upon the health care delivery system.

Flexibility is also necessary in adapting hospital information systems to local environments. It cannot be expected, and this is one of the lessons of the past, that one system can be transferred to another location without a pre-analytic phase in order to define the requirements of the new site and an adaptive phase where these requirements are translated into the mechanisms of the system. The otherwise necessary mirror-like copy of organisational and internal structures is only possible in a very few cases. Consequently, systems have to be ready for changes and this preferably without compromising their principles of architecture.

Communication is necessary between the various layers within the systems. When only financial systems are created and in operation, e.g. it is not necessary to leave the system in order to go to its various branches of operation. The same is true for order entry systems without communication to laboratory systems or administrative systems or those in the patients' proximity.

The communication within a system in its various branches goes up and down those branches like ants crawling up and down in a tree and looking after their different chores while exchanging experience on their way. This type of communication, the ants type, is the intra-structural communication within systems for a single purpose (see Fig. 12).

The past has shown that such an intra-structural communication does not suffice for hospital information systems. The system aspects have to follow the human mind in addressing various issues, like those for order entry and switching over to receiving and interpreting results and finally, e.g. to address the question of patient billing.

The thoughts and issues therefore have to jump from one system aspect to a completely new structure like Tarzan swings from one tree to another until he reaches that particular system where he wants to dwell or follow a particular purpose. Fig. 13 illustrates this principle of inter-structural communication.

But Tarzan, if we want to stay with this allegory, may jump from one tree to a very different other one, he still remains within a common environment of trees of a tropical nature. The human mind, on the other side, is not only able to jump from one particular aspect of an application to another within the same overall environment, but is able to leave one system completely to enter another one with completely different rules of weighting and reasoning.

Future systems have therefore to provide this intersystem type of communication, like travelling from one galaxy to another in a sort of 'hyper-jump' as described in science fiction (Fig. 14).

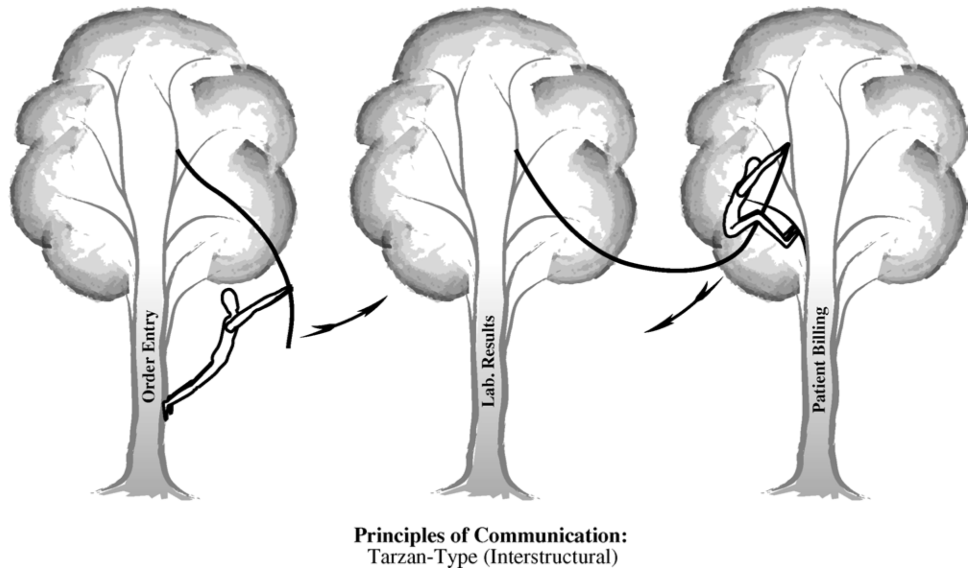

Fig. 13 Principle of communication: Tarzan type.

Expert systems in medicine indicate such a change between fields of reasoning. In one context, symptoms are weighted in a particular way, but with changing fields of interest, these weights have to change completely and systems have to adapt themselves to these different views. Human minds can do this very easily. Computer systems have only started to learn this in very crude approaches. Mostly their process of reasoning crawls up and down a tree following the principles of ants. The resulting slowness and awkwardness of the process explains why most expert systems, e.g. have not yet gained routine usage in practical medicine.

