2
Basic Concepts

2.1 Introduction

Every domain usually has its own terminology, which often differs from the ordinary understanding of concepts and terms. This chapter presents the terminology for hospital information systems and its information management, as used in this book. It is therefore essential to read this chapter carefully. All relevant concepts can also be found in the thesaurus in Appendix A.

After reading this chapter, you should be able to answer the following questions:

- What is the difference between data, information, and knowledge?
- What are information systems, and what are their components?
- What are hospital information systems?
- What are health information systems?
- What does information management mean?

2.2 Data, Information, and Knowledge

Data constitute reinterpretable representations of information, or knowledge, in a formalized manner suitable for communication, interpretation, or processing by humans or machines. Formalization may take the form of discrete characters or of continuous signals (e.g., sound signals). To be reinterpretable, there has to be agreement on how data represent information. For example, "Peter Smith" or "001001110" are data. A set of data that is put together for the purpose of transmission and that is considered to be one entity for this purpose is called a *message*.

There is no unique definition of *information*. Depending on the point of view, the definition may deal with a syntactic aspect (the structure), a semantic aspect (the meaning), or a pragmatic aspect (the intention or goal of information). We will simply define information as specific knowledge about entities such as facts, events, things, persons, processes, ideas, or concepts.

For example, when a physician knows the diagnosis (facts) of a patient (person), then he or she has information.

Knowledge is general information about concepts in a certain (scientific or professional) domain (e.g., about diseases, therapeutic methods). Knowledge contrasts with specific information about particular individuals of the domain (e.g., patients). The knowledge of a nurse, for example, comprises how to typically deal with patients suffering from decubitus.

For the sake of simplicity, we will often use the term *information processing* when we mean processing of data, information, and knowledge.

2.3 Information Systems and Their Components

Systems and Subsystems

Before talking about information systems, let us first define the concept "system." As defined here, a *system* is a set of persons, things, and/or events that forms an entity, together with their relationships. We distinguish between natural systems and artificial (man-made) systems. For example, the nervous system is a typical natural system, consisting of neurons and their relationships. A man-made system is, for example, a hospital, consisting of staff, patients, and relatives, and their interactions. If a (man-made) system consists of both human and technical components, it can be called a *socio-technical system*.

A system can, in principle, be divided into *subsystems* that comprise a subset of the components and the relationships between them. For example, a possible subsystem of the nervous system is the sympathetic nervous system. A subsystem of a hospital is, for example, a ward with its staff and patients. Subsystems themselves are again systems.

Models of Systems

When dealing with systems, we usually work with *models* of systems. A model is a description of what the modeler thinks to be relevant of a system.

In the sciences, models commonly represent simplified depictions of reality or excerpts of it. Models are adapted to answer certain questions or to solve certain tasks. Models should be appropriate for the respective questions or tasks. This means that a model is only "good" when it is able to answer such a question or solve such a task. For example, a model that only comprises the patients (and not the nurses) of a ward cannot be used for nurse staffing and shift planning.

Information Systems

An *information system* is that part of an enterprise that processes and stores data, information, and knowledge. It can be defined as the socio-technical subsystem of an enterprise, which comprises all information processing as well as the associated human or technical actors in their respective information processing roles.

"Socio-" refers to the people involved in information processing (e.g., healthcare professionals, administrative staff, computer scientists), whereas "technical" refers to information processing tools (e.g., computers, telephones, patient records). The people and machines in an enterprise are considered only in their role as information processors, carrying out specific actions following established rules.

An information system that comprises computer-based information processing and communication tools is called a *computer-supported information system*. An information system can be divided (like any system) into subsystems, which are called *sub-information systems*. The sub-information system where computer-based tools are used is called the computer-supported part; the rest is called the conventional or paper-based part of an information system.

Components of Information Systems

When describing an information system, it can help to look at the following typical *components* of information systems: enterprise functions, business processes, application components, and physical data processing components.

