Achievements, Milestones and Challenges in Biomedical and Health Informatics
J. Mantas et al. (Eds.)

doi:10.3233/SHTI220945

Health Information Systems: Past, Present, Future – Revisited

Reinhold HAUX[a,1,2]
[a]*Peter L. Reichertz Institute for Medical Informatics, TU Braunschweig and Hannover Medical School, Braunschweig, Germany*

Abstract. *Background:* Health information systems (HIS) represent an essential part of the infrastructure for the delivery of good health care. *Objectives:* To present the author's personal views on HIS developments over the last decades and on the opportunities and priorities for future HIS developments. *Methods:* Reflecting on his views, the author identified relevant semantic dimensions, which are denoted as development paths, and searched for appropriate periods to characterize HIS development leaps. *Results:* HIS developments were divided into the periods past (1961-2016), present (2017-2022), and future (the next decades). Eight development paths for HIS were considered as being relevant to presenting the author's views: life situations related to health care, entities for health care, health care facilities, settings of health care, data to be processed, features for functions, architectures of HIS, and management of HIS. For each of these paths, the past and present states as well as challenges and opportunities for future HIS developments were outlined. Discussion and Conclusions: The presented views on HIS developments and the selected development paths and periods are by nature subjective 'avant la lettre'. The views were, however, formed over almost half a century during which the author has been engaged with HIS developments, and thus may be worth reporting and discussion. If past is prologue, the tremendous HIS developments in the past and in the present may predict a similar development intensity in the future. Present HIS are significantly better than HIS of the past, however they leave room for continued improvement with an end of HIS developments far from sight.

Keywords. Health information systems, hospital information systems, medical informatics, health informatics, biomedical informatics

[1] Corresponding Author, Prof. Dr. Reinhold Haux, Peter L. Reichertz Institute for Medical Informatics of TU Braunschweig and Hannover Medical School, Muehlenpfordtstr. 23, 38106 Braunschweig, Germany; email: Reinhold.Haux@plri.de.

[2] This is a written version of a talk, given on October 29, 2022, in Athens, Greece, at the Symposion on Achievements, Milestones, and Challenges in Biomedical and Health Informatics. The Symposion was held in honor of Professor Ioannis (John) Mantas on the occasion of his retirement. Before, a talk on this topic had been given by the author on June 24, 2021, at the Joint Session of the 2021 Frank-van-Swieten-Lectures on Strategic Information Management of Health Information Systems. The title of this talk was: "Now here I am, a fool for sure! No wiser than I was before"? HIS Developments 1961-2021: On Lessons for the Future". The topic was also discussed with the author on June 30, 2022, in a panel at the 2022 Frank-van-Swieten-Lectures and on July 3, 2022, in a workshop at ICIMTH 2022.

1. Introduction

1.1. Background and Significance

Health information systems (HIS) represent an essential part of the infrastructure for the delivery of good health care [1] (section 1.1). Table 1 reflects the increasing interest in HIS and HIS research. In response, the International Partnership in Health Informatics Education (IΦE) [2]-[8] implemented an international course on HIS, the so-called Frank-van-Swieten-Lectures on Strategic Information Management of Health Information Systems [9]-[11]. The Frank-van-Swieten-Lectures commenced in 2001 and the author was one of the founders.

Table 1. Number of publications and citations on health information systems and on hospital information systems from 1961 to 2020. Search in the Web of Science Core Collection. Search terms: "health information systems" (first publications in 1971) [12], [13], [14], "hospital information systems" (first publication in 1966) [15]. Search date: July 16, 2021. Please note that, whereas publications on "hospital information systems" mainly focus on institution-centred information systems of hospitals and complex health care facilities, publications on health information systems usually comprise reports on information systems in various health care settings as well as on trans institutional information systems

year	health information systems		hospital information systems	
	publications	citations	publications	citations
1961-1970			6	
1971-1980	29	11	5	11
1981-1990	14	14	34	34
1991-2000	112	420	159	562
2001-2010	428	4.909	259	3.182
2011-2020	1.184	25.233	378	8.762

1.2. Occasions

On the occasion of his last 'active' [3] participation as a teacher with a history of shaping parts of HIS developments himself [4], the author was asked by Professor Alfred Winter, another teacher in the lecture series, to share his impressions of HIS developments with the students and teachers at the joint virtual meeting of the 2021 Frank-van-Swieten-Lectures. The joint days, where students and teachers of all participating universities meet, traditionally include lectures of this type. Dr. Winter requested of the author an understanding of his own personal views. In particular he was interested in views on:

- When can HIS be determined to be "good" HIS? And, in this context:
- Why do we often regard current HIS as "bad", or at least as not good enough?
- What improvements on HIS have been achieved during the last decades?
- When can we expect to have "good" HIS?
- What contributions can today's informatics graduates make to achieve "good" HIS in the future? What can motivate them to work on this problem?

[16], (questions translated into English with some rewording by the author).

[3] The author is retired since October 1st, 2021. He is still engaged in medical informatics, but now as professor emeritus.

[4] In 1973, almost 50 years ago, the author studied medical informatics and in 1978, more than four decades ago, he started to work in this profession. HIS were part of his field of study as well as of his professional work.

The author agreed to elaborate on this subject at the joint virtual day concluding the 2021 Frank-van-Swieten-Lectures. This manuscript is a considerably updated and revised version of the 2021 presentation, which the author could present in October 2022 in Athens at the Symposion on Achievements, Milestones, and Challenges in Biomedical and Health Informatics.

1.3. Questions

While focusing on Alfred Winter's questions, the author decided to rephrase them into more general ones:

What are the author's personal views of HIS developments during the last decades?

What are the author's personal views on opportunities and priorities for future HIS developments?

Regarding the definition of the "the last decades", the author elected to start in 1961 covering six decades.

1.4. Outline and Reminiscences

The author's answers to the refined two questions will be discussed in the result sections 3 and 4 entitled *HIS Developments: Revisiting Past, Present and Future* and *Views on HIS Development Paths*. The methods section 2 entitled *Terms, Methods, Notes, and Quotes* precedes the results. The manuscript will close with discussion and conclusion sections 5 and 6. The heading of the conclusion section 6 is a quote from Johann Wolfgang von Goethe's Faust [17] (p.19). Shall or shall we not say with respect to HIS developments "*Now here I am, a fool for sure! No wiser than I was before*"?

This manuscript recalls as reminiscences and homages two landmark events: An international seminar on medical documentation and statistics, taking place in 1961 in Berlin, Germany [18]. During this seminar, final decisions were made to launch the first international journal in 1962, devoted solely to information in biomedicine and health care and focusing on a new emerging discipline: medical informatics [19]. Also, during this seminar, a new information processing tool was presented: With punch card sorting machines, biomedical and health data could be analyzed much faster than it had been possible before. A quote from the seminar's report stated: "Prof. G. Wagner (Kiel) dealt with the various types and uses of machine punch cards, which are likely to become very important for future clinical documentation tasks. For practical demonstration, IBM had set up a complete set of machines in the conference building, so that Prof. Wagner was able to demonstrate the usefulness of machine punch cards with vivid examples from his field of work. His introductory overviews were therefore particularly valuable to the seminar participants because they were necessary as a prerequisite for understanding most of the lectures given by the American speakers." [18] (p. 27, translated into English). The report also contained a picture of Dr. Wagner's demonstration, which is presented here as Figure 1. Professor Gustav Wagner (1918-2006) was crucial for successfully launching research on information in biomedicine and health care as recognized research field of medical faculties in Germany and beyond ([20], [21].

A keynote lecture on "hospital information systems - past, present, future", given by Peter L. Reichertz during MIE 1984 in Brussels, Belgium (manuscript first in [22], later also in [23]). Professor Reichertz (1930-1987) was one of the international pioneers in the field of medical informatics [25]. He was visionary enough to recognize very early the potential of informatics for biomedicine and health care, including diagnosis, therapy,

and HIS. In the 1960s, health information systems were considered an unusual research field in medical faculties. Peter Reichertz's work in research and clinical practice strongly supported the development of HIS as a major research topic in medical informatics, with hospital information systems as an important instance [24]. His probably most comprehensive and visionary paper on health information systems was the one focused on the past, present and future of hospital information systems that he presented as his MIE keynote in 1984.

The title of this manuscript refers to a talk on "Health Information Systems: Past, Present, Future" that the author gave in 2004 at the Plenary Session of the Conference EuroMISE 2004 in Prague, Czech Republic ([26], subsequently denoted as 2004 Lecture). The title of this 2004 Lecture was deliberately chosen as hommage to the mentioned landmark paper by Peter Reichertz two decades earlier.

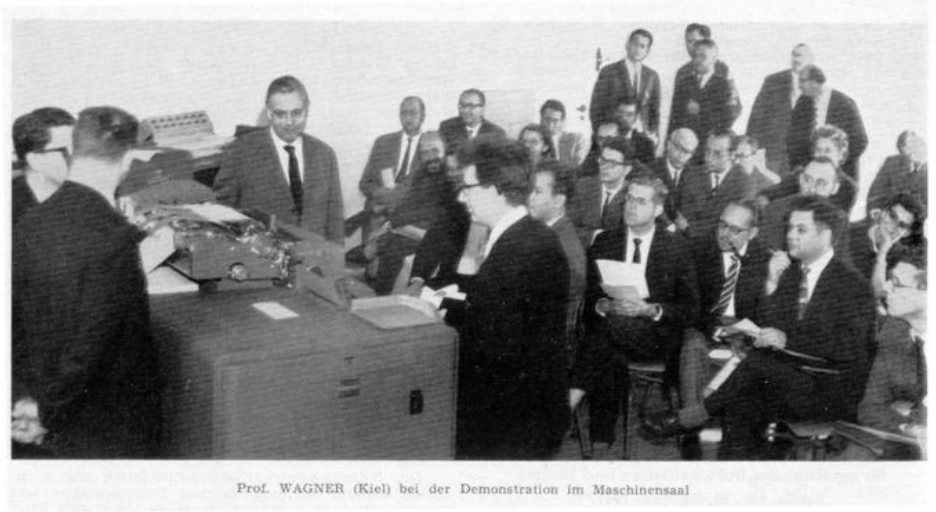

Figure 1. Dr. Gustav Wagner, 3rd from left, demonstrating in 1961 punch card machines as powerful new tools for clinical documentation and biomedical data analysis ([18], p.28).