Surely, this intragalactic type of communication is the domain of research and future application. But very certainly hospital information systems

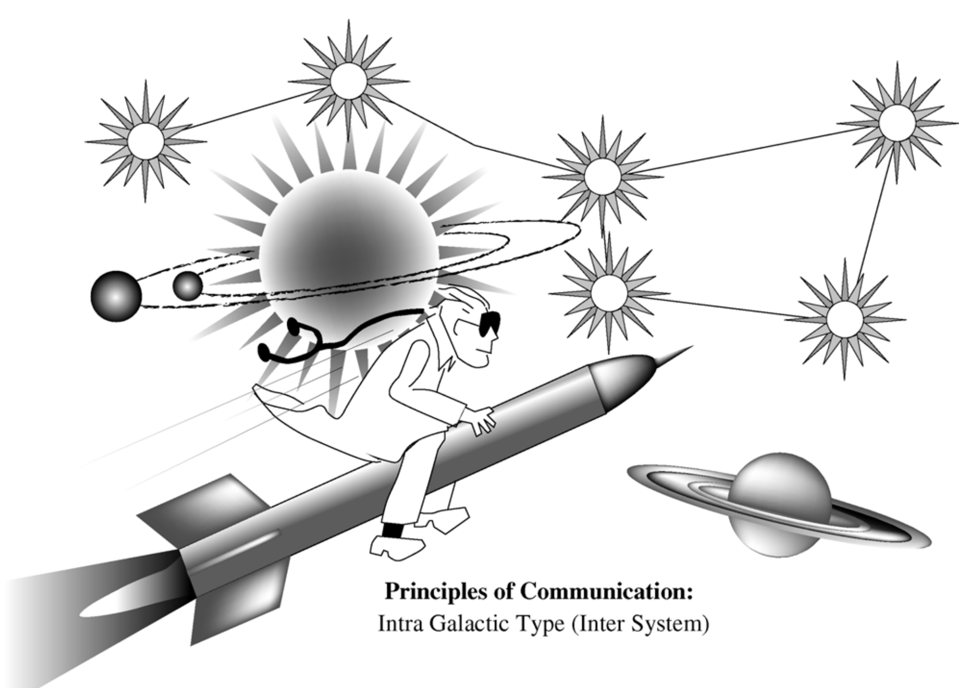

Fig. 14 Principle of communication. Intra-galactic type.

even today need the Tarzan type of communication and this is possible through a common architecture and modern technology. Carrier systems which install different applications within the same structure have the technological requirements for such an approach. Another approach is the development of networks in hospitals with connections between the different layers as shown in Fig. 5.

But technical means alone do not suffice. Information in the context of a hospital information system has to serve very different purposes, has to be handed from tree to tree in Tarzan's type of communication and even has to be sent from one galaxy to another. One principle to deal with these requirements is that of twin packaging, preferably with abstraction.

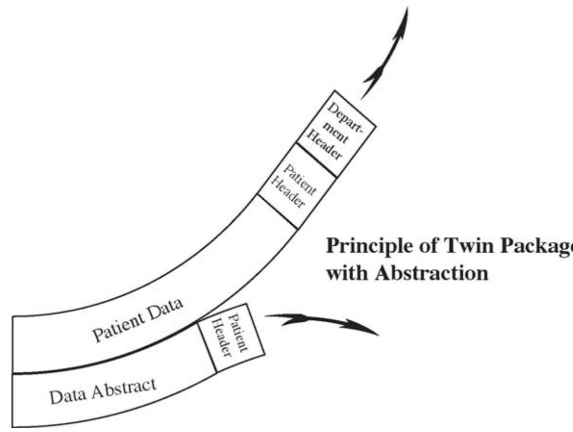

Fig. 15 Principle of twin-packaging with abstraction.

Fig. 15 tries to illustrate what is meant by this principle. Mostly certain patient data in a network have to flow to the address of a certain department or service. Here the data in detail are needed pertaining to a certain patient. However, both for this department and for the communication with other services, an abstraction of the data is needed. In radiology, e.g. the full description of the X-ray image is necessary for the process of reading and finding the diagnosis. In the patient summary, however, only the radiological diagnosis is needed resp. the final evaluation. Such is the case also for an expert system, which has to develop a final and comprehensive diagnosis. For an administrative system it is only necessary to know that a certain type of examination has been performed.

