Understanding Requirements for Computer-Aided Healthcare Workflows: Experiences and Challenges

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ABSTRACT

Medical informatics and software engineering researchers have studied how to use software technologies to define, analyze, automate, and provide decision support for healthcare workflows. We, as the requirement engineering and prototyping group of the Siemens R&D center, have been involved in the research and development of healthcare workflows. During interactions with the workflow users and developers, we found significant confusion about the terminologies and the purposes of supporting different healthcare workflows. Thus, we are motivated to classify computer-aided healthcare workflows, including their approaches, goals, and major characteristics. This paper also discusses workflow application issues and software challenges based upon our experiences and research.

Categories and Subject Descriptors

H.4.1 **[Information Systems]** Office Automation - *Workflow Management*

General Terms

Design, Human Factor.

Keywords:

Healthcare Workflows, Requirement Engineering.

1. MOTIVATIONS

Software and medical informatics professionals have developed software systems that facilitate healthcare workflows (also referred to as "medical guidelines", "procedures", "protocols", or "processes" in the literature), often through integrations of medical devices and healthcare information systems (HIS). In this paper, we refer to such systems as **Computer-Aided Healthcare Workflows**.

We, of the requirements engineering and prototyping group of the Siemens R&D center, have been extensively involved in healthcare workflow research and development in the past few years. Our involvement includes development of workflow-oriented healthcare financial systems [17], clinical systems (e.g., patient monitoring), and healthcare workflow improvement methods. We have investigated improvements for the usability and efficiency of medical devices. We have received training on commercial workflow products and their application to the healthcare domain. In addition to our industrial experience, we collaborated with university researchers on using software process and verification technologies to improve the safety of medical workflows [3].

During these activities, we interacted with many medical professionals (physicians, nurses, medical device users, and hospital financial administrators), HIS developers (medical software product managers, requirement engineers, and software developers), workflow product trainers, healthcare workflow improvement consultants, and NIH (National Institutes of Health, USA) workflow research awardees. During these interactions, we found that all the parties easily agreed that improving healthcare workflows is very important for improving healthcare quality and efficiency. However, ***the semantics behind the terminologies as they are intended by the different parties are rarely the same*** (e.g., what do you actually mean by "workflows"). It is becoming obvious that different parties often focus on different kinds/aspects of healthcare workflows, and, because of the different characteristics of those workflows, have different goals and thus take different approaches. We also noted that, although the research on medical workflow is quite active, ***the successes (at least judged based upon the financial benefits from commercial products) seem to be quite limited so far.*** Those two reasons motivate us to carry out this research that *aims to concisely classify computer-aided healthcare workflow approaches and goals, issues and challenges, and to analyze why the medical workflow products have not met expectations*. Since we did not find any prior publication addressing these items aimed at software researchers, we believe that our work would help introduce healthcare workflow to the software engineering research community. The paper is based upon our experiences gained through our engagements with medical staff and applications, and our survey of published literature.

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2. PRELIMINARY RESULTS

2.1 Healthcare Workflow Classifications

From the healthcare application perspective, we classify computer-aided healthcare workflows in the following table. Healthcare workflow research and development activities can be classified into two major areas:

- **Workflow Development**: To define (semi)-formalized, validated medical workflows that can be shared among the healthcare providers: This includes the following topics: **1)** *Authoring*: Representation formalisms (e.g., Flow-chart, Petri-Net, Planning tools, State-transition, rule-based, editing tools [22][12][13][11]). **2)** *Dissemination*: Website sponsored by government agencies (e.g., medical guideline clearing house). **3)** *Optimization*: Simulation, observations, data collections, and better resource allocation [16]. **4)** *Validation and verification*: Workflow syntax and completeness checking [13][11][12][3].
- **Workflow Execution**: To facilitate the practice of the workflows: A healthcare workflow management system (as a kind of computer-aided healthcare workflow) is software that provides workflow definition and interpretation mechanisms (i.e., workflow engine) to support the workflow executions. The workflow interpretation may invoke other software applications and guide human participation according to the workflow definition [21]. These systems can be summarized as: **1)** *UI guidance* (e.g., for patient assessment software): It is likely a single-user session and focuses on using advanced UI techniques. **2)** *Medical workflow monitoring and critique* [15]: Such a system analyzes the decisions of physicians against the evidence-based procedures to provide critique. **3)** *Providing useful reminders/alerts:* Most of the computer-aided healthcare workflows are implemented to provide medical staff reminders and alerts since most healthcare work requires staff participation and confirmation. **4)** *Healthcare quality and financial review (e.g., batch mode/data mining)*: These systems can analyze the workflow logs to identify more profitable financial alternatives. **5)** *Clinical decision support:* Provide detailed guidelines, possibly working with a knowledge base and often very specialized for certain diseases [20][9], to provide advice to the physicians.