2. Terms, Methods, Notes, and Quotes

2.1. Terms

First, the author will define the term HIS as used in the Frank-van-Swieten-Lectures. *Health information systems are socio-technical subsystems of health care settings, comprising all data, information and knowledge processing* [1] (section 2.6). Based on this definition, HIS usually are comprised of computer-based tools as well as non-computer-based tools. If we refer to HIS of specific health care facilities, we may use more specific terms like, e.g., *hospital information systems* for the information systems of hospitals. When health care is delivered to patients by more than one health care facility (e.g. when care is jointly provided by medical offices and by outpatient nursing organizations) such information systems are called here *transinstitutional HIS*. More detailed definitions and further explanations can be found in chapter 2 of [1]. Please note that the terms health care institution and health care facility are used similarly here. For example, hospitals may be referred to as health care institutions or health care facilities. The term health

care setting will be used more broadly. Patients' homes may also be settings of health care, although they are not facilities or, respectively, institutions dedicated to this purpose. Also, for the sake of ease, the term *data* will be used here instead of *data, information and knowledge*, assuming that data will, hopefully, contain information or even knowledge.

2.2. Methods

As the author was asked to share his personal views, the methods to be used for preparing this manuscript were obvious and straightforward:

Firstly, the author reflected on his views.

Secondly, the author tried to arrange these views in a manner that supported communication. As in [26] the author searched for relevant semantic dimensions and referred to them as development paths.

Finally, the author searched for appropriate periods with respective thresholds to characterizing HIS developments.

2.3. Notes

The author's personal views of HIS developments, selected development paths, and selected periods by nature are subjective 'avant la lettre' [27]. While admittedly subjective, they were formed over almost half a century during which the author was an active observer and, also, participant of HIS developments. The expressed views have also been influenced by collaborations and many valuable discussions with other persons (colleagues, decision makers, users, etc). Important persons, who strongly influenced the author when he was first engaged with this topic in the 1970s and 1980s included Marion Ball [28], Carl-Theodor Ehlers [29], [30], Gerd Griesser [31], [32], Klaus Köhler [33], Peter Reichertz [34], [35], [22], and Alfred Winter [36], later leading to [37], [38], and [1] and many others. Of course, ultimately the presented views are the author's, who claims responsibility for this manuscript. However, if credits are due, they must be shared with many others as well.

The development paths selected in the author's 2004 Lecture (there called lines of development) – amount of data, range, users, functionality, complexities, data types, technologies of / in HIS [26] (Figures 5, p. 276, and 6, p. 277) – did only partially match with the semantic dimensions that the author wanted to communicate here. Therefore another set of development paths was selected. The thresholds of the selected periods are fuzzy. There are no exact limits. Finally, others may have different opinions and might have selected different development paths and other periods.

The references were not collected systematically, as it would be usual in reviews. The references reflect the work of colleagues, who influenced the author's work and with whom the author had discussions or collaborations on HIS developments. Therefore reference selection by nature may be biased.

2.4. Quotes

Engaging with HIS developments requires dealing with HIS architectures [38]. Being aware of the relationship of HIS with architecture - the discipline dealing with the architecture of buildings as well as of cities or landscapes – may help to better understand HIS architectures. In this context, the following quote offers a remarkable statement on the

architecture of buildings: "We 're architects. We have designed numerous buildings, used by many people. We know about users. We know well their complaints: buildings that get in the way of the things they want to do. We also know well users' joy of relaxing, working, learning, buying, manufacturing, and worshipping in buildings which were designed with love and tender care as well as function in mind. We're committed to the belief that buildings help people to do their jobs or impede them and those good buildings bring joy as well as efficiency." [39] (p. 6).

HIS also have a relationship with the discipline of medical informatics, where HIS form an important aspect of this discipline, as can be seen in investigations on the discipline's content [40]-[45] as well as in its international recommendations on education [46], [47]. The second and final quote in this section is a maybe unusual description of the medical informatics discipline:

"Medical informatics is a wonderful discipline. It deals with organizing, representing, and analyzing data, information, and knowledge in biomedicine and health care. This is done in one of the most important areas for the life of all people in our world. It is engaged in an exhausting, but exhilarating struggle with one of the biggest challenges that science is facing: How do we translate data into information and how do we turn information into knowledge? Working in this field is demanding, it needs clear thinking, good judgement, and flair.

Medical informatics has many facets, all of them are both, challenging and fantastic. Medical informatics.

(1) is a *modelling discipline*. It forces us to view and understand medicine and health care better in a very broad and comprehensive manner. This may comprise pathophysiological processes, diseases, decisions, and health information systems see [48], [49] for more details.
(2) is an *empirical discipline*. In the "micro-macro spectrum of medical informatics" [50], (it demands both (i) nature (e.g. cells, human beings, populations) and (ii) institutions, devoted to health care and good and healthy living, to provide answers.
(3) is an *engineering discipline*. In medical informatics we are able to do both: In "preparing for change" [51] we may passively observe and comment, but we also can actively change our world by building tools to support diagnosis, therapy, and/or the many other facets in organizing care and healthy living.
(4) is an *organizational discipline*. It helps to change processes and organisations in order to make our world better prepared for providing good and affordable care as well as contented, joyful living in dignity and safety.
(5) aims to contribute to high-quality, efficient health care and to quality of life on the one hand and to progress in science on the other. What could, as its quintessence, be better and more stimulating as *objectives* than these, for all of us working either in practice or in research or in education?"

[52] (p. 25). Please note that the original numbering of references had to changed). The manuscript will refer to both quotes later.

3. HIS Developments: Revisiting Past, Present, and Future

3.1. Periods and Thresholds

As for the 2004 Lecture, it made sense to divide HIS developments again into the periods past, present, and future, with respective thresholds.

For the present, roughly, the last five years were selected – from about 2016 to about 2021 (when this talk was presented), or 2022 (when the manuscript was finalized).

For the past we included several decades, but no further back than 1961, the year of one of the mentioned landmark events.

To discuss opportunities and priorities on future HIS developments, the next or perhaps the next few decades should be considered.

As mentioned, these periods are imprecise, with no exact boarders. And others may choose different periods.

3.2. Development Paths

The eight development paths for HIS, which according to the author's views are critical to suggest answers to the questions raised, are presented in Table 2. These developments are abbreviated with Δ_x, $x \in \{1, \ldots, 8\}$. In addition, another line of development, Δ_0, will be mentioned, mainly to permit a link to the 2004 Lecture.

The symbol Δ was chosen as it is often used to represent change. It is also the initial letter of the Greek word Διαδρομή, pathway (Δια: through, Δρομή: road, path), and thus fitting to symbolize development paths.

3.3. Δ_0: Access to Increasing Data volumes

In the 2004 Lecture [26] (Figure 5, p. 276), increasing amounts of health-related data was the first development path discussed. In Figure 2, Δ_0 is visualized across the past, present, and future. The increase of health-related data is linked to emerging opportunities in computer-based data analysis, storage, and communication. The data increase is in part due to the increase of diagnostic and therapeutic procedures [53], [54]. New information and communication technologies, allowing the capture and processing of more data, constitute another important factor e.g. [55], [56].

Table 2. Development paths relevant to HIS developments

	HIS development paths
Δ_0	access to increasing data volumes
Δ_1	life situations related to health care
Δ_2	entities for health care
Δ_3	health care facilities
Δ_4	settings of health care
Δ_5	data to be processed
Δ_6	features for functions
Δ_7	architectures of HIS
Δ_8	management of HIS

In the past, opportunities to use computers with software products, installed there, increased continuously. The challenge of shifting data from paper-based and film-based storage to computer- based storage played a major role. This shift was combined with significantly changing processes for functions, due to the continuously increasing features of the mentioned software products. Having such data primarily on paper was related to much slower access compared to accessing data, stored on computers. This held true for patient data as well as biomedical and health knowledge data.

To date, this shift seems to have been completed for most of the developed countries. For patient information as well as biomedical and health knowledge, computer-based access to data through respective features has clearly improved the speed of access and reduced the associated effort. Finally, continuously increasing data volumes will probably lead to new ways for living and practicing health care ([57]-[60]).

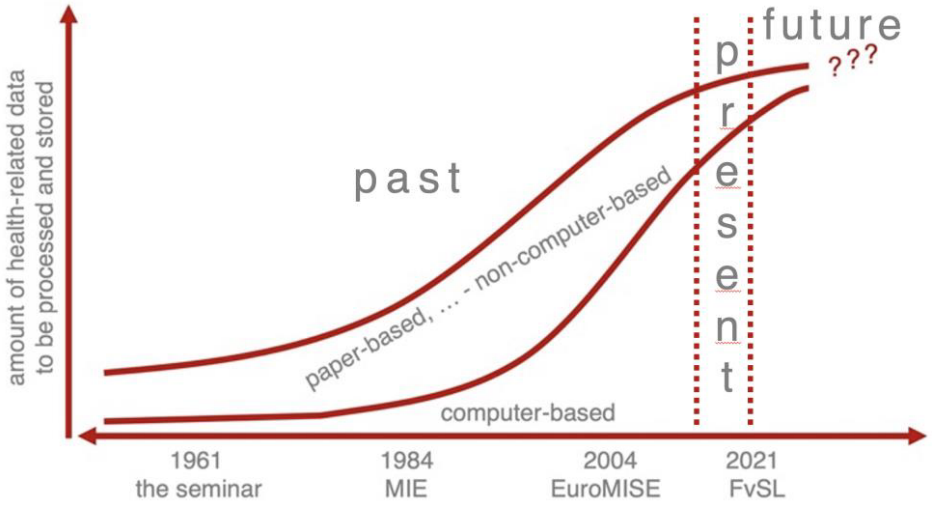

Figure 2. Roughly visualizing the increasing amounts of health-related data and their access as HIS development past across the selected periods for past, present and future. The years and events selected were discussed in sections 1,2 and 1.4.

As this shift from data stored on paper to data stored on computers seems to have been completed, we will omit Δ_0 as HIS development path. In addition, from the author's point of view, the following eight paths Δ_1 to Δ_8 can now better describe HIS developments, including the aspect of increasing data volumes.

3.4. Δ_1: Life Situations Related to Health Care

To better understand Δ_1 on life situations, related to health care, and their relevance to HIS developments, we should reflect on the fact that health care is an integral part of our lives. Health care starts when people are born (even earlier) and ends when people pass away. During some periods of our lives, the relative share of health care appears negligible, e.g., when we are in good health, living our 'normal daily lives'. Sometimes the relative share of health care is intensive, e.g., for persons, suffering from severe acute diseases and being inpatients in hospitals. Sometimes it is in between, e.g. for persons with chronic diseases who need medication or other therapeutic measures on a regular basis. Major life situations with respect to health care are prevention, wellness, emergencies, acute diseases, chronic diseases, care, and rehabilitation. In all these life situations

health care is provided through appropriate services, e.g. for diagnosis, therapy, or care (from [1], chapter 1, where more details can be found). The main objective for HIS and so also the focus of HIS developments, is to support appropriately and sometimes even to enable provision of good health care for people in their various life situations (more details can be found in [1], chapter 2). In recalling what has been mentioned in the quintessence of the second quote, good health care supports high-quality and efficient health care and improves the quality of life. Affordability and availability are other important facets of good health care.