Abstracting and providing information for a comprehensive view is mainly necessary in the medical realm of hospital information systems or the upper side of Fig. 5. But also abstracting is necessary for financial evaluation and overall planning resp. cost accounting. In medical systems, however it will become of particular interest if observations of a longitudinal matter are to be made available for the reasoning process. This means the condensation of observations of one episode to make it available as information for subsequent ones or to communicate the situation between systems, e.g. those of internal medicine to those of surgery (Fig. 15).

It really does not matter, whether the communication process and the integration are based on one central system or on the combination of central systems and peripheral storages, as indicated in Fig. 5. The principle of twin-packaging with abstracting allows for a central version as well as a peripheral one.

Fig. 16 shows a central version of such integration. The abstracts are sent to a central synthesis system, where the information is available both to the peripheral system as such as well as to other systems for their particular purpose. Fig. 17 shows a peripheral version of information synthesis. Here the abstracts or communication parts of the resp. information elements are stored within the peripheral systems and are made available to a central synthesis system for further reference.

It is necessary to define these processes of information exchange when networks are intended to move from a mere combination of information sources with information sinks to an integrating instrument in patient care and hospital management. The solution lies neither in the development of monopolistic or monolithic great multi-

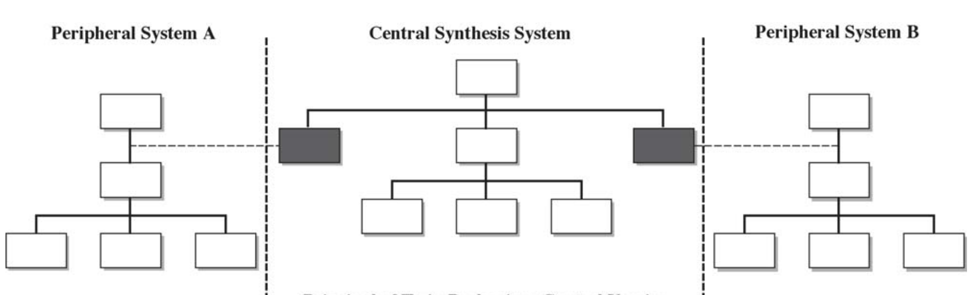

Fig. 16 Central version of synthesis with the principle of twin-packaging.

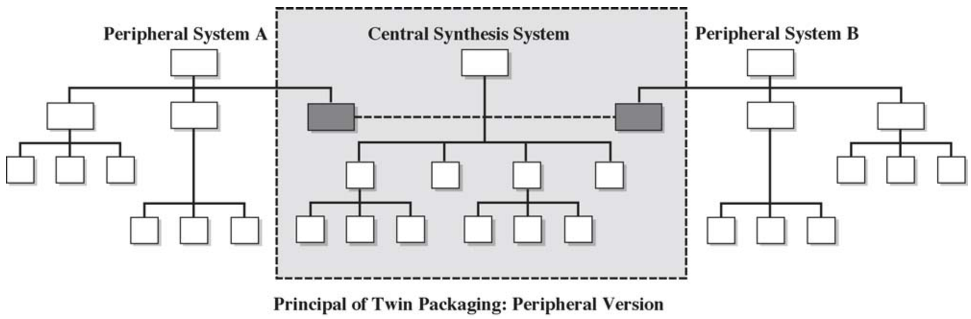

Fig. 17 Peripheral version of integration according to the principle of twin-packaging.

purpose central systems providing the integration due to comprehensive databases nor in the desintegration into single purpose dedicated systems, but in the development of multi-purpose networks systems.

Fig. 18 shows the resulting principle as described earlier [11—14]. Resulting from these requirements, the core of hospital information systems has to be broader than described in Fig. 6.

Fig. 19 consequently shows the updated aspects of the advanced core in hospital information systems. Besides the basic components shown in Fig. 6 here the communication system is expanded by network aspects and the functions of a central inquiry system is added, be it in the peripheral or central form of realization.

