A Requirement Engineering Framework for Electronic Data Sharing of Health Care Data between Organizations

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Abstract. Health care is increasingly provided to citizens by a network of collaboration that includes multiple providers and locations. Typically, that collaboration is on an ad-hoc basis via phone calls, faxes, and paper based documentation. Internet and wireless technologies provide an opportunity to improve this situation via electronic data sharing. These new technologies make possible new ways of working and collaboration but it can be difficult for health care organizations to understand how to use the new technologies while still ensuring that their policies and objectives are being met. It is also important to have a systematic approach to validate that e-health processes deliver the performance improvements that are expected. Using a case study of a palliative care patient receiving home care from a team of collaborating health organizations, we introduce a framework based on requirements engineering. Key concerns and objectives are identified and modeled (privacy, security, quality of care, and timeliness of service). And, then, proposed business processes which use new technologies are modeled in terms of these concerns and objectives to assess their impact and ensure that electronic data sharing is well regulated.

Keywords: Requirements Engineering, User Requirements Notation, health care, data sharing, privacy, quality of care.

1 Introduction

Currently, in spite of available information technology, health care providers still collect and share patient's information in an ad-hoc basis, by paper-based forms, faxes and phone. Many of the reasons for this are related to privacy and security concerns, but there is also a resistance to technology and uncertainty that investment in technology will actually result in cost-effective improvements to healthcare. The potential convenience of electronic healthcare data sharing is often overlooked. In the group of health care providers, nurses are the major persons who are responsible for collecting patient's data and entering into the electronic system. One study of information technology for palliative care showed that nurses were required to do "double entry" into electronic systems and paper charts for various reasons including

medical legal issues [1]. Such duplicate work creates the opportunity for medical errors and makes care providers (physicians, nurses etc.) hesitate to accept electronic records. Much of this duplicate work is motivated by studies showing electronic healthcare delivery to be problematic [2] which raises questions about the extent it can enhance care delivery. It is important in any switch to new technology to be able to monitor and document that quality of care is being maintained.

This paper describes a requirements management framework for electronic health care data sharing that will help healthcare providers model and evaluate new and existing healthcare processes in order to validate alignment with quality of care goals and policies as well as document compliance. Based on a case study of palliative care, we develop the framework using an ITU standard notation: User Requirements Notation (URN). In the framework, we show how to model the improvements obtained by electronic data sharing, but also address concerns like privacy, security and quality of care.

2 Background

It is expected that the number of individuals suffering from and living with chronic illness such as diabetes, heart disease and cancer will increase significantly in the forthcoming years. Providing care for chronic illness requires a movement from care delivery by a single provider and location to care delivery by multiple providers across multiple settings. Team based care delivery is challenging for the fundamental reason that our healthcare system is not designed to deliver such care. The electronic health record (EHR) provides the means for electronic data collection but there is still a need to support the underlying care delivery processes that take place. Information access and sharing must be timely, accurate and secure or quality of care delivery can suffer. Poor information sharing in team based care delivery can be a source of medical errors [3]. Thus if we are to support team base care delivery we must facilitate data sharing but also support and monitor the underlying business processes that use the data. Stead et al. [4] point to the need for an informatics infrastructure that details how to link information and business process needs to enable us to design technological solutions that provide care when and where needed, supporting processes that avoid error, and provide quality care while reducing administrative costs. The framework presented in this paper provides the basis for such an informatics infrastructure to support team based care delivery.

Our case study is taken from a health care jurisdiction in Ontario, Canada, where the applicable privacy legislation is the Personal Health Information Privacy Act [5]. PHIPA specifies the legal responsibilities of health information custodians in terms of how they are to handle personal health information. PHIPA is legislation specific to healthcare in the Canadian province of Ontario within the framework of the federal Personal Information Protection and Electronic Documents (PIPEDA) act [6]. PIPEDA has been recognized by the European Commission as being compliant with the European Union's Data Protection [7]. In the United States, there is similar legislation for healthcare in the form of the Health Insurance Portability and Accountability Act (HIPAA) [8].