In the past, Δ_1 HIS developments centred primarily on the episodic treatment of diseases, e.g. on diagnosis and therapy of inpatients in hospitals. HIS were designed to support health care services, where the relative share of health care was intensive. HIS developments were mainly institution-cantered with single health care facilities in focus. Although primarily episode-based, there was an expressed desire to overcome this limitation and to support patient-centred care as well, at least within single health care facilities.

To date, health care services, supported by HIS, still remain primarily focused on treating diseases, with the relative share of health care being intense. Even though still mostly only within single facilities, they now better focus on patients, not on single disease episodes of patients.

In the future, HIS should develop with respect to Δ_1 to support the full spectrum of health care services including in life situations, where the share of health care is negligible or in between. This extension would lead to a shift from patient-centred health care services – for persons with diseases – to person-centred health care services – for persons with diseases as well as for healthy persons.

By extending care in this fashion, health care becomes more rigorously integrated in life. In addition, other services, not considered traditionally part of health care, may become more integrated with processes of obtaining care including banking, shopping, learning, teaching or participating in cultural events. So, e.g., shopping may be combined with purchasing medication in a pharmacy or with visiting a medical office. Banking services may be obtained in a bank, located close to this office. In both cases, travel plans must take all of these services into account. HIS developments should consider that health care related services may have to be orchestrated jointly with other services, which is certainly a challenge [61], [62], [63] (pp. e27-e28).

3.5. Δ_2: Entities for Health Care

After in Δ_1 life situations related to health care have been discussed, we now will put the focus in Δ_2 on the various entities, who are giving this health care, again with respect to HIS developments.

In the past, HIS developments focused on supporting health care professionals. Initially, the support was limited primarily on physicians and later and with less intensity on nurses. With methodological and technical progress, the range of health care professionals supported through HIS grew more complete over the years.

To date, health care professionals remain the focus of HIS developments, which, for obvious reasons, makes sense. In addition, HIS developments now also take place to better support informal caregivers, i.e. persons informally taking care of patients such as family members, as well as to support the persons concerned, may they be sick and so patients or may they be healthy (see e.g. [64] with Finland as example). Enabling informal caregivers as well as patients / persons concerned to participate in health care will

allow them to contribute more. With this, HIS would also support subsidiarity, an important principle, not only in health care (e.g. [65]) by distributing required work including less but still qualified individuals.

In the future, HIS developments probably will and also should continue to address these priorities including better collaboration among health care professionals and between professionals and informal caregivers and most importantly between professionals and the patients.

A two-decade-old statement "Any technology sets a relationship between human beings and their environment, both physical and human. No technology can be seen as merely instrumental. This is especially relevant when dealing with large automatic information systems, developed to contribute to the management and integration of large organizations, such as hospitals." [66] in the author's opinion still addresses this situation of collaboration very well.

To illustrate the future Δ_2 HIS development path, additional entities for health care must be introduced in addition to the previously introduced players like health care professionals, informal caregivers, patients / persons concerned, all human beings. In the future, functionally comprehensive, 'intelligent' machines as well as other living entities (in addition to humans) such as animals and plants or a combination thereof will play an increasing role. Collaboration of intelligent machines with humans, which may be described as the collaboration of natural and artificial intelligence, will play an increasing role in good health care and should also be considered for HIS developments [67]-[69].

Further discussions on intelligent machines can be found in [70]-[76]. Of importance is that such intelligent machines differ from other machines through their autonomic decision-making capabilities (e.g. on diagnosis and therapy) or by offering shared decision making between humans and machines [77]-[79]. The author's viewpoint on such intelligent machines is explained in [68]. His suggestion that such entities should become users of HIS, with respective rights and duties, is described in [79], pp. e18-e19. With regards to HIS developments, it is important to note that HIS users are no longer exclusively humans (in their various roles: health care professionals, informal caregivers, patients / persons concerned), but machines have become actors as well. Instances of such intelligent machine entities are robots in operating rooms contributing to surgical therapies [79] and intelligent homes that support vulnerable persons as servants [68].

3.6. Δ_3: Health Care Facilities

For Δ_3, we focus on the HIS development effect by facilities that are used to provide health care services. Examples for health care facilities include hospitals, medical offices, nursing homes, nursing centres (day care, outpatient services, etc.), pharmacies as well as rehabilitation centres (inpatient, outpatient, etc.). These facilities all provide health care services, frequently in collaboration. The above list is by no means complete.

In the past, HIS developments concerning Δ_3 focused on major health care facilities such as hospitals (initially primarily university medical centres) and later and with less intensity on medical offices (e.g., [15], [22], [23], [28]-[36] as well as [80]-[83] for some early references on hospital information systems and [84]-[86] for references on information systems in medical offices). Based on these findings, development of health care services were focused primarily on those services with an intensive relative share of health care as described in Δ_1 for the past.

To date, more or less all health care facilities are considered in HIS developments, maybe in different intensities. As far as the author can see the focus is still mainly on

those services, where the relative share of health care is intense, as described before in Δ_1 for the present.

Also, in future health care facilities remain of particular importance with respect to HIS developments. However, in addition, another 'facility' has to be taken into account, which is not actually a facility at all, strictly speaking. In this facility the author wants to include informal caregivers and the patients / persons concerned. As mentioned in Δ_2 they may also participate in providing health care. For also supporting this facet of health care, this 'facility of enabled informal caregivers and patients / persons concerned' has to be included into HIS developments.

3.7. Δ_4: Settings of Health Care

Concerning settings of health care let us keep in mind that the term health care facility is used here for institutions dedicated to deliver health care services, whereas the term health care setting is used more broadly. In Δ_2 and Δ_3 HIS developments were discussed, with the focus on *who* (Δ_2: entities, Δ_3: facilities) is providing health care for the life situations in Δ_1. In Δ_4 the question will focus on *where*, in which settings, health care will take place. These settings can for obvious reasons be the facilities themselves, and so hospitals, medical offices, nursing homes and centres, pharmacies, and rehabilitation centres. In addition, other settings of health care, being located outside the walls of these facilities, have to be taken into account with respect to HIS developments. These are settings, where our 'normal' living takes place.

In the past HIS developments were concentrated on supporting physicians and nurses and had to be centred on selected health care facilities such as hospitals and medical offices (recall Δ_2 and Δ_3) and there, because of technical limitations, within the walls of these facilities.

To date, as in Δ_3, more or less all health care facilities are considered in HIS developments, again mainly within their walls. However, due to much better connectivity and a broad availability of mobile devices, present HIS developments also try to overcome such walls when appropriate for good health care services, e.g. for virtual consultations between patients, being at home, and their physicians, being in their medical office.

Due to the methodological and technical progress achieved in recent decades, for future HIS developments, technology is no more a major limitation for even globally reaching settings, where health care might be provided through entities and facilities of health care. Settings within the walls of health care facilities may still remain in the centre of HIS developments, but these walls are no more borders for HIS. Other settings can now also be taken into account, may it be locally, e.g. within a community, and even worldwide. Among these additional settings of health care are homes, workplaces, and even transport media such as cars. With this progress in future services for life situations, where the share of health care in our lives seems to be negligible or in between, can better be considered. And so the full spectrum health care services (recall Δ_1) can now be better taken into account for HIS developments. Some references, reporting on these developments, are [87]-[101].

Examples for health care, which could now better be supported by HIS, are prevention, wellness, functional deficits (frailty, …), 'mild' chronic situations, and palliative care.

3.8. Δ_5: Data to be Processed

This line of development discusses questions on data to be processed or provided in HIS (see [1], section 3.2 for details regarding current HIS). To discuss this line of HIS developments let us at first have a look at Figure 3. In the Figure's centre are 'classical' methods for diagnosis and therapy. These methods are, e.g., conversation with and direct physical examinations of patients, lab tests or signal and imaging procedures in diagnostics, or talk, medication, and surgical, internistic or radiological interventions in therapy. In addition to these classical methods, molecular methods and environment-based methods have meanwhile been added, for both diagnosis and for therapy. In [102] this is described as spectrum of methods for diagnosis and therapy first primarily investigating the patients 'phenome' and then having been extended to also include investigating their 'genome' and their 'exposome'. All these methods produce data.

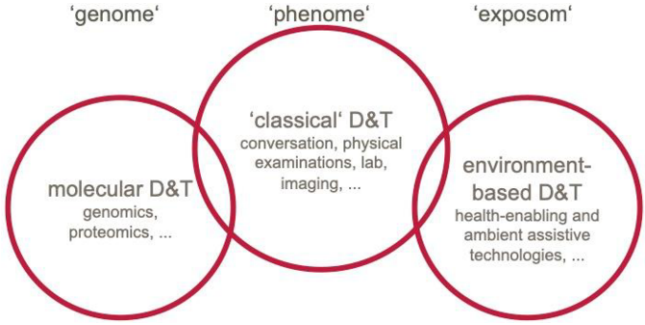

Figure 3. Methods for diagnosis and therapy (D&T).

In the past HIS developments had to consider a huge variability of data from classical methods, which in themselves were tremendously improved and extended during this time. Discussion on interoperability standards for representing and communicating data were at the beginning not a priority. With increasing amounts of data on computers (recall Δ_0) this changed, and interoperability standards came up. Also, molecular data have been successively added.

To date, HIS developments are considering phenome and genome data. Also, data from the environment of patients / persons concerned started to be used. Progress on health-enabling and ambient assistive technologies played an important role, with improved sensor and communication technologies on or at their bodies or in their rooms and with extensive use of smart mobile tools (recall [87]-[101] from Δ_4 as well as [103], [104]). Interoperability standards for representing and communicating data are now a priority.

For future HIS developments all types of data, mentioned here – phenome, genome and exposome data – will have to be extensively considered for providing good health care. The still ongoing discussions on interoperability standards will hopefully lead to opportunities for globally sharing and communicating data, when needed.

3.9. Δ_6: Features for Functions

Closely related to Δ_5, this line of development discusses questions on functions to be supported by features of HIS (see [1], section 2.9, on the meaning of the term features,

as used here, and [1], section 3.3, for details regarding on functions to be supported by features in current HIS).