An *enterprise function* describes what acting human or machines have to do in a certain enterprise to contribute to its mission and goals. For example, "patient admission," "clinical documentation," or "financial controlling" describe typical enterprise functions. Enterprise functions are ongoing and continuous. They describe what is to be done, not how it is done. Enterprise functions can be structured into a hierarchy of functions, where a function can be described in more detail by refined functions. Enterprise functions are usually denoted by nouns or gerunds (i.e., words ending with -ing).

An *activity* is an instantiation of an enterprise function working on an individual entity. For example, "Dr. Doe admits patient Jane Smith" is an activity of the enterprise function "patient admission." Just as enterprise functions, they can be put together in a hierarchy of activities. In contrast to enterprise functions, activities have a definite beginning and end.

To describe the chronological and logical sequence of a set of activities, *business processes* are useful. They describe the sequence of activities together with the conditions under which they are invoked, to achieve a certain enterprise goal. Business processes are usually denoted by verbs (for

example, “dismiss a patient,” “document a diagnosis,” or “write a discharge letter”). As they are composed of individual activities, they also have a definite beginning and end. While enterprise functions concentrate on the “what,” business processes focus on the “how” of activities.

We will refer only to enterprise functions and business processes with respect to information processing.

Whereas enterprise functions and business processes describe what is done, we now want to consider tools for processing data, in particular so-called application components and physical data processing components. Both are usually referred to as *information processing tools*. They describe the means used for information processing.

Application components support enterprise functions. We distinguish computer-based from paper-based application components. Computer-based application components are controlled by *application programs*, which are adapted *software products*. A software product is an acquired or self-developed piece of software that is complete in itself and that can be installed on a computer system. For example, the application component “patient management system” stands for the installation of a software product to support the enterprise functions of patient admission, transfer, and discharge.

Paper-based application components are controlled by working plans that describe how people use paper-based physical data processing components. For example, the application component “nursing documentation organization” contains rules regarding how and in which context to use the given forms for nursing documentation. Paper-based in this sense comprises not only paper as the main documentation carrier, but also other nonelectronic documents such as radiology films or teeth impressions.

Communication and cooperation among application components must be organized in such a way that the enterprise functions are adequately supported.

Physical data processing components, finally, describe the information processing tools that are used to realize the computer-based and the paper-based application components (Figure 2.1). Physical data processing components can be human actors (such as the person delivering mail), paper-based physical tools (such as printed forms, telephones, books, patient record), or computer systems (such as terminals, servers, personal computers). Computer systems can be physically connected via data wires, leading to physical networks.

Figure 2.1: Typical physical data processing components (e.g., computer, printer telephone, paper-based patient record, blackboards) on a ward.

Architecture and Infrastructure of Information Systems

The *architecture* of an information system describes its fundamental organization, represented by its components, their relationships to each other and to the environment, and by the principles guiding its design and evolution.[15] The architecture of an information systems can be described by the enterprise functions, the business processes, and the information processing tools, together with their relationships.

There may be several architectural views of an information system, e.g., a functional view looking primarily at the enterprise functions, a process view looking primarily at the business processes. Architectures that are

15. Institute of Electrical and Electronics Engineers (IEEE). Std 1471-2000: Recommended Practice for Architectural Description of Software-Intensive Systems. September 2000. http://standards.ieee.org.

equivalent with regard to certain characteristics can be summarized in a certain *architectural style*.

When the focus is put onto the types, number, and availability of information processing tools used in a given enterprise, this is also called the *infrastructure* of its information system.

2.4 Hospital Information Systems

With the definition of information systems in mind, a hospital information system can be easily defined. A *hospital information system* is the socio-technical subsystem of a hospital, which comprises all information processing as well as the associated human or technical actors in their respective information processing roles. Typical components of hospital information systems are enterprise functions, business processes, application components, and physical data processing components (see section 2.3). For the sake of simplicity, we will denote the enterprise functions of a hospital as *hospital functions*.

As a consequence of this definition, a hospital has a hospital information system from the beginning of its existence. Therefore, the question is not whether a hospital should be equipped with a hospital information system, but rather how its performance can be enhanced, for example, by using state-of-the- art information processing tools, or by systematically managing it.

