

Recent Advances in Healthcare Software

Toward Context-Aware and Smart Solutions

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INFORMATION AND communication technology (ICT) has opened the door to fundamental transformations in healthcare. Since Gunther Eysenbach defined *electronic health* (e-health) in 2001 as “the intersection of medical informatics, public health and business,”¹ the adoption of technology has reshaped healthcare. Mobile devices, such as mobile phones and tablets, have gained relevance in this domain because they let medical personnel put in place treatments and monitoring strategies for both inpatients and outpatients.

These developments gave birth to *mobile health* (m-health), which was defined by Robert Istepanian and his colleagues.² More recently, with the spectacular growth of the Internet of Things (IoT) and related technologies, the focus of interest has been broadening from mobile technologies to include context-aware and smart technologies. Such technologies can sense, explore, understand, and use the context of patients. This in turn has ushered in *smart health* (s-health)—the “provision of health services by using context-aware network and sensing infrastructures.”³

All these changes have been driven by promises of improved quality, reduced costs, and the increased capacity to carry out medical research. Charles Friedman’s “fundamental theorem” of biomedical informatics postulates that a person operating in partnership with a computer-based information source performs better than the same person operating alone.⁴ However, experience has shown that some major investments in healthcare ICT don’t yield the expected benefits and can even have adverse impacts. Indeed, even the installation of a software system by the same vendor in two

different healthcare environments might lead to drastically different outcomes, in which one installation is considered a success and the other is plagued with problems. This raises the question of why some health software installations don’t meet expectations but others do. Here, we explore this question along the three corollaries of Friedman’s theorem.

From Software Systems to People Systems

Friedman’s first corollary states, “Informatics is more about people than technology.”⁴ Healthcare is already a “smart” industry. Engineering software for smart healthcare has many possible interpretations but must not be misunderstood as merely a call to build software that attempts to shift decision making from people to computers. Rather, the goal is to build software that enhances and facilitates people’s ability to interact in smart-healthcare processes in increasingly complex and heterogeneous environments.

Software engineers have to analyze people systems and design software that supports and enhances their operations in changing environments. To some degree, this turns the traditional notions of software engineering on their head. That is, the emphasis switches from analyzing use cases in which users might interact with a software system to analyzing *support cases* in which software functions might support people in certain context-dependent aspects of their interaction with other actors in the healthcare (people) system.

Traditional software engineering has focused primarily on machinery. People appear at the machine’s periphery—outside the box. However, their interactions are modeled

as a function of the machine. This works well as long as the overall system functions are regular and well understood by the software engineer. This isn’t always the case in healthcare, which is a complex, knowledge-intensive field full of context-dependent irregularities and processes. Attempts to build software systems that act as central entities to enact and control such processes will likely fail. Healthcare systems are successful only if they seamlessly support medical professionals’ work and enable the integration of patients in all processes.

Companies such as Philips cooperate with users to realize this goal. For instance, triage is sped up by complex image-processing systems that feed to decision support systems that connect to several data sources and people throughout the hospital and beyond. Also, minimally invasive techniques that combine several imaging modalities and very-low-dose x-rays with real-time feedback from robots and catheters can help monitor and speed up treatments. So, patients can be released earlier from hospitals, and their well-being improves. In addition, extensive logging connected to data analysis has led to greatly reduced maintenance costs, improved uptime and availability, and improved user interfaces.

From Data Systems to Information-Knowledge Systems

Friedman’s second corollary points out that software-based information resources must offer something that the person using them doesn’t already know. In other words, the software should provide information or knowledge—not just data. A recurring criticism of healthcare software (for example, electronic-medical-record

systems) is that users are often overwhelmed by the amount of data presented to them and find it a challenge to locate and filter the information they require.

So, the development of health-care information services proves challenging because it not only requires a sound understanding of the information needs for a particular healthcare situation but also must consider users' background knowledge. Theoretical models developed in the domains of collaboration science and agent-based systems, such as the concept of common ground between collaborating agents,⁵ offer a useful basis for developing such context-aware information systems. Other emerging innovations include rich anatomical models that accelerate analysis of patient images and other data, highlighting the most interesting elements and organs for diagnosis or treatment. Also, machine learning, data mining, and process mining are good examples of automated ways to transform raw data into information and knowledge.

A related challenge pertains to the interoperability of diverse health-care software and ICT systems. International standards such as HL7 (Health Level 7), SNOMED-CT (Systematized Nomenclature of Medicine—Clinical Terms), and DICOM (Digital Imaging and Communications in Medicine) have been developed and adopted for decades. However, interoperability problems still frequently occur, particularly with legacy systems, which might be mission-critical and difficult to replace. Such problems might cause usability challenges due to the extra work of having to reenter data or manually transfer it between systems.

Interoperability problems might also threaten patient safety. Critical

data might be lost or corrupted in translation, or the lack of interoperability between medical devices with alerting functions might result in alert fatigue. In addition, the integration of medical systems with other sources of contextual data makes the problem harder because the integration domains might be different. In the case of contextual data that accumulates at high speeds, the integration problem is even more apparent and presents additional challenges related to big data characteristics—namely, velocity, variety, and volume.

Validating the Intended Use

Friedman's third corollary reminds us that complex information technologies are often used in unintended ways and that these interactions' outcomes can't be predicted reliably. Still, the common practice has been to validate (and certify) health-care software with respect to its intended use, not its actual use in its deployment environment. In contrast, companies such as Philips apply agile processes to incorporate user expectations early during development. They also track the software's actual use for improvement actions and programs.^{6,7}

Validating the intended use continues to be important for the development of health-care software (in particular, for premarket quality assurance, certification, and licensing). However, we still need to devise processes and methods for continuous validation when health-care software is deployed in specific environments.