The importance of architecture has already been stressed several times. Architecture in this context means the 'art of construction', the philosophy behind an approach including also aspects of user psychology and system ecology, which is meant as the eventual new biotope developing out of the interaction between information systems, organizational structures and the human beings who live and work in this new environment. Systems are changed by this system's ecology, human behaviour adapts to systems aspects and develops new abilities to interact with the system.

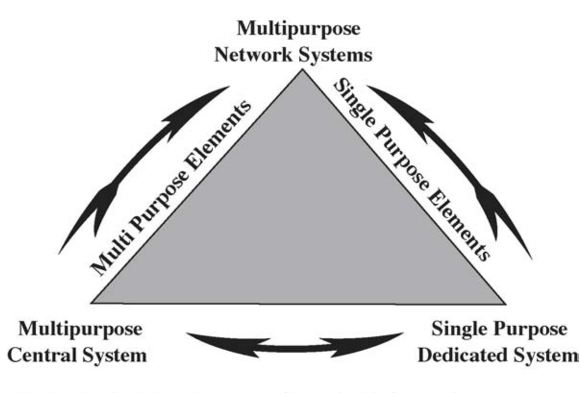

Fig. 18 Multi-purpose and single-purpose elements of a system for a multi-purpose network system.

The resulting consequence is the necessity to provide means for adaptations of functions of the system to the new requirements of the developing systems ecology. 'Hard-programming' is no longer sufficient to cope with these requirements. 'Carrier systems' have been described as to be able to provide the tools for change to meet these requirements (see [11—14]).

Fig. 20 describes the principle of such carrier systems. The system logic is no longer within the program itself, but is separated from the program and is defined in a formalized structure kept separate from the application logic as such. Modern hospital information systems follow this philosophy of carrier systems: they provide for a separate definition of the logic of screen events, printing and process using high level approaches for defining the elements and steps of screen definition, information display, storage and regrouping. These approaches attempt to make this technique independent from certain machines or, in other words, to make the system runnable also on smaller hardware, so that the logic may be developed or used on different sites and on different machines (an own attempt to transfer the software developed within the own system onto System/1 and smaller types had to be discontinued because of lack of support).

6. Architecture and user psychology

Information systems are not placed into the void. It has been stressed several times that they react with their environment and form a new user ecology. This development, however, has to be planned by architectural approaches. Such an approach includes the recognition and implementation of the development of user psychology and behaviour into the constructional process. Organizational and psy-

Common Data Base System

A logical connection has to be provided between the varying parts. The data base feeds the horizontal systems and contains summaries or key data from vertical systems and other sources.

A/D/T-System

The admission, discharge and transfer system provides the entry and exit points for patients and determines their location within the system. Main functions are:

- Positive identification and record linkage.
- Initialization of storage and process control data.
- Production of identification carriers and necessary forms.

The Communication System

The communication system will:

- Provide the on-line connection between the users and the various application systems respectively the main data structures.
- Provide a network between the various computer facilities in the hospital and will thus make the development of distributed services and databases feasible.

The Central Inquiry System

has to combine the most important data of the patient together with identification, administrative and other items of general interest. Summary of data types available and status information regarding requisitions, abstracts of medical reasoning and the cource of the disease respectively their classification have to be made available according to access classes determined by the status of the user. Review of previous episodes.

Fig. 19 Advanced integrating core of hospital information systems.