All groups of people and all areas of a hospital must be considered when looking at information processing. The sensible integration of the different information processing tools in a hospital information system is important.

Hospital staff can be seen as part of the hospital information system. For example, when working in the department of patient records, or as an operator in an ICT department, staff members directly contribute to information processing. In their role as user of the hospital information system, they use information processing tools (e.g., a nurse may use a telephone or a computer). Each employee may continuously switch between these two roles.

The *goal* of a hospital information system is to sufficiently enable the adequate execution of hospital functions for patient care, including patient administration, taking into account economic hospital management as well as legal and other requirements. Legal requirements concern data protection or reimbursement aspects, for example. Other requirements can be the decision of a hospital executive board on how to store patient records, for example.

To support patient care and the associated administration, the *tasks* of hospital information systems are:

- to make information, primarily about patients, available: current information should be provided on time, at the right location, to author-

ized staff, in an appropriate and usable form. For this purpose, data must be correctly collected, stored, processed, and systematically documented to ensure that correct, pertinent, and up-to-date patient information can be supplied, for instance, to the physician or a nurse (Figure 2.2);

- to make knowledge, for example, about diseases, about side effects, and interactions of medications, available to support diagnostics and therapy;
- to make information about the quality of patient care and the performance and cost situation within the hospital available.

Figure 2.2: A healthcare professional accessing patient information.

In addition to patient care, university medical centers undertake research and education to gain medical knowledge and to teach students.

When hospital information systems make available

- the right information and knowledge

- at the right time
- at the right place
- to the right people
- in the right form,

so that these people can make the right decisions, this is also described as *information and knowledge logistics*.

Hospital information systems have to consider various *areas* of a hospital, such as

- wards,
- outpatient units,
- service units: diagnostic (e.g., clinical laboratory, radiological department), therapeutic (e.g., operation room) and others (e.g., pharmacy, patient records archive, library, blood bank),
- hospital administration areas (e.g., general administration, patient administration and accounting, technology, economy and supply, human resources),
- offices and writing services for (clinical) report writing.

In addition, there are the management areas, such as hospital management, management of clinical departments and institutes, administration management, and nursing management.

These areas are related to patient care. They could be broken down further. For university medical centers, additional areas, needed for research and education, must be added to the above list.

Obviously, the most important *people* in a hospital are the patients and, in certain respect, their visitors. The most important groups of people working in a hospital (Figure 2.3) are

- physicians,
- nurses,
- administrative staff,
- technical staff, and
- health informaticians, health information management staff.

Within each group of people, different needs and demands on the hospital information system may exist, depending on the tasks and responsibilities. Ward physicians, for example, require different information than physicians working in service units or than senior physicians.

Figure 2.3: Different people working in a hospital (here, nurses and physicians in an emergency department).

2.5 Health Information Systems

From Hospital Information Systems to Health Information Systems

In many countries, the driving force for health care and for ICT in health care has recently been the trend toward a better coordination of care, combined with rising cost pressure. One consequence is the shift toward better integrated and shared care. This means that the focus changes from isolated procedures in one healthcare institution (e.g., one hospital or one general practice) to the patient-oriented care process, encompassing diagnosis and therapy, spreading over institutional boundaries (Figure 2.4).

In the United States, for example, healthcare organizations are merging into large *integrated healthcare delivery systems*. These are healthcare institutions that join together to consolidate their roles, resources, and operations to deliver a coordinated range of services and to enhance effectiveness and efficiency of patient care. The situation in Europe is also changing from hospitals as centers of care delivery to decentralized networks of healthcare delivery institutions that are called regional networks or healthcare networks. Enterprise boundaries are blurring. Hospital information systems will increasingly be linked with information systems of other healthcare organizations.

The future architecture of hospital information systems must take these developments into account. They must be able to provide access or to ex-

change patient-related and general data (e.g., about the services offered in the hospital) across its institutional boundaries.

Figure 2.4: A general practitioner contacting a hospital by phone.