Researchers have worked on applying requirement engineering concepts and tools to provide methodologies to ensure compliance and traceability between organizational goals and the business process that are supposed to achieve those goals. [9] describes how to apply one of the main goal-oriented requirements engineering methodologies (KAOS) to model regulations. They explain how to transform regulation documents into goal, objects and threat models incrementally and how to maintain a level of traceability from the source document to those models. [10] introduced the Requirement-based Access Control Analysis and Policy Specification (ReCAPS) method to integrate access control analysis, improve software quality and develop policy and requirements-compliant systems. This method emphasizes compliance between different policy levels, requirements and system designs. In [11], i*, a modeling language similar to Goal-oriented Requirement Language (GRL), was used to design information systems within a social context. In [12], User Requirements Notation (URN) was used as a basis for a framework to track legal compliance between health care processes and privacy legislation.

We will use URN as a basis for our framework as well. URN was designed for modeling and analyzing requirements in the form of goals and scenarios prior to design [13]. It can be used to model most kinds of reactive and distributed systems, as well as business processes [14]. URN combines two complementary notations: the Goal-oriented Requirement Language (GRL) and Use Case Maps (UCM) which are used for modeling goals and processes respectively. Figure 1 and figure 2 show a brief summary of these two notations.

URN is a draft ITU-T standard [13] that combines goals and scenarios in order to help capture, model and analyze user requirements at the early stages of design. It can be applied to describe most kinds of reactive and distributed systems as well as business processes. URN is the only modeling language that can model goals and processes at the same time while providing traceability between them. URN integrates two notations, namely the Goal-oriented Requirement Language (GRL) and Use Case Maps (UCM). GRL is used to model, with AND/OR graphs, the relationships and strategies around how actors and tasks are organized to achieve goals and objectives. Figure 1 shows a subset of the main GRL elements. An example of a GRL diagram is shown in the figure 3.

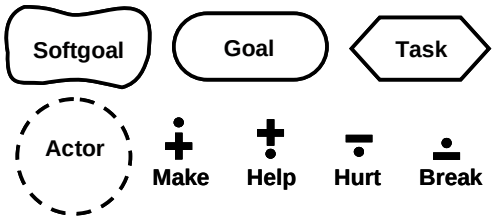

Figure 1: Subset of GRL notation

The UCM notation is used to model business processes and system behaviour in terms of related scenarios and use cases. Scenario paths connect start points (preconditions and triggering events), end points (post-conditions and resulting events), and responsibilities. Responsibilities indicate where actions, transformations,

or processing are required. They can be performed in sequence, concurrently (using AND-forks and AND-joins) or as alternatives (with guarded OR-fork and OR-join). Complex processes can be defined at any level of abstraction and be decomposed with stubs, which act as containers for sub-maps. The subset of the UCM notation used in this chapter is shown in Figure 2, and an example of a UCM diagram is shown in Figure 4.

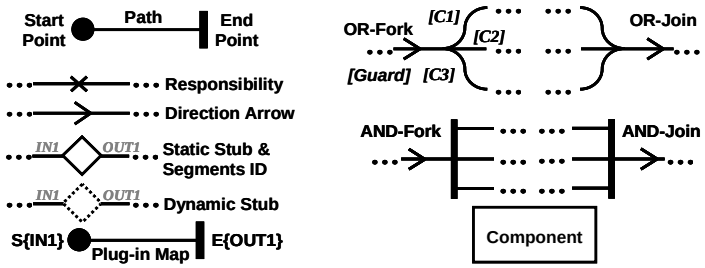

Figure 2: Subset of UCM notation

The UCM process view specifies the responsibilities to be performed (the *what* aspects) by *whom*, *when*, and *where*. The GRL goal view provides a rationale (*why*) for the business process elements, together with an explanation of why alternative solutions were chosen or not. More details on URN are provided in [15] [13]. A detailed analysis of the capabilities of URN in comparison with other well-known business process modeling languages is given in [16].