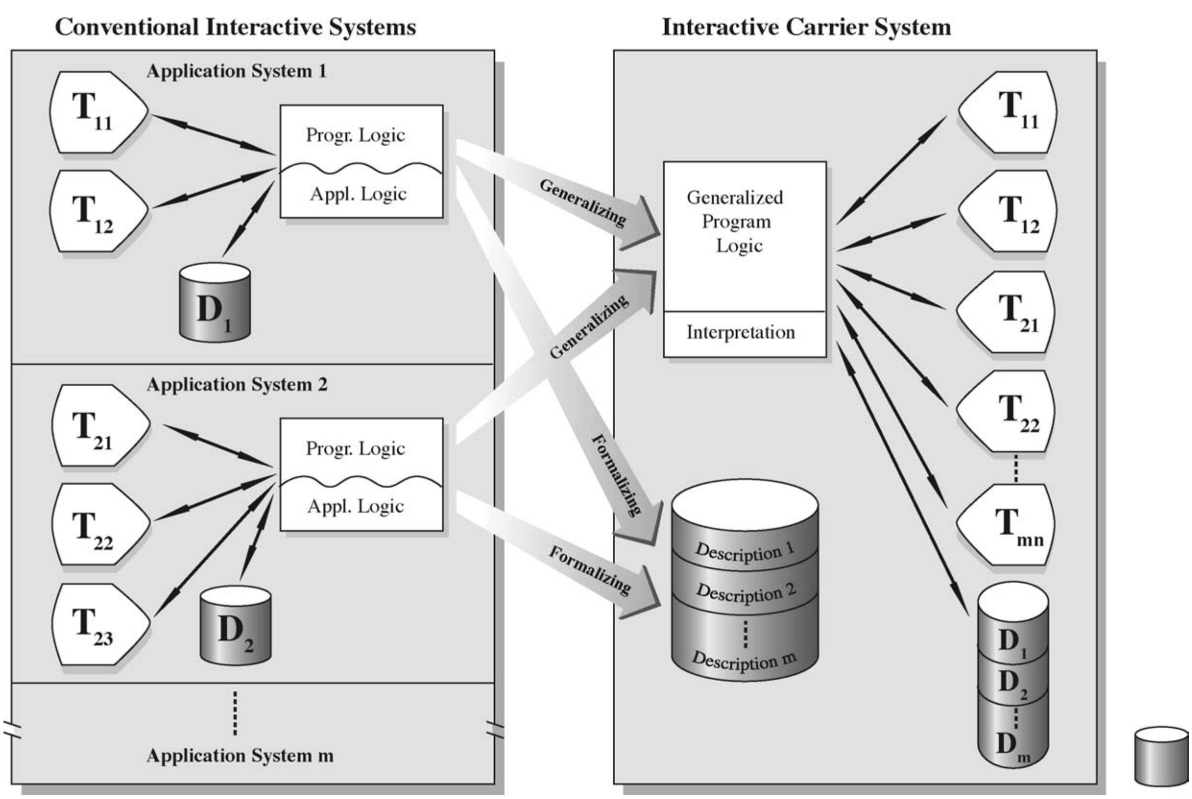

Fig. 20 The principle of carrier systems (taken from [20]).

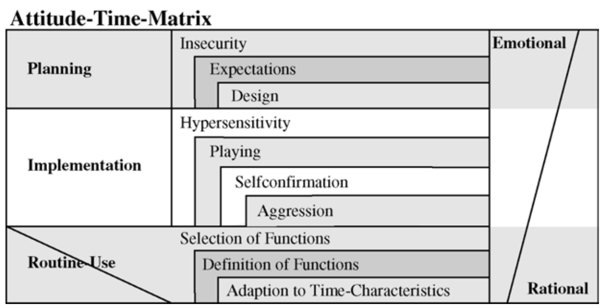

Fig. 21 Phases of user reaction during planning, implementation and routine use (see [8,17,18]).

chological obstacles are considered to be the most important ones on the way towards the successful implementation of information systems in the hospital (see [3,8,17]).

A time dependent development of attitude can be seen during almost every introduction of a system into an environment, which as such has not directly been involved into the acquisition. Even if such an involvement has been the case, changes between insecurity, hypersensitivity and realistic approach to pragmatism characterizes the development from emotional to rational attitude. Fig. 21 shows such a time-attitude matrix, broken down in phases and components.

This stresses the necessity of coping with user psychology in the implementation of systems in hospitals. Not only the system has to be taught as such but one also has to prepare for the reaction with the system. This stresses also the necessity of a pre-introductory phase which is not only necessary to prepare the system for the introduction into the new environment according to its particular aspects, but also to prepare the environment for the system, both in organizational and psychological-sociological aspects.

For the immediate future, this has the consequence that appropriate installation means have to be available when a major change is made in a hospital which, e.g. is the change from a complete manual and traditional system to a fully computerized type of operation. Whether such a technology transfer team is formed by the hospital itself under the leadership of medical informatics, is brought in from an independent consulting firm or provided by the vendor, is basically of no major concern. All varieties and combinations are possible. And in preparing the transition, one has to be reminded that major changes sometimes are easier to accomplish than subtle differences and adaptations in the daily way of life. And these types of changes are the gist of a transition into a new systems ecology.