A lot of technical and legal issues have to be solved before trans-institutional computer-supported *health information systems*, or information systems spreading over institutional boundaries in health care, will adequately support trans-institutional patient care. For example, a general willingness to cooperate with other healthcare providers must exist; optimal care processes must be defined, and recent business processes be redesigned; accounting and financing issues must be regulated; questions of data security and data confidentiality must be answered, together with questions on data ownership (patient or institution) and on responsibilities for distributed patient care; issues on long-term patient records (centralized or decentralized) must be discussed; and technical means for integrated, trans-institutional information processing must be offered (telemedicine, e-health), including general communication standards.

When dealing with hospital information systems, we will consider these aspects of health information systems.

Patient Care and the Web

The Internet plays an increasingly important role within health care. First, many healthcare organizations offer information on their services on the Internet. Healthcare professionals and patients therefore can easily inform themselves on the available healthcare services in a city or area, and they

can find specialized institutions for their needs. Second, more and more clinical knowledge is available on the Internet. For example, the National Library of Medicine grants free access to over 12 million MEDLINE citations back to the mid-1960s.[16] This clinical knowledge is available both for the healthcare practitioners as well as for patients and their relatives. Digital libraries will have a rising influence on the distribution of human knowledge.[17] Third, there are already several initiatives offering patients the possibility to manage their personal health record on the Internet. This means that the patient-related history is available anywhere at any time. Fourth, the rising connectivity of healthcare institutions and the rising bandwidth of the Internet allows telemedical applications. Telemedicine means to provide diagnostics and therapy even when the patient and the healthcare professional are at remote places. Applications can be found, for example, in the areas of teleradiology, teledermatology, and telesurgery.

The potential of Internet technologies to support health care thus seems tremendous. However, it is important to guarantee that the information offered on the Internet is valid, up-to-date, correct, and complete. Here, initiatives such as HON[18] offer ways to ensure the quality of health-related information on the Internet.

2.6 Information Management in Hospitals

In general, management comprises all leadership activities that determine the enterprises' goals, structures, and behaviors. Accordingly, *information management* in hospitals are those management activities in a hospital that deal with the management of information processing in a hospital and therefore of its hospital information system. The goal of information management is systematic information processing that contributes to the hospital's strategic goals (such as efficient patient care and high satisfaction of patients and staff). Information management therefore directly contributes to the hospital's success and ability to compete.

The general tasks of information management are planning, directing, and monitoring. In other words, this means

- planning the hospital information system and its architecture,
- directing its establishment and its operation, and

16. NLM. National Library of Medicine. PubMed. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi.

17. President's information technology advisory committee (PITAC). Digital Libraries: Universal Access to Human Knowledge—PITAC report to the president. Arlington: Nation Coordination Office for Computing; 2001. http://www.ccic.gov/pubs/pitac/pitac-dl-9feb01.pdf.

18. HON. Health on the Net Foundation. http://www.hon.ch.

- monitoring its development and operation with respect to the planned objectives.

Information management encompasses the management of all components of a hospital information system—the management of information, of application components, and of physical data processing components.

Information management can be differentiated into strategic, tactical, and operational management. Strategic information management deals with information processing as a whole. Tactical information management deals with particular enterprise functions or with application components that are introduced, removed, or changed. Operational information management, finally, is responsible for operating the components of the information system. It cares for its smooth operation, for example, by planning necessary personal resources, by failure management, or by network monitoring. Information management in hospitals is discussed in detail in Chapter 5.

2.7 Examples

Example 2.7.1: Architecture of a Hospital Information System

Here is an extract of the description of the architecture of the hospital information system of the Plötzberg Medical Center and Medical School (PMC). As mentioned, PMC is a fictitious institution, which will be used in examples and exercises in this book.