URN models are built using the Eclipse-based jUCMNav tool [17]. jUCMNav supports an extensible meta-model for extending the set of diagrams, model elements and links the tool can work with as well as a data exchange layer for integration with other tools and systems. [18]

3 Palliative Care Scenario

Palliative care is care provided to patients at end of life when curative therapies are not an option. Palliative care is an ideal domain to study team based care delivery across multiple settings as that is an integral part of palliative care delivery. [19]

In this scenario, the health authority responsible for palliative care in a region of Ontario, Canada proposes to build a palliative care information system (PAL-IS). The intent is that PAL-IS will facilitate sharing of patient information among healthcare providers such as doctors, nurses and case managers as well as support the underlying processes of care delivery such as decision making and treatment dissemination. This goal for PAL-IS is consistent with the overall goal of palliative care, which is to improve the life quality for patients who have life-threatening illness and their families.

Improving patients' access to healthcare services and delivery of healthcare services from providers are also important goals for PAL-IS. Technically, PAL-IS should ensure communicate between patients and healthcare providers is efficient and

timely. PAL-IS should support and ensure patients can get timely access to their nurses or physicians whether in hospital, home or other care centers and healthcare providers can respond to patients quickly based on their requests or needs. If care issues can be identified and managed efficiently then their hospital stays can be shortened or avoided.

The most important challenge is to establish a framework and process for ensuring that PAL-IS meets the needs of the region for palliative care. In such an information system, patients are being monitored remotely and their personal health information is being integrated among different organizations. Privacy and security concerns arise.

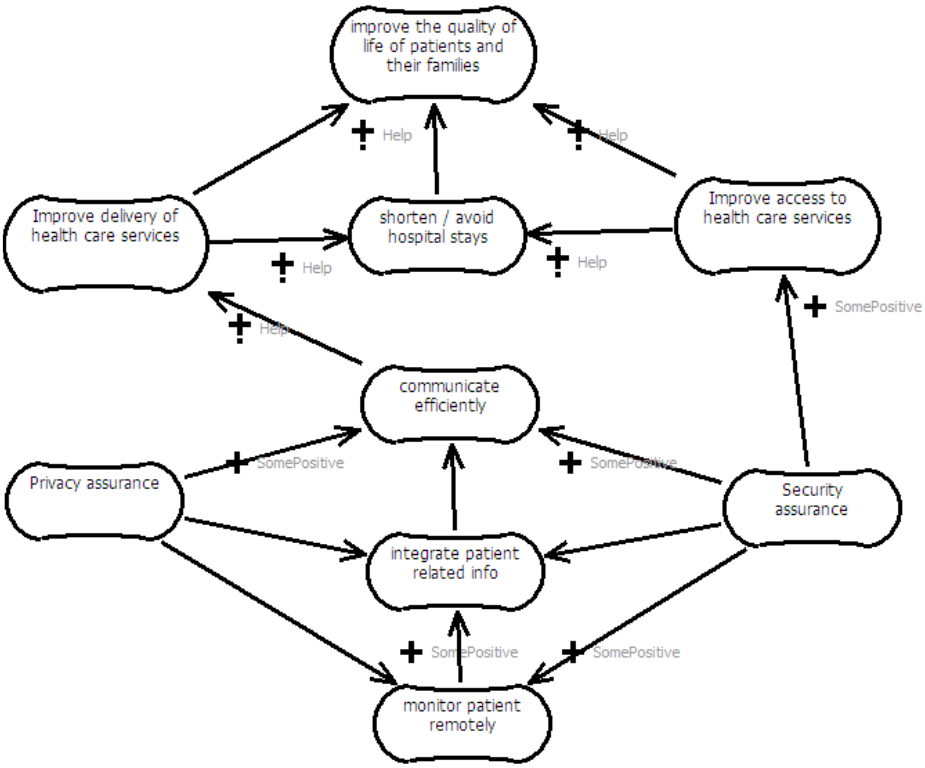

Figure 3: The goals of PAL-IS

The goal model for the health care organization and PAL-IS is described as a GRL model in figure 3. Improving the life quality of patients and their families is the top goal in the health care service, and monitoring patients remotely together with ensuring privacy and security at the same time is one of the basic objectives our system should meet.

The goals in Figure 3 are not completely independent; they affect or contribute to each other. Privacy and security concerns, as the most basic goals, should be fulfilled first. Actually, without privacy and security assurance, monitoring patients remotely,

integrating patient information and communication among organizations are not allowed to proceed, even if there is no technology at all.

With assurance of privacy and security, PAL-IS can provide timely access to palliative care services for patients or their families from home, and promote the services delivered to their home quickly, and finally reach the top goal of improving the quality of life of patients and their families.