In the past HIS developments on Δ_6 centred on developing software products in order to provide features for basic health care functions, so that the increasing amount of data to be processed could be handled (recall Δ_0). The entities, for whom these features have been provided, were health care professionals. Features on these software products were mostly for functions on patient care (less for research) and, at least at the beginning, closely related to administrative and documentation matters as well as to meeting legal requirements. Features for functions on decision support started (see e.g. [81]). During the years, such features were continuously extended for further functions.

In to date HIS developments, features are now significantly extended for a broad spectrum of patient care functions. They also include analytics functions beyond direct patient care. Users of these basic and advanced features are still primarily health care professionals. There are extended opportunities for decision support in patient care, often discussed and implemented under the term artificial intelligence (recall [67]-[76] from Δ_2).

In future these HIS developments on basic and advanced features for functions will continue. And, as the spectrum of functions will continue to be modified (recall the increase of diagnostic and therapeutic procedures, mentioned in section 3.3), they are in some respect developments on a moving target. In future such HIS developments should be provided for supporting all entities of care (recall Δ_3 and see e.g. [105]), although, with good reasons, features to support health care professionals remain in the centre of this development path. Also, such features will have to be provided in all health care facilities and in all settings of health care, as discussed before.

3.10. Δ_7: Architectures of HIS

Let us now discuss the last two paths of HIS developments, which are actually the central ones for those, being involved in such developments. The first of these paths is on HIS architectures and their infrastructures and so with a focus on technology and functionality.

In the past, from 1961 to present, there were tremendous HIS developments, mostly related to an increasing use of computers with their steadily expanding software products, better communication networks, and better and more kinds of devices for entities of care as users, leading to better access (recall Δ_0 and Δ_5) and better features for functions (recall Δ_6) in HIS. HIS developments concentrated on health care facilities and health care professionals. Approaches for modelling and analysing HIS architectures were developed (e.g. [37], [106]-[108]). Knowledge on HIS architectures is now content in educational programs in biomedical and health informatics and in health information management (e.g. [46], [47], [111]-[117]). Textbooks on HIS or with HIS as chapters became available (e.g. [31]-[33], [38], [116]-[120]).

To date, this development path continues still intensively, now on the institutional as well as, and with greater emphasis as in the past, on the trans institutional level (recall Δ_1). Architectural styles are on debate. As institutional architectures might not be able to be easily and straightforwardly extended to trans institutional ones, paradigm shifts might be needed.

Future architectures of HIS should take into account what has been mentioned in paths Δ_1 to Δ_6. This will clearly be challenging for the practice of and for research on HIS. And this will have consequences for teaching about HIS.

3.11. Δ_8: Management of HIS

The second path of HIS developments, which is central for those, being involved in such developments, is on management of HIS and so with a focus on organizational and governance aspects.

Compared to developments on architectures of HIS (Δ_7), reflections on appropriate approaches on how to manage HIS started later, as issues of technology and functionality were paramount. Like in Δ_7 they concentrated on health care facilities and health care professionals (e.g. [121]-[123]), of course, as in all paths, with exceptions (e.g. [124]). Many of the textbooks, mentioned in Δ_7 also considered this management aspect, some even put the focus on this topic (e.g. [125]-[127]). In particular in larger health care facilities, such as hospitals, organizational units on information management and information technology with chief information officers (CIOs) as chairpersons had partially been established in the long run.

To date, like in Δ_7, this development path continues on the institutional and also, and here as well with greater emphasis as in the past, on the transinstitutional level. It became apparent that transinstitutional HIS management differs from institutional HIS management. Also, it became clear that transinstitutional HIS management is of considerable importance for patient-centred care as well as for biomedical and public health research. CIOs and respective units are now the rule, no more the exception, at least in larger health care facilities.

Future management of HIS should take into account what has been mentioned in paths Δ_1 to Δ_7. Like in Δ_7 this is as well challenging for the practice of and for research on HIS. And this will have consequences for teaching about HIS. Like in enterprises outside health care and due to the increased relevance of information for providing good health care – and so also due to the increased relevance of HIS – consideration should be given to CIOs becoming members of the boards of directors in health care facilities.

4. Views on HIS Development Paths

4.1. The Development Paths in Summary

The main impressions on the development paths Δ_1 to Δ_8, described before, are summarized in Table 3.

For the sake of ease, let us also recall the instances, which have been mentioned for the topics in the development paths Δ_1 to Δ_6. These were

for life situations related to health care (Δ1): prevention, wellness, emergencies, acute diseases, chronic diseases, care, and rehabilitation as major life situations;

for entities for health care (Δ2): the patients / persons concerned, health care professionals (physicians, nurses, …), informal caregivers, and ‘intelligent‘ machines;

for health care facilities (Δ3): hospitals, medical offices, nursing homes, nursing centers (day care, outpatient services, …), pharmacies as well as rehabilitation centers (inpatient, outpatient, …) and the ‘facility provided by informal caregivers and the patients / persons concerned‘;

for settings of health care (Δ4): the health care facilities, mentioned before, as well as homes, workplaces, and even transport media such as cars;

for data to be processed (Δ5): phenome, genome and exposome data;

and for features for functions (Δ6): basic and advanced features to support functions.

Table 3. Summarizing major impressions on past, present and future HIS developments, as described before, for all development paths. While entries in past and present intend to characterize existing developments, entries in future mention opportunities and priorities. In order to point out major trends the impressions are strongly simplified, both in content and time. In addition, they are personal views of the author, with the risk of being subjectively biased.

		HIS developments		
	development paths	**past main focus**	**present main focus**	**future opportunities**
Δ_0	access to increasing amounts of data	paper-based, shifting to computer-based	computer-based	(see Δ_1 - Δ_8)
Δ_1	life situations related to health care	disease episodes; institution-centred	diseases; patient-centred	health care as part of the whole life; person-centred
Δ_2	entities for health care	health care professionals	health care professionals, caregivers, persons	these humans plus 'intelligent' machines
Δ_3	health care facilities	selected health care facilities	health care facilities	health care facilities plus enabled caregivers, persons
Δ_4	settings of health care	selected health care facilities	health care facilities	health care and other settings, global reach
Δ_5	data to be processed	phenome	phenome and genome	phenome, genome and exposome
Δ_6	features for functions	basic health care features	plus advanced features, for professionals	plus advanced features, for all entities of care
Δ_7	architectures of HIS	institutional, for health care facilities	also transinstitutional, for health care facilities	architectures also take paths Δ_1 to Δ_6 into account
Δ_8	management of HIS	institutional, for health care facilities	also transinstitutional, for health care facilities	management also takes paths Δ_1 to Δ_7 into account

4.2. HIS Developments Paths Grouped into Thematic Spaces

Table 4 is clustering the eight HIS developments paths into three thematic spaces. The questions, raised for each space, may be helpful in approaching on how HIS can be appropriately further developed.

Table 4. The HIS developments paths grouped into thematic spaces.

	Space	**Major Question**	**Line**
α	HIS health care space	- For which life situations related to health care, - by which entities for health care, - from which health care facilities and - in which settings of health care will health care be delivered?	Δ_1 Δ_2 Δ_3 Δ_4
β	HIS analytics space	Given α: - Which data can be processed - by which features?	Δ_5 Δ_6
γ	HIS management space	- How can HIS be managed so that - HIS architectures and infrastructures are available, which appropriately support and sometimes even enable to deliver good health care for a given α and a given β?	Δ_8 Δ_7

4.3. Management of HIS as Mapping

For some readers it might be helpful to formulate management of HIS as mapping (recall the thematic spaces of Table 4).

Let LS be the set of all life situations related to health care and let $\wp(\text{LS}) := \{x \mid x \subseteq \text{LS}\}$ as powerset of LS comprise all combinations of such life situations. Let EHC be the set of all entities for health care, HCF the set of all health care facilities, SHC the set of all settings of health care, D the set of all data to be processed, F the set of all features for functions, and let $\wp(\text{EHC})$, $\wp(\text{HCF})$, $\wp(\text{SHC})$, $\wp(\text{D})$ and $\wp(\text{F})$ be the respective power sets, as defined before for LS. Let HIS-A be the set of all instances for architectures of HIS.

Management of HIS, viewed as mapping, here denoted as HIS-M, may then be defined as

$$\textbf{HIS-M}: \wp(\text{LS}) \times \wp(\text{EHC}) \times \wp(\text{HCF}) \times \wp(\text{SHC}) \times \wp(\text{D}) \times \wp(\text{F}) \rightarrow \text{HIS-A} \quad (1)$$

This mapping might be put into words as follows: Given combinations of certain life situations, certain entities for health care, certain health care facilities, certain settings of health care, certain data, and certain features available: HIS management has to make available HIS architectures and infrastructures, which appropriately support and sometimes even enable entities for health care to deliver good health care for people in their various life situations.

Please note that the parameters, mentioned in the HIS-M function, relate to instances of the development paths, which have been summarized before in section 4.2.

4.4. Management of HIS versus Health Care Planning and Organization

Management of HIS, at least as it is formulated here, does not reflect on why certain parameter values for the HIS-M-function were taken.

This may lead to the question, why one has to consider such values for the parameters of this mapping as taken. Shouldn‘t they be regarded as subjects for modification? And why not trying to identify ‘good parameter value constellations‘ to achieve ‘good HIS architectures’? Reflecting about good or even optimal parameter value constellations concerns parameters in the HIS health care space and in the HIS analytics space of Table 4.

Let us recall, what has been stated in section 3.4: “The main objective for HIS” … “is to support appropriately and sometimes even to enable provision of good health care for people in their various life situations” and that “good health care supports high-quality and efficient health care and improves the quality of life” as well as affordability and availability.

Reflecting about delivering good health care for the various life situations is primarily a matter of health care planning and organization and so for persons / institutions being responsible for making decisions here. This means that looking for good or even optimal parameter value constellations in the HIS health care space and in the HIS analytics space is in their responsibility. It is not primarily a task of HIS management. However, providing information for decision makers in health care planning and organization on how HIS can well support and enable to deliver good health care is in the scope of those persons / institutions involved in HIS management.

Are there clear borders between tasks of HIS management and tasks of health care planning and organization? As far as the author can see this is not the case. The main reason is probably that planning and organizing health care needs in-depth knowledge on opportunities for HIS and for HIS developments for doing their tasks well. And for

managing HIS it can be helpful to be well-informed about potential alternative parameter value constellations in the HIS health care space and in the HIS analytics space for future health care services. Insofar HIS management and health care planning and organization seem to mutually influence each other.