> The hospital information system of PMC supports the hospital functions of patient treatment with patient admission and discharge, decision support, order entry, clinical documentation and service documentation; handling of patient records; work organization and resource planning; and hospital administration.
>
> Those hospital functions are supported by some bigger and over a hundred smaller application components (partly computer-based, partly paper-based). The biggest application component is the patient management system (PMS), the computer-based application component that supports patient admission, transfer, and discharge. In addition, several computer-based departmental application components are used for work organization and resource planning (e.g., in the radiological department, in the laboratory department, and in outpatient units). Nearly all computer-based application components are interconnected, using a communication server. Some computer-based application components are isolated systems without interfaces.
>
> Paper-based application components are used for special documentation purposes (e.g., documentation in operation rooms), and for order entry and communication of findings.
>
> The application components are realized by physical data processing components. As computer-based physical data processing component, ap-

proximately 40 application and database servers are operated, and over 4,000 personal computers are used. Over 1,000 printers of different types are installed. Most computer-based physical data processing components are interconnected to a high-speed communication network.

As paper-based physical data processing components, over 2,000 telephones and 800 pagers are used. Over 2,000 different paper-based forms are used to support different tasks. More than 400,000 patients records are created and used each year, and a dozen local archives are responsible for patient record archiving. A paper-based mailing system allows for paper-based communication between departments.

Example 2.7.2: Comments on the Future of Health Information Systems

For the physicians of the 1990s and beyond, computer workstations will be their windows on the world. Much of the necessary technology already exists. Desktop or bedside, in the office or at the hospital, computers can respond to a simple click of a mouse pointing device....In the future, the physician will be able to access the patient record largely by using the mouse and doing very little typing. Moreover, the record will include graphics and images as well as extensive text. Outpatient records will be integrated with inpatient data by using the capabilities of communications networks that link hospitals with the clinics and private offices of their medical staff members...."[19]

Through the further development of information systems at the university hospitals, the following goals are of special importance:

- Patient based (facility-wide) recording of and access to clinical data for team-based care.
- Workflow integrated decision support made available for all care takers through up-to-date, valid medical knowledge.
- Comprehensive use of patient data for clinical and epidemiological research, as well as for health reports....

The following tasks shall have priority and will be worked on in the next years:

- The introduction of a patient based, structured, electronic health record.
- The step-wise introduction of information system architectures that support cooperative, patient centered and facility-wide care.
- The establishment of a suitable network and computer infrastructure in order to be able to, via the Internet, inform about the care offered at a particular hospital.

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19. Ball M, Douglas J, O'Desky R, Albrigh J. Healthcare Information Management Systems—A Practical Guide. New York: Springer; 1991. p. 3.

- The introduction of efficient, usable mobile information and communication tools for patient care....[20]

From the experience gained so far..., a number of direct benefits from health telematics can be identified:...

- More people can be diagnosed and treated at their local clinics or hospitals, though without the facilities of urban referral hospitals. For the first time, it is technically feasible to contemplate the provision of universal health care....
- Health telematics allows the global sharing of skills and knowledge. Access to international centers of excellence for various specialties becomes possible from many locations. Medical expertise can be available to anyone on request....
- Cost savings can be achieved by reducing the transport of patients and travel of healthcare professionals, as well as by allowing home care of patients who would otherwise require hospitalization....[21]

The future tasks of health care include: greater cooperation, more quality and economics and greater adjustment to the needs of patients. The information age offers great possibilities to solve these tasks, maybe even possibilities that we can't begin to imagine today.

The neuralgic point though in the discussion of telematics in health care is the uniting of data. Especially with regard to personal patient data, we are forthright dealing with the most personal of all data, and special caution is to be exercised when dealing with these data. After all, questions of power are raised through the uniting of data: greater transparency also means greater control.[22]

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20. Deutsche Forschungsgemeinschaft (DFG): Informationsverarbeitung und Rechner an Hochschulen—Netze, Rechner und Organisation. Empfehlungen der Kommission für Rechenanlagen für 2001-2005 (information processing and computer systems for universities; in German), Kommission für Rechenanlagen der Deutschen Forschungsgemeinschaft. Bonn: DFG; 2001. http://www.dfg.de.