7. How will new technologies change hospital information systems?

The major changes due to new technologies will be caused by the rapid deployment of more and more powerful small computers. The same computer power can be bought today at a price of around 1/150 of the price 12—14 years ago. This certainly enhances the possibility of creating independent systems in the satellite layer (see Fig. 5), both on the side of hospital administration and patient care. This enhances also the production of problem-oriented software. The more people have access to these tools, the more hidden talents will be wakened and tapped for the production of software to solve immediate problems. Some of this software will be ready for generalization and general distribution. Only a very small part will meet the requirements for routine usage and exportation to other sites. But since more attempts will be made, the resulting number of available software will increase dramatically. This leads to the phenomenon of an 'exploding universe', with the various new galactic systems moving more and more away from a central hierarchical system, but also from central integrating forces. The tasks of medical informatics therefore will move away from the construction of individual systems towards more comprehensive system analysis, construction of networks and devising schemes for twin-packaging and hierarchies of information to provide exchange and integration.

With new developing technologies such as optical disks, higher storage capacity, fiber glass optics, etc. there will be many incremental improvements in storage, transmission and speed. However, very often a technology is hailed as a major breakthrough, but still does not find its way into practical use. An example for this is, e.g. the optical disk already mentioned. But then, after some time of crawling around, the new technology will attack with a big jump. Where and when it happens is very often difficult, if not impossible to predict.

Fig. 22 gives a few highlights of new trends and technologies as they emerge at the moment and as they get ready to conquer the field of new applications in the hospital environment.

Pictorial data processing systems are under development, combining multiple sources of (digitized) data into single display and manipulation units. They start emerging in radiology for digital X-ray pictures, computer tomograms, NMR-scans and sonograms. The technology of today is already very advanced with high resolution and good technical quality. The work stations being developed right now try to mimic the possibilities of viewboxes

Pictorial Data Processing and Transmission

First starting in radiology and making available digital x-ray pictures, sonograms, CT-scans, NMR-scans etc. for review and manipulation including 3D-synthesis and projection

Videotex Applications

In in-house networks using new storage technology, e.g. optical disks to replace conventional archives

Comprehensive Work Stations

- giving combined access to the various information systems of digital, pictorial or videotex nature
- providing local computer power for dedicated tasks, word processing and personal computing
- linking to central facilities and computing

Linkage of Expert Systems to Data Bases

To make use of routinely sampled data for decision support and management

Fig. 22 Highlights of new technology.

with overlays, comparisons, zoom-effects and definitions of areas of interest. But also new features appear: the processing of information into a 3D-synthesis. It does not seem to be only the stereoscopic views that cue a 3D-impression: more powerful seem to be the depth perception due to movements of the head (and the position of the viewer) and the resulting changes in perspectives. Laboratory devices try to simulate such changes in perspectives: sensing devices at the head of the viewer indicate the movement of the head and lead to resulting changes of the picture, vibrating mirrors create depth perception and rotating diodes give an almost eary picture of the image to be presented. But also good stereoscopic and perspective presentation of skulls and skeletal images of CT-scans give almost unbelievable clear pictures of impression fractions, distortions, etc. which so far, were indicated only by additive linear silhouettes in X-ray projections.

Initially these pictorial data systems will be only available within specialized departments. Later on, however, a linkage over a hospital network may make it possible to combine these technologies with digital information systems giving the physician on the wards the possibility to look at the presentations during his work on the patient, in his office or whenever this information is needed. In some way, these technologies will eliminate the need for specialists that have learned to interpret two-dimensional projective X-rays during a long time of residency and subsequent experience.

Videotex applications may be soon around the corner. The experiences gained now in commercial systems may make it possible to develop in-house networks for storage of static data, such as old patient records and other data, both of administrative and patient care origin. Here the optical disk may serve as convenient storage medium in the evolution to replace conventional archives. Ideally, also these networks should be linked together with digital networks, both for information processing and display as well as, in the future, transmission of pictorial data.