In figure 4, we use a UCM diagram to document a key business process or scenario that PAL-IS must support for pain management. A cancer patient is on two medications for his pain. A homecare nurse and a physician are monitoring the patient's symptoms through PAL-IS. One of the patient's daily jobs is to send his pain score to the nurse through the system. There are four pain alerts with different priorities in the system, depending on the pain scores the patient sent. If the patient enters a low number for the pain score, the alert is set at a low priority. The number will be recorded and the nurse will simply continue monitoring. But if the patient enters a high number for the pain score indicating severe pain, the alert would be set as a high priority and the nurse would contact the physician for appropriate action such as getting an updated prescription. Once a new prescription is issued, the nurse will send it back to the patient. [20]

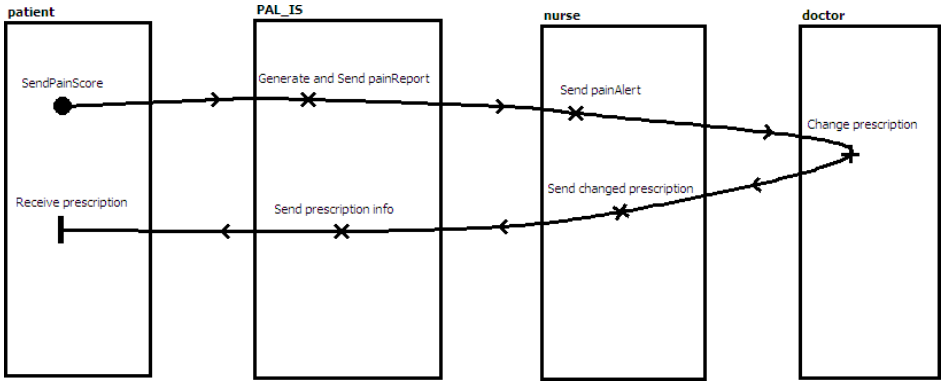

Figure 4: PainScore reporting and PainAlert generating processes in PAL-IS

For comparison, figure 5 shows the current process that must be followed without the PAL-IS system. The nurse records the patient's pain score manually and periodically and must visit the patient in person, or contact them over the phone. Based on the paper version records, the nurse is responsible for analyzing the pain scores, generating a pain score report and making a judgment if a pain alert is a low priority or a high one. The nurse is also the person to send the pain alert to the corresponding doctor, again by calling or faxing a paper-based document. If the doctor receives the pain alert document with a high priority, they will write a new prescription and send it back the nurse, who is going to send it to the waiting patient. All the steps are manual and time-consuming, especially for the nurse to analyze pain scores and generate a pain score report.

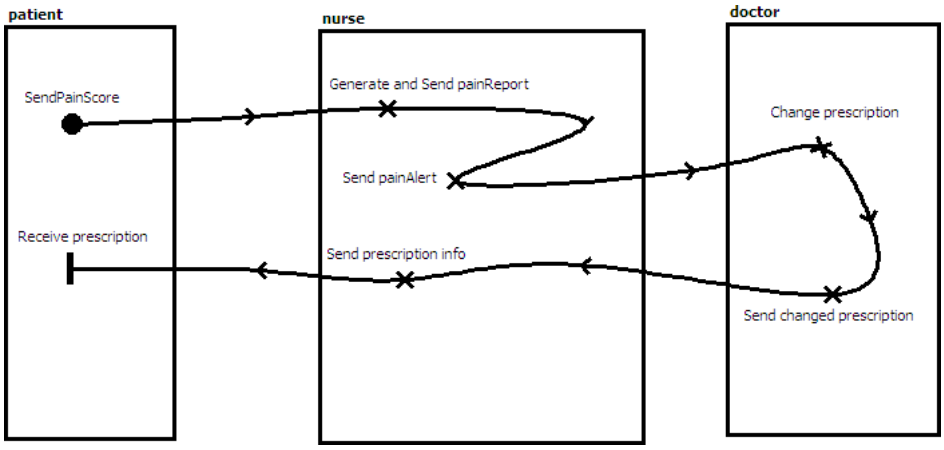

Figure 5: PainScore reporting and PainAlert generating processes without PAL-IS

In the above manual process, there are a few measurements to make sure the patient is properly taken care:

- The nurse should talk to the patient and take his/her pain score at least once every 4 hours.
- The nurse should analyze the patient's pain scores and update his/her pain score report at least once every 4 hours.
- Once a pain alert with a high priority is issued, the patient should receive his/her changed prescription within one hour.