21. World Health Organization (WHO). A Health Telematics Policy, Report of the WHO Group Consultation on Health Telematics 11-16 December 1997. Geneva: World Health Organization; 1998.

22. Speech of German Minister for Health, Andrea Fischer, at the occasion of the first meeting of the symposium "telematics in healthcare," August 19, 1999, Bonn.

2.8 Exercises

Exercise 2.8.1: HIS as a System

As introduced, a system can be defined as a set of people, things, and/or events that form an entity, together with their relationships. Which people, things, or events can you find when looking at a hospital information system? In what relationship do they stand to one another? To solve this exercise, take into account the components of hospital information systems as defined in section 2.3.

Exercise 2.8.2: Goals of Models

Find two models that represent a city. What are the goals of these models? What are their components?

Exercise 2.8.3 Information Processing Tools in a Hospital

Look at Figures 2.5, 2.6, 2.7, and 2.8. Which information and communication tools are used? Which hospital functions may be supported by those tools?

Figure 2.5: The office of a senior physician.

Figure 2.6: The office of a general practitioner.

Figure 2.7: An intensive care unit.

Figure 2.8: A laboratory unit.

Exercise 2.8.4: Information Processing of Different Healthcare Professional Groups

Consider the different professional groups in a hospital (e.g., physician, nurse, administrative staff, hospital manager, patient, visitor), and describe some of their typical information processing needs.

Exercise 2.8.5: Information and Knowledge Logistics

Select one typical business process in a hospital (such as admitting a patient, requesting an examination, planning of therapeutical procedures, documenting diagnoses, etc.) and find three examples how information and knowledge logistics can fail. Which consequences may arise for the quality and for the costs of patient care from this failure?

Exercise 2.8.6: Buying an HIS

Look at the definition of hospital information systems in section 0. Based on this definition, is it possible to buy a hospital information system? Explain your answer. What do vendors of hospital information systems thus really sell?

Exercise 2.8.7: Health Information Systems

Look at the comments on the future of health information systems in example 2.7.2. Which possible benefits are discussed, and which problems?

2.9 Summary

When working on hospital information systems, we must distinguish among data, information, and knowledge:

- Data can be defined as a representation of information, or knowledge, in a formalized manner, suitable for communicating, interpreting, or processing.
- Information can be defined as specific knowledge about entities such as facts, events, things, persons, processes, ideas, or concepts.
- Knowledge can be defined as general information about concepts in a certain domain.

A system is a set of people, things, and/or events that forms an entity, together with their relationships. Systems can be divided into subsystems and can be represented by using models. Models are a description of what the modeler thinks to be relevant to a system. Remember that models

- usually form a simplified representation of reality,
- should be adapted to a specific question or task, and
- should be appropriate to provide answers for these question or tasks.

A hospital information system can be defined as the socio-technical subsystem of a hospital that comprises all information processing functions and the human or technical actors in their information processing role. Typical components of hospital information systems are

- the hospital functions supported,
- the business processes that take place,
- the application components that support the hospital functions,
- the physical data processing components that realize the application components.

The subsystem of the HIS where computer-based tools are used is called the computer-supported part of the hospital information system. The architecture of an information system describes its fundamental organization, represented by its components, their relationships to each other and to the environment, and by the principles guiding its design and evolution.

The goal of an HIS is to

- adequately enable the execution of hospital functions for patient care,
- taking economic, legal, and other requirements into account.

When the HIS makes available

- the right information (about patients, …) and the right knowledge (about diseases, …)
- at the right time
- in the right place

- for the right people
- in the right form

so that these people can make the right decisions, this is called information and knowledge logistics.

When working on a hospital information system, you should consider all areas of a hospital, such as wards, outpatient units, service units, administration departments, reporting services, management units, as well as all groups of people in a hospital, such as patients, visitors, physicians, nurses, administrative staff, technical staff, and health informaticians.

Health information systems stand for trans-institutional information systems spreading over institutional boundaries in health care.

Information management in hospitals is those management activities in a hospital that deal with the management of information processing and therefore with the management of the hospital information system.