These developments necessitate also the emergence of new types of work stations, which make the access possible to the different information systems of digital, pictorial or video-text nature. Overlays have to be possible, windows into various systems, paging backwards and forwards and sideways with 3D-manipulation and other means of presenting data in new ways and flexible forms. These work stations have to provide access to local computer power for dedicated tasks like word processing and personal computing, but also have to give access to more advanced statistical software, e.g. graphical systems and other services offered by central computing facilities.

The last item given in Fig. 22 is conceptually of great importance, though the realisation to a usable tool will be very difficult and requires scientific analysis and development efforts. Nonetheless, the linkage of a data to counselling and expert systems has already been attacked in some instances. The 'HELP' system may be considered as a prototype [18].

In expert systems in the future, a synthesis will occur between the old probabilistic and algorithmic approaches and the new ways of using inference machines, rule based approaches and other techniques formalizing the experience and approach of the human expert. Research is necessary in order to investigate the determining and discriminating variables, the interrelation between causes and the resulting changes and further factors of influence. It cannot be assumed that all this can be verbal-

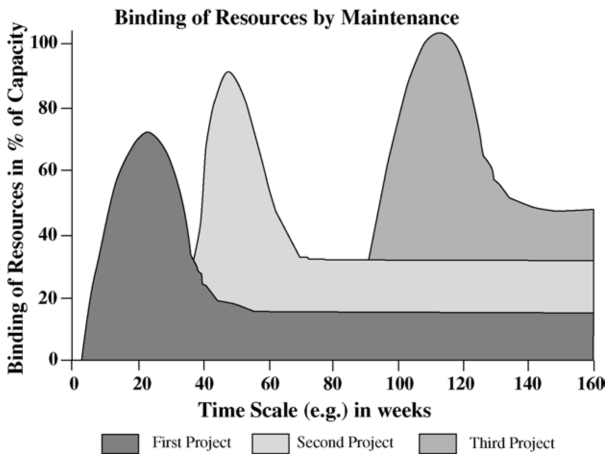

Fig. 23 The binding of resources by increasing maintenance.

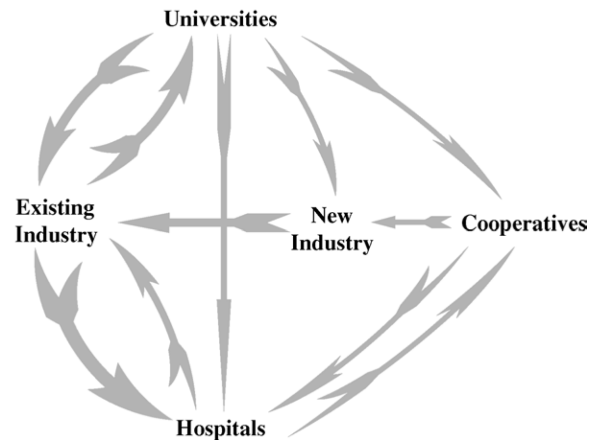

Fig. 24 The different forms of development.

ized by experts out of their experience. But the combination of analytical research and formalizing empirical experience will lead to better results than using only one of these great reservoirs of cognition. Advantages can be expected, when routine data bases can be linked with expert systems both for the exploration of facts, generation of hypotheses and the application of decision rules onto data obtained by routine examinations and specific diagnostic procedures. Here lies a wide field for creative research in the field of Medical Informatics and Clinical Medicine.

8. Who carries the development?

In the past, with 'straightforward systems', many developmental efforts were found in larger university and care providing hospitals. Industry made several approaches which were unsuccessful, as long as not adaptable carrier systems were available.

Fig. 23 describes how here the maintenance problem by accumulating residual maintenances gradually devoured all developmental resources.

One way to cope with the problem was the development of carrier systems, centralizing the maintenance tasks for systems aspects and making it possible to spread out development over several installations. The industrial distribution of a system with the resulting spreading of error discovery, pressure for adaptation and maintenance is another important factor.

Fig. 24 shows what has happened in the past and is happening at present. Whereas most of the earlier developments started in universities, industry has taken an early influence on these developments and certainly some of the prototypes have been taken by existing industry in an attempt to market hospital information systems. Some of these attempts have been successful, others have failed. Naturally out of old industries developed new industries, either continuing to exist or joining with existing industries to new ventures. But also out of hospitals and universities cooperatives have resulted, still functioning as cooperatives and sometimes developing into new industries. The main thrust now goes from existing industry and cooperatives to hospitals and the routine application in these hospitals takes strong influence on the systems being developed and maintained for the market. Existing industries still have recourse to universities for new ideas and developments. Also a shift of interest has occurred from larger university hospitals to common hospitals and this will increase with the resulting demand for more routine-oriented and 'of-the-shelf' systems which, nonetheless, will need adaptation and introduction.