5. Discussion

5.1. Limitations

As already mentioned in section 2.3, these are the author's personal views of HIS developments. Although there has been always an international exchange, this work has been done primarily in Germany and Austria and so in Europe, in two developed countries, having a certain organization and legislation of health care. The views as well as the selected development paths and periods must probably be subjective. Others may have taken other development paths and other thresholds for periods and even the content of past, present and future in the paths could have been different. The views were, however, formed over almost half a century, during which the author has been engaged with HIS developments, and thus may be worth reporting and discussion.

As also mentioned in section 2.3 the references are mainly addressing the work of colleagues, who influenced the author's work. Therefore, reference selection by nature may be biased.

The focus laid here is on HIS developments with respect to supporting health care, which might also be regarded as limitation. An additional focus could have been laid on HIS developments supporting research, in particular in biomedicine and health sciences, but also in computer science and engineering. In [1] this aspect has been e.g. addressed under an additional life situation called research for life and in sections like the one on information systems in medical research.

Last, but not least, the complexity and variability of HIS and HIS developments is huge and hard to grasp, which per se limits to deal with this topic. The level of discussion here could be compared to that of briefly characterizing the tip of an iceberg, where the iceberg would have to be discussed as a whole.

5.2. Balancing Issues

Opportunities can be associated with challenges. Such conflicts might lead to the necessity of carefully balancing the advantages of opportunities against the disadvantages of challenges. With respect to HIS developments the author wants to highlight some conflicts, where careful balancing is needed.

Increasing amounts of health-related data can be helpful for providing good health care to people. This increase may also lead to a higher risk of violating data protection and data security. However, safeguarding informational self-determination of individuals is an important asset.

Virtual communication, maybe in a global reach of care, and, maybe, given by 'intelligent' machines is mentioned as opportunity. This can also lead to disadvantages, as virtual communication should support, but by no means substitute personal relationships. Also, here appropriate balances have to be found, to avoid a loss of direct personal contact between humans through this development.

Health care services from informal caregivers and patients / persons concerned themselves is ambiguous, too. On the one side the wish to receive comprehensive services from health care professionals is obvious but increasing services through health care professionals will at some point come to limits in various ways. On the other side informal caregivers and patients / persons concerned may also want to be more responsible for oneself, in particular if they are enabled. But they will in many cases not be able to replace professional help. Also, here appropriate balancing is necessary, also in the context of achieving appropriate subsidiarity (recall Δ2). In addition, HIS may help to support this balancing through helping to enable good collaboration between all entities of health care.

5.3. Other Factors and Paths

When looking at the thematic spaces in Table 4 we can see that the mentioned development paths concentrate of being able to adequately deal with HIS management and HIS architectures. Aspects such as (maybe competing) interests of the various stake holders in health care and in IT industries, of how and which health care services are reimbursed, aspects of financing, of political priorities, of the intention to primarily generate profit, or of legal and governmental actions are not considered here. They might be of equal or of even more influence on HIS developments. Whereas in the past technology was often a major limiting factor, the mentioned future opportunities of HIS developments now often are limited by traditional health care planning and organization and respective legislation and reimbursement schemes, not considering the new opportunities of HIS developments.

Evaluating HIS has been and is an important additional factor for HIS developments, which could not be discussed here (e.g. [129], [130]). Systematically evaluating HIS and their benefits for entities for health care, for health care facilities, for public health, and for research in biomedicine and health sciences through well-designed studies (if possible, through randomized trials) remains a major issue.

The author also wants to refer to topics, mentioned in [53], pp. 605-607, for medical informatics research fields. Many of them correlate to HIS developments, such as "seamless interactivity with automated data capture and storage for patient care, and beyond", "informatics diagnostics", "informatics therapeutics", "informatics capability-enhancing extensions, both mental and physical", or "automated, individualized health advice and education". Although they would have been worth to be discussed in more detail, they have been touched only marginally here in order to have the major HIS development paths in the focus.

Last, but not least, education has to be mentioned as important additional factor for HIS developments. Education here is twofold. One the one hand education concerns empowering HIS users, i.e. entities of care such as health care professionals, informal caregivers and patients / persons concerned. On the other hand it concerns adequately educating specialists in HIS architectures and HIS management. The latter has briefly been touched in paths Δ_7 and Δ_8.

5.4. Discussion Outcomes from Frank-van-Swieten-Lectures and ICIMTH

As mentioned at the beginning, before the Symposion on October 2022 in Athens these thoughts have been presented and discussed during the 2021 and 2022 Frank-van-Swieten-Lectures and during ICIMTH 2022.

In particular in the 2022 discussions it was raised that two additional development paths might have been worth to be mentioned in addition:
Interoperability standards, because of their importance as well as because of the progress achieved.
Devices, as in particular tremendous progress has been made through mobile devices with their 'apps', and that this progress has significantly influenced and improved functions and features of HIS.

In the development paths, the author considered as relevant, standards were part of the Δ_5 path on data to be processed and devices were part of Δ_7 on architectures of HIS. The author agrees that it might be worth to consider standards and devices as separate paths, as well as some other paths, mentioned in section 5.3.

One colleague - well-known, high-qualified and well-respected, not only by the author - added that in his opinion the mentioned future developments in HIS are already a reality. Here the author did not share this opinion and suggested to run studies in order to see whose opinion is more in line with the reality of HIS.

5.5. Call for Research

The views of HIS developments, described here, reflect the author's personal views of HIS developments. Others are kindly encouraged to do research on the statements made, e.g. on some of the development paths. Can it be shown that the author's statements on paths are correct or wrong? And if they could be shown as being wrong, are there other development paths with better evidence? Is there any data to verify or falsify some of the statements? Or is there any data to specify development paths more precisely?

5.6. Call for Discussion

The author wants to put the presented views on past, present and future HIS developments up for discussion. Comment on these views, critically discussing the author's statements in each of the paths and so participating in a debate on HIS developments, are very welcome.

Unfortunately, there was no immediate invited discussion of the paper, resulting of the 2004 Lecture ([26]). Such a discussion, however, took place on a related paper, forecasting related future developments in 2000 for the year 2013 [128]. It might be of interest looking at the invited comments there, with a very broad view on how HIS developments should support health care [131]-[143] and at the reflections made in 2013 [144]-[147].

6. "Now here I am, a fool for sure! No wiser than I was before"?

The conclusion section starts with recalling and commenting the two quotes of section 2.4:

With respect to the quote on architecture, we have to recognize that we are still on our way to reach the goal of building HIS, where users enjoy "relaxing, working, learning, buying, manufacturing, and worshipping" [39] (p. 6). Transposed for HIS this means: where entities for health care are appropriately supported and enabled through HIS in delivering good health care for people in their various life situations. And so, for HIS specialists, to having designed HIS "with love and tender care as well as function in mind"

[39] (p. 6). It has to be added that systematically dealing with the theory and practice of the architecture of buildings and with their engineering has a much longer tradition than dealing with HIS architecture and HIS management. Books on architecture of buildings have already been published two thousand years ago [148]. Another significant difference can be found in the materials to be used. For the engineering of buildings, they developed rather steadily, at least as far as the author can see. For information systems there was a huge change in the materials to be used, when computers with their software products became available during the last century.

With respect to the quote on medical informatics, we can see that also for HIS we are "engaged in an exhausting, but exhilarating struggle with one of the biggest challenge that science is facing" [52] (p. 25). Even more, HIS developments will remain a major topic for future medical informatics research, practice, and education.

This conclusions section closes by giving an answer to the question:

Shall or shall we not say with respect to HIS developments
"*Now here I am, a fool for sure! No wiser than I was before*"?

and so referring to Johann Wolfgang von Goethe's Faust [17] (p.19), as mentioned in section 1.4. After describing HIS developments in past and present the answer is evident, at least in the author's opinion. With respect to HIS developments Goethe's Faust statement can not be applied. We are wiser now! We learned many lessons! There were tremendous developments in the past and we can contribute to such developments in the future: For good health care for people in their various life situations. Present HIS are much better than HIS of the past and probably nobody would want to get back to a past state. We, however, also have to recognize that we are by no means at the end of HIS developments. It seems that we are still in the middle or even at the beginning. There is room for continued improvement with an end of HIS developments far from sight.

Acknowledgements

Cordial thanks go to Alfred Winter, who motivated the author to give lectures on this topic and who therefore initiated to write this manuscript as well as for our joint work and shaping discussions on HIS developments since 1984. Discussions with him also lead to important improvements of this manuscript. Many of the thoughts presented here were influenced by the authors of [1], a current textbook on HIS: Elske Ammenwerth, Franziska Jahn, Michael Marschollek, and Bianca Steiner, as well as, again, Alfred Winter, and where the author has the pleasure to be co-author, too. John Mantas was so kind to offer the author the opportunity to give a talk on this topic in the Symposion on Achievements, Milestones, and Challenges in Biomedical and Health Informatics, which took place on the occasion of his retirement, and to accept this manuscript to be published in the Symposion's proceedings. He also helped with the Greek explanations. Christoph Lehmann kindly agreed to suggest edits of the author's German-biased English. And, again, he not only turned this text into a much better readable English style, he also helped to sharpen the author's reflections. Translations of German texts into English have been well supported by DeepL [149]. Last, but not least, it has to be acknowledged once again that this work on HIS has been influenced by joint projects and by many valuable discussions with other persons. Among them are all colleagues mentioned in

this section and in section 2.3, as well as authors in the References section. Many others could be added.

References

[1] Winter A, Ammenwerth E, Haux R, Marschollek M, Steiner B, Jahn F. Health Information Systems. Technological and Management Perspectives. Cham: Springer Nature. To appear.

[2] IΦE – International Partnership for Health Informatics Education. https://www.iphie.org. Last access: August 3, 2022.

[3] Gatewood LC, Limburg M, Gardner RM, Haux R, Jaspers MW, Schmidt D, Wetter T. International Master Classes in Health Informatics. Int J Med Inform. 2004;73:111-6.

[4] Jaspers MW, Gardner RM, Gatewood LC, Haux R, Evans RS. An International Summer School on Health Informatics: A Collaborative effort of the Amsterdam Medical Informatics Program and IΦE – the International Partnership for Health Informatics Education. Int J Med Inform. 2007; 76: 538-46.

[5] Jaspers MW, Gardner RM, Gatewood LC, Haux R, Leven FJ, Limburg M, Ravesloot JH, Schmidt D, Wetter T. IPHIE: an International Partnership in Health Informatics Education. Stud Health Technol Inform. 2000;77:549-53.

[6] Jaspers MW, Gardner RM, Gatewood LC, Haux R, Schmidt D, Wetter T. The International Partnership in Health Informatics Education. Stud Health Technol Inform. 2004;107:884-8.