Since all the steps are manual, the nurse, as the main responsible person in the document generating and exchanging process, is overloaded. Now, let us go back to figure 4, the painScore reporting and prescription changing process in the PAL-IS. With the help of an Information System, the nurse will not have to manually take records from the patient and generate the pain score report. The following are the steps in this process:

1. The patient will enter his/her pain score periodically into the system.
2. The information system will update the patient's pain score report automatically and give a pain alert number indicating a low or high priority. The pain score report and the pain alert are sent to the nurse's computer.
3. The nurse will process the pain alerts based on priorities, and send them electronically to corresponding doctors.
4. For a pain alert with high priority, the doctor will issue a new prescription and send back the nurse electronically.
5. The changed prescription is finally sent from the nurse to the patient through the information system.

From the above example, we see that the process sharing healthcare data through PAL-IS is completely electronic. Also, there are some measurements to improve care, which are different from those in the manual process:

- To use PAL-IS, all users need be identified for security purposes.
- The patient should enter a pain score at least once every 4 hours.

- If the information system did not receive the patient's two consecutive pain scores, a low priority alert would be raised and sent to the nurse. The nurse should contact the patient immediately by phone.
- If the patient entered a pain score greater than 7/10, a pain alert should be issued immediately from the information system to the nurse and then to the doctor. The patient should receive the changed prescription within one hour.

4 Framework

Figure 6 depicts the processes involved in the electronic data sharing of healthcare data between organizations, based on the PAL-IS case study. In this model, there is a central information system, through which organizations send and receive patients' data, to reach the objective of electronic healthcare data sharing.

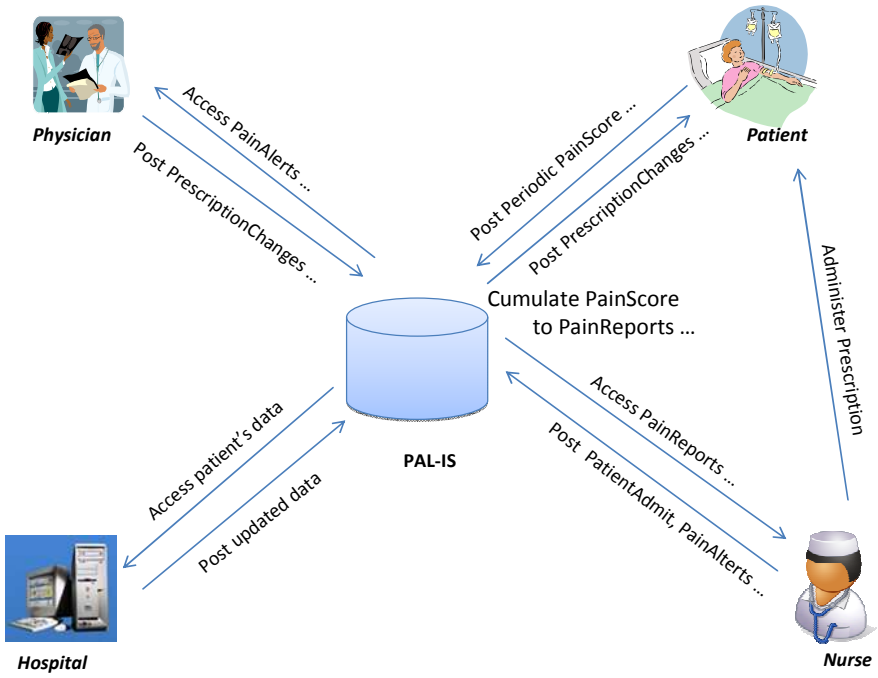

Figure 6: Model of Electronic Data Sharing between Organizations

In addition to enabling the electronic flow of information between patient, nurse and doctor, the information system is also able to collect and report statistics on how efficiently and effectively care is being provided. The GRL diagram can be amended to indicate tasks (linked to the appropriate UCM diagram for detailed analysis) which are critical to the goals of the organization. Associated with those tasks, can be

metrics which measure how effectively and efficiently care can be provided. This is depicted below in figure 7.