Current and Future Healthcare Solutions

Patients are becoming health-care customers. During their life, their

need for care might increase or decrease along the health continuum (see Figure 1). Normally, people live healthily, needing only low-level support to stay healthy. Health-care professionals might interact with them in prevention programs, which might lead to the increased involvement of those people at risk for serious health problems. When symptoms' severity increases, diagnosis and treatment might occur, which means intensive interaction between patients and health-care professionals. Finally, after treatment, especially of chronic diseases, after-care and home care keep patients involved at the level at which they can be warned when their condition worsens.

In all phases, health-care customers are more or less connected to health-care professionals. They're informed about health-care practices, and new products help them take responsibility for their health. However, a shortage of health-care professionals will occur if care continues to be delivered the way it is now. Fortunately, new solutions are addressing the involvement of health-care customers themselves, supporting medical practices and moving care outside the hospital. So, health-care products and services can no longer be single-point solutions. They must relate to and integrate with products addressing other parts of the health continuum.

Future products will need to provide decision support at many points on the health continuum. In emergency and monitoring cases, during diagnosis and treatment, real-time reactions are necessary to ensure timely care to reduce further damage to the patient. Such decision support must be provided intuitively, helping medical professionals and not

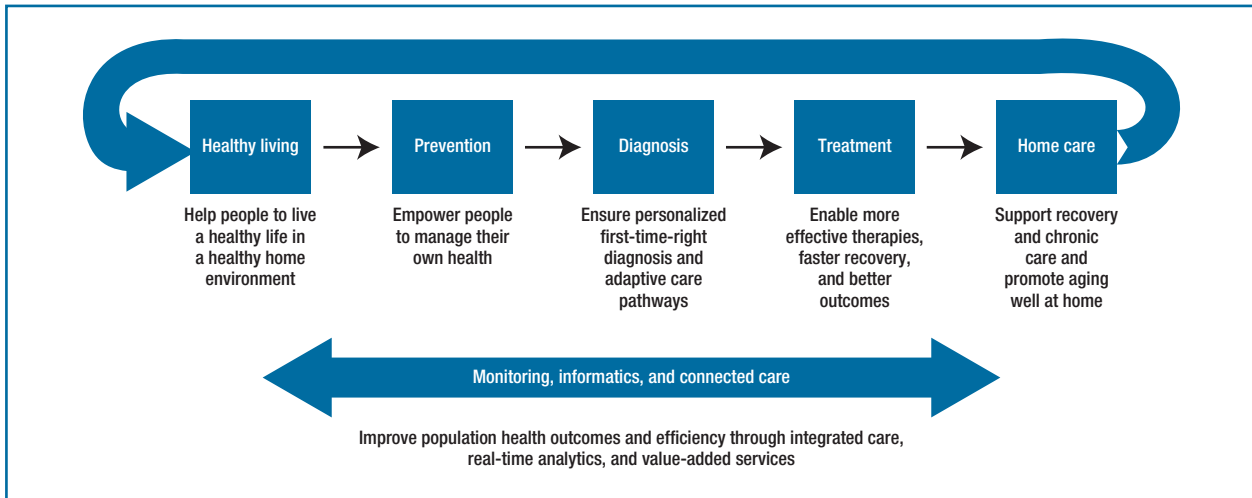


FIGURE 1. The health continuum covering the lifespan of healthcare customers. Healthcare products and services must relate to and integrate with products addressing other parts of this continuum.

distracting them. Part of the real-time decision support will be directed toward actuators, including complex robots. Decision support will be based on a rich set of information including the patient, other patients, populations, their healthcare history, and the context. This requires IoT solutions to be reliable and to link professional dependable healthcare solutions with low-cost commodity equipment, whose results aren't always completely trustworthy.

Besides improving medical treatment and putting patients at the center of the treatment process, new healthcare solutions will focus on prevention. To this end, solutions that foster people's participation in healthy activities and their development of healthier habits will soon gain importance.

In This Issue

Integrating new context-aware and smart technologies and making them work flawlessly along with existing

systems are enormous challenges for the software community. This theme issue presents some of the most recent advances in and applications of software for context-aware and smart healthcare.

In "Healthy Routes in the Smart City: A Context-Aware Mobile Recommender," Fran Casino and his colleagues describe a system that employs real-time, contextual information from smart cities and user smartphones to recommend healthy routes.

In "In the Pursuit of *Hygge* Software," Henrique Vianna and his colleagues discuss two healthcare scenarios in which technology could support social conviviality. Their approach uses distributed technologies to ubiquitously provide treatment for noncommunicable diseases. They describe a middleware solution and two applications—an activity reminder and a health advisor.

Finally, in "Crowd-Based Ambient Assisted Living to Monitor the

Elderly's Health Outdoors," Ana Cristina Garcia and her colleagues present the SafeNeighborhood system. SafeNeighborhood combines data from multiple sensors and collective intelligence to create safer outdoor spaces for the elderly.

The healthcare industry is constantly evolving and adapting to a changing and demanding environment. Thanks to the adoption of technology, our understanding of healthcare provision is transforming at an unprecedented pace. But paradigms such as e-health, m-health, and s-health are possible only if the right software solutions are put in place to guarantee security, dependability, reliability, privacy, and efficiency.

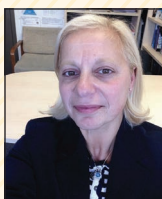
The three context-aware applications described in this issue provide a succinct view of the state of smart healthcare. We hope they also give you a glimpse of the future. ☞



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