[7] Jaspers MW, Gardner RM, Gatewood LC, Haux R, Schmidt D, Wetter T. The International Partnership for Health Informatics Education: Lessons Learned from Six Years of Experience. Methods Inf Med. 2005; 44: 25-31 and Yearb Med Inform; 2005.173-182.

[8] Turner AM, Facelli JC, Jaspers M, Wetter T, Pfeifer D, Gatewood LC, Adam T, Li YC, Lin MC, Evans RS, Beukenhorst A, van Mens HJT, Tensen E, Bock C, Fendrich L, Seitz P, Suleder J, Aldelkhyyel R, Bridgeman K, Hu Z, Sattler A, Guo SY, Mohaimenul IMM, Anggraini Ningrum DN, Tung HR, Bian J, Plasek JM, Rommel C, Burke J, Sohih H. Solving Interoperability in Translational Health. Perspectives of Students from the International Partnership in Health Informatics Education (IPHIE) 2016 Master Class. Appl Clin Inform. 2017;8:651-9.

[9] Ammenwerth E, Knaup P, Winter A, Bauer AW, Bott OJ, Gietzelt M, Haarbrandt B, Hackl WO, Hellrung N, Hübner-Bloder G, Jahn F, Jaspers MW, Kutscha U, Machan C, Oppermann B, Pilz J, Schwartze J, Seidel C, Slot JE, Smers S, Spitalewsky K, Steckel N, Strübing A, Haak MV, Haux R, Ter Burg WJ. On Teaching International Courses on Health Information Systems. Lessons Learned during 16 Years of Frank - van Swieten Lectures on Strategic Information Management in Health Information Systems. Methods Inf Med. 2017;56:e39-e48.

[10] Haux R, Ammenwerth E, ter Burg WJ, Pilz J, Jaspers MW. An International Course on Strategic Information Management for Medical Informatics Students: Aim, Content, Structure, and Experiences. Int J Med Inform. 2004;73:97-100.

[11] Jaspers MW, Ammenwerth E, Ter Burg WJ, Kaiser F, Haux R. An International Course on Strategic Information Management for Medical Informatics Students: International Perspectives and Evaluation. Int J Med Inform. 2004;73:807-15.

[12] Deshajes JC, Seidman DR. Health Information Systems. Soc-Eco Planning Sc. 1971;5:515-33

[13] Glasser JH. Health-Information Systems: A Crisis or Just More of The Usual? Am J Public Health. 1971;61:1524-30.

[14] Morrill EE, Oser JL, Kusnetz HL. Occupational Health Information Systems – Their Concepts and Functions. Am J Public Health. 1971;61:2469-73.

[15] Buchanan JM. Automated Hospital Information Systems. Mil Med. 1966;131:1510-2.

[16] Email of Alfred Winter of May 18, 2021, to the author.

[17] von Goethe JW. Faust Parts I & II. Part I first published in 1808. A Translation into English by A.S. Kline, 2003. https://www.poetryintranslation.com/klineasfaust.php. Last access: August 3, 2022.

[18] Oberhoffer G. Bericht über das Internationale Seminar für medizinische Dokumentation und Statistik, Berlin, 16.-28. Oktober 1961. [Report on the International Seminar on Medical Documentation and Statistics, Berlin, 16.-28. October 1961]. Methods Inf. Med. German. 1962;1:27-30.

[19] McCray AT, Gefeller O, Aronsky D, Leong TY, Sarkar IN, Bergemann D, Lindberg DA, van Bemmel JH, Haux R. The Birth and Evolution of a Discipline Devoted to Information in Biomedicine and Health Care. As Reflected in its Longest Running Journal. Methods Inf Med. 2011;50:491-507.

[20] Koller S, Wagner G, editors. Handbuch der medizinischen Dokumentation und Datenverarbeitung. [Handbook of Medical Documentation and Data Processing]. Stuttgart: Schattauer; 1975. German.

[21] van Bemmel JH, Bergemann D. In Memoriam Gustav Wagner (1918-2006). Methods Inf Med. 2007;46:1.
[22] Reichertz PL. Hospital Information Systems - Past, Present, Future -. Key-note address during 'Medical Informatics Europe 84', 5th Congress of the European Federation for Medical Informatics, Brussels, September 10-13, 1984. Manuscript available from the author upon request.
[23] Reichertz PL. Hospital Information Systems - Past, Present, Future. Int J Med Inform. 2006;75:282-99.
[24] Haux R. Analysing the Scientific Publications of Peter Reichertz: Reflections from the Perspective of Medical Informatics Knowledge Today. J Med Syst. 2019 Dec 11;44(1):23.
[25] Wagner GA, Lindberg DA. In Memoriam Peter L. Reichertz. Methods Inf Med. 1987;26:179-82.
[26] Haux R. Health Information Systems - Past, Present, Future. Int J Med Inform. 2006;75:268-81.
[27] van Bemmel JH. Medical Informatics is Interdisciplinary Avant la Lettre. Methods Inf Med. 2008;47:318-21.
[28] Ball MJ. An Overview of Total Medical Information Systems. Methods Inf Med. 1971;10:73-82.
[29] Ehlers CT, Hollberg N, Proppe A, editors. Computer: Werkzeug der Medizin [Computer: Tool for Medicine]. Springer: Berlin; 1970. German.
[30] Ehlers CT. Einpassung eines EDV-Systems und seiner Planung in das Funktionskonzept eines Großklinikums [Ehlers CT. Integration of an EDP System and its Planning into the Functional Concept of a Large Hospital]. In: Reichertz PL, Schwartz B, editors. Informationssysteme in der medizinischen Versorgung [Information Systems in Health Care], 53-69. Stuttgart: Schattauer; 1978. German.
[31] Griesser G. Das Krankenhaus-Informations-System [The Hospital Information System]. Hippokrates. 1969;40:262-75. German.
[32] Griesser G, Schneider W. Das Krankenhaus-Informationssystem [The Hospital Information System]. In: Koller S, Wagner G, editors. Handbuch der medizinischen Dokumentation und Datenverarbeitung. [Handbook of Medical Documentation and Data Processing], 870-94. Stuttgart: Schattauer; 1975. German.
[33] Köhler CO. Integriertes Krankenhaus-Informationssystem [Integrated Hospital Information System]. Meisenheim am Glan: Anton Hain; 1973. German.
[34] Reichertz PL. The Medical System Hannover (MSH) and Regional Activities in Germany. In: Proceedings of MEDIS '72, Osaka International Symposium on Medical Information Systems,127-53. Tokyo: Kansai Institute of Information Systems; 1972.
[35] Reichertz PL. Strategy Considerations for Hospital Information Systems. In: Proceedings of MEDIS '75, Tokyo International Symposium on Medical Information Systems,11-8. Tokyo: Kansai Institute of Information Systems; 1975.
[36] Winter A, Haux R, Schleisiek KP. Systematic Development of a Hospital Information System with Distributed Data- and Methodbase Systems: the AACHMED Project. In Roger FH, Grönroos P, Tervo-Pellikka R, O'Moore R, editors. Medical Informatics Europe 85, 487-591. Berlin: Springer; 1985.
[37] Winter A, Haux R. A Three-level Graph-based Model for the Management of Hospital Information Systems. Methods Inf Med. 1995;34:378-96.
[38] Winter A, Haux R, Ammenwerth E, Brigl B, Hellrung N, Jahn F. Health Information Systems – Architectures and Strategies. London: Springer; 2011.
[39] Caudill WW, Peña W, Kennon PA. Architecture and You: How to Experience and Enjoy Buildings. New York: Whitney Library of Design; 1978.
[40] Elkin PL, Brown SH, Wright G. Biomedical Informatics: We are what We Publish. Methods Inf Med. 2013;52:538-46.
[41] Gülkesen H, Haux R. Research Subjects and Research Trends in Medical Informatics. Methods Inf Med. 2019;58:e1-e13.
[42] Lyu PH, Yao Q, Mao J, Zhang SJ. Emerging Medical Informatics Research Trends Detection Based on MeSH Terms. Inform Health Soc Care. 2015;40:210-28.
[43] Maojo V, García-Remesal M, Bielza C, Crespo J, Perez-Rey D, Kulikowski C. Biomedical Informatics Publications: A Global Perspective. Part I: Conferences. Methods Inf Med. 2012;51:82-90.
[44] Maojo V, Garcia-Remesal M, Bielza C, Crespo J, Perez-Rey D, Kulikowski C. Biomedical Informatics Publications: A Global Perspective. Part II: Journals. Methods Inf Med. 2012;51:131-7.
[45] Schuemie MJ, Talmon JL, Moorman PW, Kors JA. Mapping the Domain of Medical Informatics. Methods Inf Med. 2009;48:76-83.
[46] Recommendations of the International Medical Informatics Association (IMIA) on Education in Health and Medical Informatics. Methods Inf Med. 2000;39:267-77.
[47] Mantas J, Ammenwerth E, Demiris G, Hasman A, Haux R, Hersh W, Hovenga E, Lun KC, Marin H, Martin-Sanchez F, Wright G; IMIA Recommendations on Education Task Force. Recommendations of the International Medical Informatics Association (IMIA) on Education in Biomedical and Health Informatics. First Revision. Methods Inf Med. 2010;49:105-20.