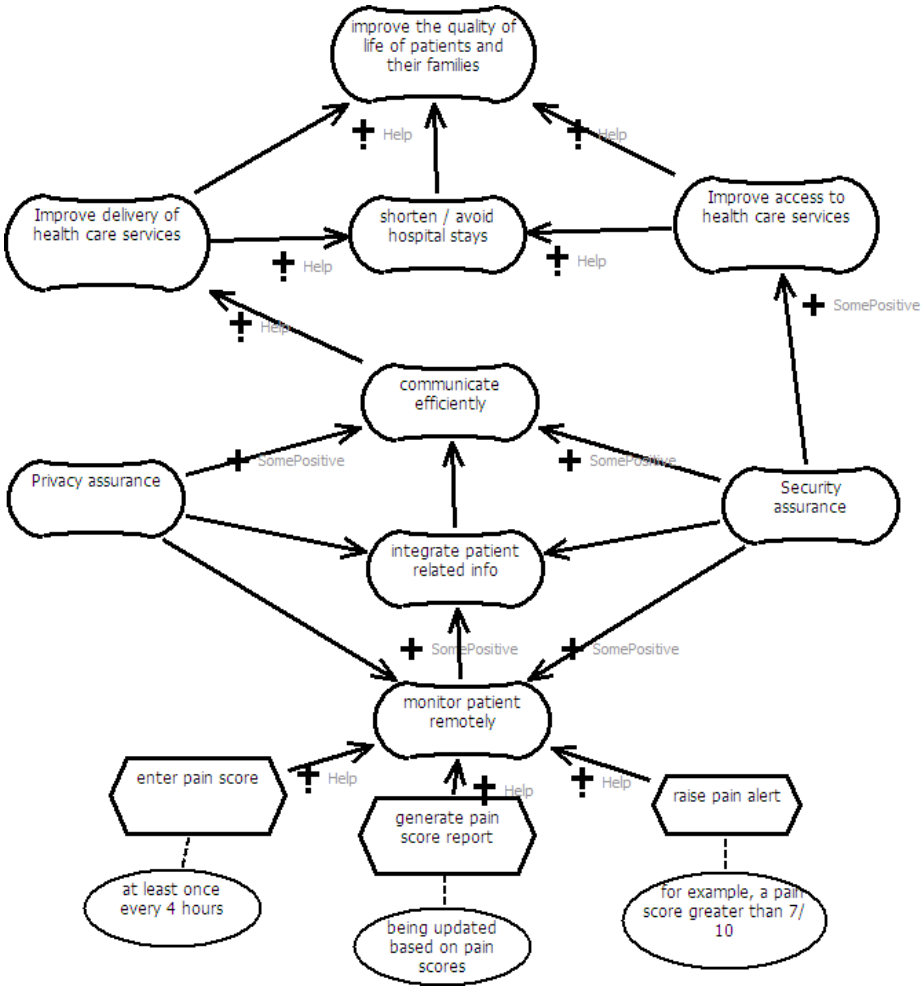

Figure 7: The GRL diagram with linked tasks

Figure 7 shows how the processes involved in PAL-IS affect the goals defined in figure 3. Here, we provide three processes as examples. A patient is supposed to enter a pain score at least once every 4 hours. A pain score report is created, based on the most recent pain scores from the patient, and sent to a nurse for review. If the patient failed to enter two consecutive pain scores or if a pain score greater than 7/10 was entered, the information system will raise a pain alert.

5 Conclusions

In evaluating our framework, we can see that in using URN, the healthcare provider is able to not only articulate their goals, but link them to the relevant business processes. In the case where the business processes are supported by an information system, they can further define and mandate additional data collection and reporting on metrics to monitor how effectively the organization goals are being achieved. In order to achieve this, though, the healthcare provider will need to invest in modeling explicitly both the goals the provider is trying to achieve and the processes that are enacted to realize them, as well as identifying appropriate metrics to measure progress, and ensure that the necessary data is collected.

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