9. Concluding remarks

This analysis has looked at various points of interest in describing the past, present and the future of hospital development. It does not consider itself to be comprehensive. On the contrary, it is selective on a purpose. Nonetheless, a few traces could be drawn from the projection of past developments and the present state into the future, attempting to highlight some requirements and new possibilities.

When looking again at the global tasks of information systems as presented in Fig. 2 and if consequently one tries to reflect the role of hospital information systems in fulfilling the tasks of a hos-

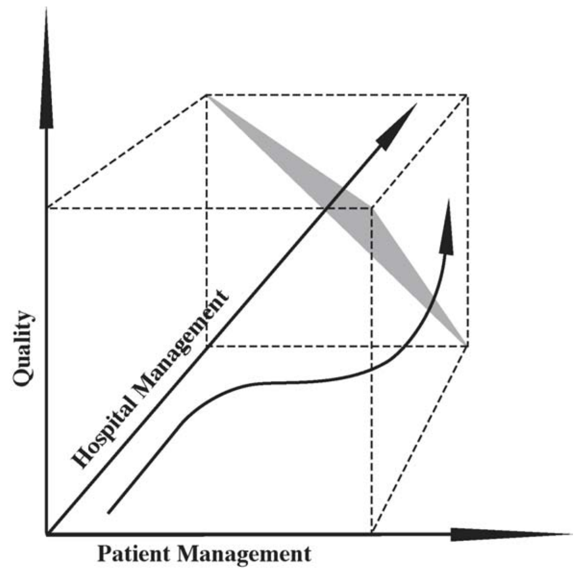

Fig. 25 Pyramid of hospital objectives.

pital, one is reminded that the goals of hospitals are dualistic in nature.

The system 'patient', be it in terms of the individual patient or a population, is the primary target of the delivery of health care. Efforts here may not be coincidental with the goal of running the hospital efficiently in terms of hospital economy and employees satisfaction. Professional recognition somehow centers between both goals.

So far, the development of hospital information systems has started at the zero point of Fig. 25 and has moved along the axes of hospital management. It then has turned and is nowadays gradually moving towards patient management in order to maximize both objectives. Necessary in the future is the movement up to the top of the pyramid towards quality of care.

Certainly quality of care does not automatically optimize hospital management in terms of economy. Hospitals have to have a broader goal in mind than only their own businesslike operations.

Future hospital information systems will have to concentrate more and more on the quality of medicine. Systems will increase in the area of patient management, but also of direct problem management with the help of pictorial data and expert systems.

Fig. 26 tries to summarize the development so far from a systems point of view. We presently are in the transition between integration phase I and the proliferation. Integration phase II must be attempted next and some tentacles of the present development point into this direction. The proliferation, however, can lead to a galactic isolation. This has to be avoided by controlled structures in terms

Phases of Hospital Systems

spot applications

Sub-systems approaches:

- Laboratory
- Administration
- Radiology
- Etc.

Integration phase I:

- Centralized
- (Common) data base (s)
- Communication

Proliferation of:

- Functions
- Systems
- Hardware

Integration phase II with the development of:

- Architectural approaches
- Networks and
- New components
- ? the future
- 'Galactic isolation' or
- Controlled structures providing new
  - hierarchies and orientation by
  - problems and objectives?

Fig. 26 Historical development of hospital systems.

of architectural hierarchies and the development towards the objectives of solving problems for the complex and sometimes antagonistic goal structure of hospitals.

The development of hospital information systems therefore should be considered to be 'social engineering' as well as the pursuit of scientific objectives in medicine for the increase of quality of medical care. This requires comprehensive research and the cooperation of clinical medicine, medical informatics, industry and administration. The development certainly is still quite at the beginning, not yet approaching its end of possibilities. However, because it is social engineering in changing systems ecology, it is a field which deserves careful attention and concern of all involved in order to create a useful future.

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