[48] Hasman A, Haux R. Modeling in Biomedical Informatics - An Exploratory Analysis. Part 1. Methods Inf. Med. 2006;45:638-42.
[49] Hasman A, Haux R. Modeling in Biomedical Informatics - An Exploratory Analysis. Part 2. Int J Med Inform. 2007;76:96-102.
[50] Kulikowski CA. The Micro-macro Spectrum of Medical Informatics Challenges: From Molecular Medicine to Transforming Health care in a Globalizing Society. Methods Inf Med. 2002;41:20-4.
[51] Reichertz PL. Preparing for Change: Concepts and Education in Medical Informatics. Comput Methods Programs Biomed. 1987;25:89-101.
[52] Haux R. On Determining Factors for Good Research in Biomedical and Health Informatics. Some Lessons Learned. Yearb Med Inform. 2014;9:255-64.
[53] Haux R. Medical Informatics: Past, Present, Future. Int J Med Inform. 2010;79:599-610.
[54] World Health Organization. Global Observatory for eHealth. http://www.who.int/goe/en/. Last access: August 3, 2022.
[55] International Telecommunicaton Union. Measuring the Information Society Report 2018. Volume 1. Genf: ITU; 2018.https://www.itu.int/en/ITU-D/Statistics/Pages/publications/misr2018.aspx. Last access: August 3, 2022.
[56] International Telecommunicaton Union. Measuring the Information Society Report 2018. Volume 2. ICT Country Profiles. Genf: ITU; 2018. https://www.itu.int/en/ITU-D/Statistics/Pages/publications/misr2018.aspx. Last access: August 3, 2022.
[57] Martin-Sanchez FJ, Lopez-Campos GH. The New Role of Biomedical Informatics in the Age of Digital Medicine. Methods Inf Med. 2016;55:392-402.
[58] Shortliffe EH. Digital Medicine and Biomedical Informatics: What's in a Name? Methods Inf Med. 2016;55:389-91.
[59] Al-Shorbaji N, Bellazzi R, Gonzalez Bernaldo de Quiros F, Koch S, Kulikowski CA, Lovell NH, Maojo V, Park HA, Sanz F, Sarkar IN, Tanaka H. Discussion of " The New Role of Biomedical Informatics in the Age of Digital Medicine". Methods Inf Med. 2016;55:403-21.
[60] Haux R, Hein A, Kolb G, Künemund H, Eichelberg M, Appell JE, Appelrath HJ, Bartsch C, Bauer JM, Becker M, Bente P, Bitzer J, Boll S, Büsching F, Dasenbrock L, Deparade R, Depner D, Elbers K, Fachinger U, Felber J, Feldwieser F, Forberg A, Gietzelt M, Goetze S, Gövercin M, Helmer A, Herzke T, Hesselmann T, Heuten W, Huber R, Hülsken-Giesler M, Jacobs G, Kalbe E, Kerling A, Klingeberg T, Költzsch Y, Lammel-Polchau C, Ludwig W, Marschollek M, Martens B, Meis M, Meyer EM, Meyer J, Meyer Zu Schwabedissen H, Moritz N, Müller H, Nebel W, Neyer FJ, Okken PK, Rahe J, Remmers H, Rölker-Denker L, Schilling M, Schöpke B, Schröder J, Schulze GC, Schulze M, Siltmann S, Song B, Spehr J, Steen EE, Steinhagen-Thiessen E, Tanschus NM, Tegtbur U, Thiel A, Thoben W, van Hengel P, Wabnik S, Wegel S, Wilken O, Winkelbach S, Wist T, Wolf KH, Wolf L, Zokoll-van der Laan M. Lower Saxony Research Network GAL. Information and Communication Technologies for Promoting and Sustaining Quality of Life, Health and Self-sufficiency in Ageing Societies – Outcomes of the Lower Saxony Research Network Design of Environments for Ageing (GAL). Inform Health Soc Care. 2014;39:166-87.
[61] Alt R, Demirkan H, Ehmke JF, Moen A, Winter A. Smart Services: The Move to Customer Orientation. Electron Markets. 2019;29:1–6.
[62] Alt R, Ehmke JF, Haux R. Henke T, Mattfeld DC, Oberweis A, Paech B, Winter A. Towards Customer-induced Service Orchestration – Requirements for the Next Step of Customer Orientation. Electron Markets. 2019;29:79–91.
[63] Al-Shorbaji N, Borycki EM, Kimura M, Lehmann CU, Lorenzi NM, Moura LA, Winter A. Discussion of "Representation of People's Decisions in Health Information Systems: A Complementary Approach for Understanding Health Care Systems and Population Health". Methods Inf Med. 2017;56:e20-e29.
[64] Ammenwerth E, Duftschmid G, Al-Hamdan Z, Bawadi H, Cheung NT, Cho KH, Goldfarb G, Gülkesen KH, Harel N, Kimura M, Kırca Ö, Kondoh H, Koch S, Lewy H, Mize D, Palojoki S, Park HA, Pearce C, de Quirós FGB, Saranto K, Seidel C, Vimarlund V, Were MC, Westbrook J, Wong CP, Haux R, Lehmann CU. International Comparison of Six Basic eHealth Indicators Across 14 Countries: An eHealth Benchmarking Study. Methods Inf Med. 2020;59:e46-e63.
[65] De Lusignan S, Krause P. The Hayes Principles: Learning from the National pilot of Information Technology and Core Generalisable Theory in Informatics. Inform Prim Care. 2010;18:73-7.
[66] Fessler JM, Grémy F. Ethical Problems in Health Information Systems. Methods Inf Med. 2001;40:359-61.
[67] Topol EJ. High-performance Medicine: The Convergence of Human and Artificial Intelligence. Nat Med 2019; 25:c44–56.
[68] Haux R. Some Thoughts on Extended Collaboration of Entities with Natural and with Artificial Intelligence in Health Care and Beyond. Stud Health Technol Inform 2019;262:1–6.

[69] Haux R, Gahl K, Jipp M, Kruse R, Richter O, editors. Zusammenwirken von natürlicher und künstlicher Intelligenz. [Collaboration of Natural and Artificial Intelligence]. Wiesbaden: Springer VS; 2021. German.
[70] Gulshan V, Peng L, Coram M, et al. Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs. JAMA 2016;316:2402–10.
[71] Haenssle HA, Fink C, Schneiderbauer R, Toberer F, Buhl T, Blum A, Kalloo A, Hassen ABH, Thomas L, Enk A, Uhlmann L. Reader Study Level-I and Level-II Groups. Man Against Machine: Diagnostic Performance of a Deep Learning Convolutional Neural Network for Dermoscopic Melanoma Recognition in Comparison to 58 Dermatologists. Ann Oncol 2018;29:1836–42.
[72] Hollis KF, Séroussi B, Soualmia, LF, editors. Artificial Intelligence in Health: New Opportunities, Challenges, and Practical Implications. IMIA Yearbook of Medical Informatics 2019. Stuttgart: Thieme; 2019.
[73] Kulikowski CA. Beginnings of Artificial Intelligence in Medicine (AIM): Computational Artifice Assisting Scientific Inquiry and Clinical Art – with Reflections on Present AIM Challenges. Yearb Med Inform. 2019;28:249–56.
[74] Rahwan I, Cebrian M, Obradovich N, Bongard J, Bonnefon JF, Breazeal C, Crandall JW, Christakis NA, Couzin ID, Jackson MO, Jennings NR, Kamar E, Kloumann IM, Larochelle H, Lazer D, McElreath R, Mislove A, Parkes DC, Pentland AS, Roberts ME, Shariff A, Tenenbaum JB, Wellman M. Machine Behaviour. Nature. 2019;568:477–86.
[75] Ronicke S, Hirsch MC, Türk E, Larionov K, Tientcheu D, Wagner AD. Can a Decision Support System Accelerate Rare Disease Diagnosis? Evaluating the Potential Impact of Ada DX in a Retrospective Study. Orphanet J Rare Dis. 2019;14:69.
[76] Shortliffe EH. Artificial Intelligence in Medicine: Weighing the Accomplishments, Hype, and Promise. Yearb Med Inform. 2019;28:257–62.
[77] Beck S. The problem of ascribing legal responsibility in the case of robotics, AI & SOCIETY. 2016;31:473-81.
[78] Schilling M, Kopp S, Wachsmuth S, Wrede B, Ritter H, Brox T, Nebel B, Burgard W. Towards a multidimensional perspective on shared autonomy. Proc. AAAI Fall Symposium Series: Shared Autonomy in Research and Practice, 338-44. Paolo Alto, Ca.: AAAI;2016.
[79] Steil J, Finas D, Beck S, Manzeschke A, Haux R. Robotic Systems in Operating Theaters: New Forms of Team-Machine Interaction in Health Care. Methods Inf Med. 2019;58:e14-e25.
[80] Bakker AR. The Development of an Integrated and Co-operative Hospital Information System. Med Inform. 1984;9:135-42.
[81] Gardner RM, Pryor TA, Warner HR. The HELP Hospital Information System: Update 1998. Int J Med Inform. 1999;54:169-82.
[82] Jahn F, Issler L, Winter A, Takabayashi K. Comparing a Japanese and a German Hospital Information System. Methods Inf Med. 2009;48:531-9.
[83] Scherrer JR. The Integrated Real-time Hospital Information System: DIOGENE. World Hosp. 1983;19(4):8-11.
[84] Hartmann KW. The Computer in the Doctor's Office. Report on an IMIA (T.C.4) Conference. Methods Inf Med. 1980;19:169-71.
[85] Moehr JR. The Computer in the Doctor's Office. Methods Inf Med. 1981;20:217-22.
[86] Reichertz PL, Moehr JR, Schwarz B, Schlatter A, von Gärtner-Holthoff G, Filsinger E. Evaluation of a Field Test of Computers for the Doctor's Office. Methods Inf Med. 1979 Apr;18(2):61-70.
[87] Chi NC, Demiris G. A Systematic Review of Telehealth Tools and Interventions to Support Family Caregivers. J Telemed Telecare. 2015;21:37-44.
[88] Choi YK, Lazar A, Demiris G, Thompson HJ. Emerging Smart Home Technologies to Facilitate Engaging With Aging. J Gerontol Nurs. 2019;45:41-8.
[89] Elgert L, Steiner B, Saalfeld B, Marschollek M, Wolf KH. Health-Enabling Technologies to Assist Patients With Musculoskeletal Shoulder Disorders When Exercising at Home: Scoping Review. JMIR Rehabil Assist Technol. 2021;8:e21107.
[90] Haux R. My Home Is My Hospital. On Recent Research on Health-Enabling Technologies. Stud Health Technol Inform. 2016;226:3-8.
[91] Haux R, Marschollek M, Wolf KH. Some Thoughts on Personal Living Environments as New Diagnostic and Therapeutic Areas. Stud Health Technol Inform. 2013;190:8-12.
[92] Maeder AJ, Williams PAH. Health Smart Homes: New Challenges. Stud Health Technol Inform. 2017;245:166-19.
[93] Mielke C, Voss T, Haux R. Residence as a Diagnostic and Therapeutic Area – A Smart Home Approach. Stud Health Technol Inform. 2017;238:92-5.