Such software systems have been developed with varying degrees of success. For example, there are a number of products that use UI guidance to support patient assessment and financial workflows. Siemens has products that analyze claim coding to reduce coding errors, hence improving reimbursements to a healthcare organization. However, overall success seems still limited. For example, it is difficult to have a healthcare organization deploy these products easily since they often need extensive customization specific to the operating needs of that organization. The high cost of extensive customization is a major obstacle to wide use the workflow systems.

2.2 Application Challenges

This section discusses the challenges from the healthcare workflow application point of view, which might not be directly related to software development (e.g., the legal issues), but motivates software research. Those issues might exist for developing other software as well. However, they are essential for the wide use of computer aided healthcare workflow systems.

Data Aspect: 1) Different healthcare providers and their HIS/knowledge bases often use different terminologies and data value scale/representations [18]. This makes integration and deployment of workflow systems difficult. **2)** How to collect accurate, yet sufficiently large volumes of data for workflow

Healthcare Workflows	***Approach***	***Goals***	***Examples***	***Workflow Properties***
Administrative: *For managing patients and healthcare organization.*	• *Simulation,* • *Automation,* • *Integration.*	• *High administrative efficiency* • *Better tool support*	• *Check-in/Out, Discharge,* • *Bed assignment,* • *Quick-check-in,* • *Newborn paper work.*	*Single user or distributed across organizations. In general, it is quite mechanical and routine.*
Financial: *For managing the revenue of healthcare organizations.*	• *Automation/ Integration* • *Service quality Measurement* • *Profitable alternative*	• *Higher profit* • *Reducing financial errors* • *Speed up reimbursements*	• *Insurance follow-up* • *Better claim coding*	*Contract complexity. Quick response to changes in Medicare and new medical admin organizations.*
Clinical operational: *For executing the tasks for diagnosis and treatment [20].*	• *Integration* • *Simulation* • *Automation* • *Data collection* • *Standardization*	• *Better outcome/quality* • *Patient safety,* • *Efficiency,* • *Dissemination* • *Training*	• *Order/Administer medications* • *Patient monitoring* • *Collaborative, tele-medicine*	*Exposes software vendor to liability.* *In general, it is quite mechanical and routine.*
Clinical decisional: *For patient assessment, disease diagnosis, and treatment plan development.*	• *Survey of the guideline use* • *Patient/disease-specific workflow* • *Provide advice.*	• *Better outcome* • *Clinical trials* • *Ease clinical operational*	• *Cough,* • *Headache,* • *Chest pain* • *Abdominal pain*	*Requires human intelligence and medical knowledge. Computerizing them will expose software vendors to liability.*
Clinical therapeutic: *Needs to have the functions of both clinical operational and clinical decisional.*	• *Planning capabilities* • *Standardization,* • *Patient/disease-specific*	• *Care outcome* • *Efficiency of devices* • *Service quality*	• *Cancer treatment* • *Diabetes Mellitus* • *Physical therapy[5]* • *Disease management* • *Longitudinal studies*	*Require staff team work.* *Include both long and short duration processes.*
Laboratory: *For acquiring data that supports the diagnosis*	• *Integration,* • *Simulation,* • *Data collection*	• *Efficiency of the lab and devices* • *Service quality*	• *Sample collection* • *Image analysis*	*Mechanical* *Some require skills and reasoning*

analysis and validation, without interfering with or unduly burdening the workflow [10][8][12]? We have seen that while analyzing current practice (which was believed to be inefficient) is agreed to be useful, no one is willing to collect the data because of the workload. **3)** Clinical data collection/analysis needs a long time to validate certain workflows and check on the effectiveness of their computer support (e.g., long-term care data collection for chronic diseases).

Integration: 1) How different kinds of workflows (e.g., administrative, clinical treatment) can be integrated, although supported by different software applications [7][23]? How to plug external medical guidelines easily into hospital workflows [18]? **2)** How to integrate both event forecasting (e.g., a patient will come to ICU in 30 minutes), and data propagation (e.g., providing all relevant, timely data for the new patient)? **3)** How to test feasibility or ensure reliable execution of the integration of multiple inter-related workflows without causing interference?

Legal/regulatory: 1) Does a (computer-aided) clinical workflow need to be approved by FDA? **2)** Is the workflow vendor responsible for workflow definition incompleteness or for errors in executing the deployed workflow support? **3)** Who would own the intellectual property on the computerized workflows if their manual versions are results of many medical research efforts?

Usability: **1)** Computer-aided workflows need to be evaluated in a real healthcare setting to ensure their efficiency and usability [6] [23] while not disturbing the workflow itself. **2)** Avoid overloading the tasks for a staff. If a workflow brings 50 alerts a day, it will become too overwhelming to respond [4]. It should provide guidance for the priority of the tasks (e.g., to address the safety critical nature of the clinical workflows) and support easy switching among those tasks. **3)** How to design the appropriate interactions among usability and security features in a workflow system so that the hindering from each other can be avoided.