[94] Mohktar MS, Redmond SJ, Antoniades NC, Rochford PD, Pretto JJ, Basilakis J, Lovell NH, McDonald CF. Predicting the Risk of Exacerbation in Patients with Chronic Obstructive Pulmonary Disease Using Home Telehealth Measurement Data. Artif Intell Med. 2015;63:51-9.
[95] Nagapuri S, Maeder AJ, Williams PAH. Health Smart Homes: User Perspectives. Stud Health Technol Inform. 2019;266:127-35.
[96] Steiner B, Elgert L, Saalfeld B, Schwartze J, Borrmann HP, Kobelt-Pönicke A, Figlewicz A, Kasprowski D, Thiel M, Kreikebohm R, Haux R, Wolf KH. Health-Enabling Technologies for Telerehabilitation of the Shoulder: A Feasibility and User Acceptance Study. Methods Inf Med. 2020;59:e90-9.
[97] Wang J, Warnecke JM, Deserno TM. The Vehicle as a Diagnostic Space: Efficient Placement of Accelerometers for Respiration Monitoring During Driving. Stud Health Technol Inform. 2019;258:206-210.
[98] Wang J, Aguirre Mehlhorn M, Ditler K, Effner B, Deserno TM. Tracking Activities of Daily Living in the Home Office. Stud Health Technol Inform. 2022;289:162-5.
[99] Wang J, Wang J, Miao H, Marschollek M, Wolf KH, Lynch KA, Gong Y. Leveraging Aging in Place Through Sensor-Enhanced In-Home Monitoring. Stud Health Technol Inform. 2018;250: 19-23.
[100] Wang J, Warnecke JM, Haghi M, Deserno TM. Unobtrusive Health Monitoring in Private Spaces: The Smart Vehicle. Sensors. 2020;20:2442.
[101] Warnecke JM, Boeker N, Spicher N, Wang J, Flormann M, Deserno TM. Sensor Fusion for Robust Heartbeat Detection during Driving. Annu Int Conf IEEE Eng Med Biol Soc. 2021;2021:447-50.
[102] Martin-Sanchez F, Gray K, Bellazzi R, Lopez-Campos G. Exposome Informatics: Considerations for the Design of Future Biomedical Research Information Systems. J Am Med Inform Assoc. 2014;21:386–90.
[103] Haux R, Koch S, Lovell NH, Marschollek M, Nakashima N, Wolf KH. Health-Enabling and Ambient Assistive Technologies: Past, Present, Future. Yearb Med Inform. 2016;S76-91.
[104] Knaup P, Schöpe L. Using Data from Ambient Assisted Living and Smart Homes in Electronic Health Records. Methods Inf Med. 2014;53:149-51.
[105] De Quiros FGB, Dawidowski AR, Figar S. Representation of People's Decisions in Health Information Systems. A Complementary Approach for Understanding Health Care Systems and Population Health. Methods Inf Med. 2017;56:e13-e19.
[106] Brigl B, Hübner-Bloder G, Wendt T, Haux R, Winter A. Architectural Quality Criteria for Hospital Information Systems. AMIA Annu Symp Proc. 2005;2005:81-5.
[107] Winter A, Brigl B, Funkat G, Häber A, Heller O, Wendt T. 3LGM2-Modeling to Support Management of Health Information Systems. Int J Med Inform. 2007;76:145-50.
[108] Wendt T, Häber A, Brigl B, Winter A. Modeling Hospital Information Systems (Part 2): Using the 3LGM2 tool for modeling patient record management. Methods Inf Med. 2004;43:256-67.
[109] Ammenwerth E, Knaup P, Winter A, Bauer AW, Bott OJ, Gietzelt M, Haarbrandt B, Hackl WO, Hellrung N, Hübner-Bloder G, Jahn F, Jaspers MW, Kutscha U, Machan C, Oppermann B, Pilz J, Schwartze J, Seidel C, Slot JE, Smers S, Spitalewsky K, Steckel N, Strübing A, Haak MV, Haux R, Ter Burg WJ. On Teaching International Courses on Health Information Systems. Lessons Learned during 16 Years of Frank - van Swieten Lectures on Strategic Information Management in Health Information Systems. Methods Inf Med. 2017;56:e39-e48.
[110] Haux R, Ammenwerth E, Häber A, Hübner-Bloder G, Knaup-Gregori P, Lechleitner G, Leiner F, Weber R, Winter A, Wolff AC. Medical Informatics Education Needs Information System Practicums in Health Care Settings – Experiences and Lessons Learned from 32 Practicums at Four Universities in Two Countries. Methods Inf Med. 2006;45:294-9.
[111] Hovenga EJ, Grain H. Health information systems. Stud Health Technol Inform. 2013;193:120-40.
[112] Knaup P, Haux R, Häber A, Lagemann A, Leiner F. Teaching the Fundamentals of Information Systems Management in Health Care. Lecture and Practical Training for Students of Medical Informatics. Int J Med Infor. 1998;50:195-205.
[113] Minou I, Mantas J. An e-Learning Approach to Hospital Information Systems. Stud Health Technol Inform. 2015;213:122-5.
[114] Protti DJ. Teaching Hospital Information Systems by Simulating What Really Happens. Methods Inf Med. 1989;28:281-4.
[115] Tan JK. Graduate Education in Health Information Systems: Having all your Eggs in One Basket. J Health Adm Educ. 1993;11:27-55.
[116] Hasman A, Mantas J, editors. Text Book in Health Informatics: A Nursing Perspective. Amsterdam: IOS; 2001.
[117] Haux R, Winter A, Ammenwerth E, Brigl B. Strategic Information Management in Hospitals. An Introduction to Hospital Information Systems. New York: Springer; 2004.

[118] Lehmann CU, Kim GR, Johnson KB, editors. Pediatric Informatics Computer Applications in Child Health. New York: Springer; 2009.
[119] Van Bemmel JH, Musen MA, editors. Handbook of Medical Informatics. Heidelberg: Springer; 2002.
[120] Van de Velde R, Degoulet P. Clinical Information Systems. A Component-Based Approach. New York: Springer; 2003.
[121] Brigl B, Ammenwerth E, Dujat C, Gräber S, Grosse A, Häber A, Jostes C, Winter A. Preparing Strategic Information Management Plans for Hospitals: A Practical Guideline. Int J Med Inform. 2005;74:51-65.
[122] Winter A, Takabayashi K, Jahn F, Kimura E, Engelbrecht R, Haux R, Honda M, Hübner UH, Inoue S, Kohl CD, Matsumoto T, Matsumura Y, Miyo K, Nakashima N, Prokosch HU, Staemmler M. Quality Requirements for Electronic Health Record Systems. A Japanese-German Information Management Perspective. Methods Inf Med. 2017;56:e92-e104.
[123] Winter AF, Ammenwerth E, Bott OJ, Brigl B, Buchauer A, Gräber S, Grant A, Häber A, Hasselbring W, Haux R, Heinrich A, Janssen H, Kock I, Penger OS, Prokosch HU, Terstappen A, Winter A. Strategic Information Management Plans: The Basis for Systematic Information Management in Hospitals. Int J Med Inform. 2001;64:99-109.
[124] Saranto K, Flatley Brennan P, Casey A, editors. Personal Health Information Systems: Tools and Strategies for Citizens' Engagement. Kuopio: University of Kuopio; 2009.
[125] Ball MJ, Simborg DW, Albright JW, Douglas JV, editors. Healthcare Information Management Systems. A Practical Guide. New York: Springer; 1991.
[126] Lorenzi NM, Riley RT. Managing Technological Change. Organizational Aspects of Health Informatics. New York: Springer; 2004.
[127] Lorenzi NM, Riley RT. Organizational Aspects of Health Informatics. Managing Technological Change. New York: Springer; 1995.
[128] Haux R, Ammenwerth E, Herzog W, Knaup P. Health Care in the Information Society. A Prognosis for the Year 2013. Int J Med Inform. 2002;66:3-21.
[129] Ammenwerth E, Rigby M, editors. Evidence-Based Health Informatics. Promoting Safety and Efficiency through Scientific Methods and Ethical Policy. Amsterdam: IOS; 2016.
[130] Abbott PA, Foster J, de Marin HF, Dykes PC. Complexity and the Science of Implementation in Health IT – Knowledge Gaps and Future Visions. Int J Med Inform. 2014;83:e12-22.
[131] Bakker AR. Health Care and ICT, Partnership is a Must. Int J Med Inform. 2002;66:51-7.
[132] Berg M. Patients and Professionals in the Information Society: What Might Keep Us Awake in 2013. Int J Med Inform. 2002;66:31-7.
[133] Fieschi M. Information Technology is Changing the Way Society Sees Health Care Delivery. Int J Med Inform. 2002;66:85-93.
[134] Gell G. Safe, Controllable Technology? Int J Med Inform. 2002;66:69-73.
[135] Grimson J, Grimson W. Health Care in the Information Society: Evolution or Revolution? Int J Med Inform. 2002;66:25-9.
[136] Hasman A. Medical informatics: Quo Vadis? Int J Med Inform. 2002;66:113-20.
[137] Möhr JR. On Fortune Telling for Health Informatics. Int J Med Inform. 2002;66:95-106.
[138] Silva JS, Ball MJ. Prognosis for Year 2013. Int J Med Inform. 2002;66:45-9.
[139] Safran C. Health Care in the Information Society. Int J Med Inform. 2002;66:23-4.
[140] Stefanelli M. The Role of Methodologies to Improve Efficiency and Effectiveness of Care Delivery Processes for the Year 2013. Int J Med Inform. 2002;66:39-44.
[141] Takeda H, Endoh H. Commentary on 'Health Care in the Information Society. A Prognosis for the Year 2013'. Int J Med Inform. 2002;66:107-11.
[142] van der Lei J. Information and Communication Technology in Health Care: Do We Need Feedback? Int J Med Inform. 2002;66:75-83.
[143] Zvárová J, Pribík V. Information Society in Czech Healthcare 'Starting Point' to Prognosis for the Year 2013. Int J Med Inform. 2002; 6:59-68.
[144] Haux R, Ammenwerth E, Knaup P. Reflections on 'Health Care in the Information Society – a Prognosis for the Year 2013'. J Med Syst. 2014;38:72.
[145] Knaup P, Ammenwerth E, Dujat C, Grant A, Hasman A, Hein A, Hochlehnert A, Kulikowski C, Mantas J, Maojo V, Marschollek M, Moura L, Plischke M, Röhrig R, Stausberg J, Takabayashi K, Uckert F, Winter A, Wolf KH, Haux R. Assessing the Prognoses on Health care in the Information Society 2013 – Thirteen Years After. J Med Syst. 2014;38:73.
[146] Stausberg J. Citation Analysis of the Prognosis of Haux et al. for the Year 2013. J Med Syst. 2014;38:71.
[147] Ückert F, Ammenwerth E, Dujat C, Grant A, Haux R, Hein A, Hochlehnert A, Knaup-Gregori P, Kulikowski C, Mantas J, Maojo V, Marschollek M, Moura L, Plischke M, Röhrig R, Stausberg J, Takabayashi K, Winter A, Wolf KH, Hasman A. Past and Next 10 Years of Medical Informatics. J Med Syst. 2014;38:74.

[148] Vitruvius. Ten Books on Architecture. The books appeared about 30-20 B.C.; English Translation e.g. in Rowland ID, Howe, TN, editors. New York: Cambridge University Press; 1999.
[149] DeepL GmbH, www.deepl.com. Last access: August 3, 2022.