Multiple Views: Different medical roles (e.g., nurse, doctor) often have different understandings of the same workflow. The view of each role is focused only on one aspect and their views may conflict [1] since their concerns can be different. Also, a single role may require different views, depending on context and activity (e.g. a nurse in ICU performs many different activities: patient assessment, dispensing medication, and fluid treatment, which would be better facilitated with different views.)

Adaptability: **1)** Medical guidelines often need to adapt to the healthcare environments (e.g., availability of certain medicines and equipment) [1]. **2)** Workflows need to be adaptable to different healthcare providers. Physicians (even of the same specialty) may differ in their workflows because of their different personal experiences or training, and thus they require the workflow system to support doing things their way.

Maintenance: **1)** Implementations of workflows, particularly clinical guidelines, need to be upgraded with advances of medical guidelines. **2)** Administration workflows need to respond to legislative and regulatory changes (e.g. add privacy notification to check-in process, change in Medicare allowances)

2.3 Software Challenges

This section summarizes the challenges in applying the software technologies to support the healthcare workflows:

- **Guideline validation**: How to check the completeness, execution feasibility/reliability, and syntax of the workflows? Software technology can easily identify syntax errors. However, it is limited in identifying semantics-related errors (e.g., insufficient safety checks) without additional information.
- **Model mapping**: How to integrate medical guidelines with other medical information systems (e.g., patient monitoring, radiology information systems, electronic patient records)?
- **Formalizing the medical guidelines**: How to formalize the values in the guidelines to allow a computer to analyze or execute guidelines?
- **Support a variety of control/execution flows**: Need to be able to support flexibility in executing workflows, especially for exception conditions, which might need special recovery and roll-back mechanisms.
- **Support adaptability**: How to make the workflow execution adaptable to different medical purposes (screening, disease management, surveillance); different healthcare roles; and different kinds of healthcare organizations (e.g., clinic vs. hospitals). A highly adaptable system could be overly complex and have too much overhead (e.g., performance). Achieving a good balance is the challenge.
- **Support capturing real-time information**: Workflow support should be provided with the most recent medical and patient information since the medical environment and the patient information change frequently. Software techniques could be used to identify promptly and adjust accordingly the guidance that is based upon out-of-date information, all without undue overhead to the system.

2.4 Successes and Failures

Based upon our experience, we found that practically-used medical workflow management systems are limited to these areas: **1)** Single user, requiring non-intelligent workflows, e.g., healthcare administrative workflows (e.g., check-in patients) [14]. **2)** Single user, medical guideline automation for certain diseases [18][19][20][21]. **3)** Analyzing the workflow-related financial data.

Based upon our knowledge, it seems that medical workflow management systems are much less successful implementing distributed workflows that are multi-user in nature and may cross organizations; we have identified three possible reasons for this:

Mismatched underlying models (computer-aided workflow model vs. medical staffs' working model): Workflow representations are generally based on flow-charts or state-transition diagrams whose successful executions depend on the full availability of the required data. However, clinicians often have to act on incomplete data, either because of the time pressure to finish a certain procedure, or because of lack of availability of certain medical specialists.

Data querying has been used to generate reminders and alerts: Workflows are often incrementally implemented by hard-wiring the control flows in the software application code or some event handling mechanisms. The queries on the data state can help generate alerts or work-list items. This is often sufficient for transitioning between loosely coupled workflow steps or to spawn new workflows. In sum, the workflows were often implemented with data-state or event-triggering paradigms [17], rather than explicitly defined procedural/state-transition paradigms.

Medical workflow's execution must be maintained to be consistent with real world medical events regardless of what reminders or alerts indicate. One example is that, if a patient recovers quicker than expected, and is discharged on doctors' orders, then all previously requested workflow tasks based upon an earlier diagnosis and plan would no longer need to be marked as urgent and should now be marked unneeded and removed from reminders, alerts or work-lists.

3. IMPACT AND FUTURE WORK

The advances of technologies, such as wireless networking and sensor technologies, will make it more feasible to apply software technologies to healthcare workflows. Thus, ***a comprehensive set of software-related requirements for computer-aided healthcare workflows*** would be needed to introduce software professionals into this application area. The software analysis technologies might be applied to analyze the correctness of the healthcare workflows; the data extraction technologies will provide the required data for the clinical diagnosis. Data mining technologies will help acquire knowledge about the workflows and their executions. The software integration technologies will automate the clinical operational and laboratory workflows.

Additionally, using a framework to classify healthcare workflow requirements (possibly functional and non-functional) will ease the communications between healthcare staff and software professionals. Without such classification, as indicated by our prior experience, the requirements would have to be developed from scratch and thus take more effort to develop. Our work as presented here aims at those two goals and should have significant impact on helping software professionals in developing computer-aided healthcare workflows.

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