Challenges in Designing Technology for Reducing the Need for Synchronous Communication in the Perioperative Environment

Leendert W. M. Wienhofen and Pieter J. Toussaint

Department of Computer and Information Science
Norwegian University of Science and Technology
Sem Sælands vei 7-9
NO-7491 Trondheim
Norway
leendert.wienhofen@idi.ntnu.no
pieter@idi.ntnu.no

Abstract: This paper describes health informatics as a field of research and some of the challenges that are faced when designing a complex event processing middleware gathering input from multiple legacy sources in a hospital environment. The goal of the system is to reduce the need for synchronous communication between medical stakeholders by creating a situational awareness and thereby cause fewer interruptions.

1 Introduction

This paper presents some health informatics specific challenges which pose interesting research questions for creating a software architecture for supporting medical staff in their daily work. The work presented in this paper is part of the COSTT project, which has as its main objectives:

- First objective: To enable flexible, 'Just-in-time' coordination of work in a highly collaborative and dynamic work environment
- Second objective: To achieve this by creating a shared work space that gives all the actors involved in the collaboration real-time insight into the work process, e.g. its progress and possible deviations from the expected course.
- Third objective: To derive this insight automatically from samples of data in brief.

The project is set in a hospital environment, more specifically, the perioperative domain (right before, during and right after surgery). In brief, in COSTT, we investigate how relevant digital events can be retrieved from the different sources available and presented to different actors as a meaningful visualization of the perioperative process, and as such creating situational awareness. This situational awareness should lead to a reduced need for synchronous communication. Prior to describing the architecture, we first give a definition of health informatics (HI) and four typical communication strategies.

2 Health Informatics Background

The MEDLINE definition of HI is as follows: "*The field of information science concerned with the analysis and dissemination of medical data through the application of computers to various aspects of health care and medicine*". This is a relatively broad description, though [HH+96] are a bit more specific: "*Medical informatics is the discipline concerned with the systematic processing of data, information and knowledge in medicine and health care. The aims of medical informatics are twofold: (i) to provide solutions for problems related to data, information and knowledge processing; and (ii) to study the general principles of processing data, information and knowledge in medicine and health care. The ultimate goal should always be to improve the quality of health care, and of research and education in medicine and the health sciences*.".

One can argue that point (i) is true for just about any domain within informatics, whereas (ii) focuses on the medical part. However, the authors are also pointing out that modelling is an important topic in HI, and emphasize that the abstraction needs to leave out the details while retaining only relevant information. So to actually provide a solution (ref (i)) in a multidisciplinary field as HI is a more challenging task that in a field which is less multidisciplinary.

Hasman also mentions systematic processing of data as a characteristic, as well as "*humans form part of the information systems*", which means the information systems are not useful without human interaction. One of the main findings of [Gr09] supporting this feature is: "*EPR*[1] *use will always require human input to re-contextualize knowledge*".

Coiera [Co03] loosely defines HI as "*health informatics is the logic of healthcare*", followed by a more formal "*health informatics is the study of information and communication systems in healthcare*", and continues:

"*HI is particularly focused on:*

Understanding the fundamental nature of these information and communication systems, and describing the principles which shape them

[1] EPR means Electronic Patient Record

Developing interventions which can improve upon existing information and communication systems

Developing methods and principles which allow such interventions to be designed

Evaluating the impact of these interventions on the way individuals or organisations work, or on the outcome of the work."

Through the three-loop model, Coiera visualises the systematic processing of data, modelling, abstraction, human in the loop, etc which have been pointed out above.

Coiera also points out the distinction between information systems and communication systems. Information systems are designed to manage activities, whereas communication systems include people, messages, mediating technologies and organisational structures. This distinction is less explicit in other definitions of HI, even though data and human in the loop are mentioned.

In HI, due to the non-deterministic nature, it is very hard (according to some impossible) to capture patterns and base knowledge on that. In cases where it not feasible to create a knowledge base, supporting the communication around the problem can still be very helpful in resolving the problem.

Information systems nowadays are becoming more and more integrated with communication systems, so it might be hard to see the difference in some systems. Though, from a systems design perspective, one should always keep in mind that there indeed is a distinction between the two, no matter how entangled the end-product might become. In addition, they should be designed in a problem-based approach and not a technology-based approach.

A wrongly designed and implemented system can lead to information that is falsely taken as true and can in the worst case lead to death of a patient.

2.1 Communication Possibilities

Health care work can be supported by technology in many ways, though it is through communication one can cooperate. Coeira [Co03] clearly describes the context of communication system use, spread over time and space. The four different possibilities (*1 same time, same place, 2 same time, different place, 3 different time, same place, 4 different time, different place*) all pose their benefits and drawbacks (see an abstraction below) and are based on the context of communication and can be supported by different technologies.

1. The most semantically rich form of communication is face-to-face, where both stakeholders are at the same place at the same time, being able to see each other and notice subtle changes in body language, intonation, etc.

2. Less rich is communication at the same time, but from different locations, also called synchronous communication. It is an interruptive way of communication, and certain features that form the total picture of communication are not transferred. Just as with modelling, a simplification of the real world means that features get lost. In a phone call, one can hear but not see each other, with a video conference, one can also see the peer, though for example due to latency and image quality, certain subtleties can get lost in the transfer.

3. Asynchronous communication is spread over time, but at the same place. As the stakeholders are not present at the same time, one needs to rely on message passing and conversations are a series of messages.

4. Finally we have store-and-forward systems for the different time and different place situations.

In the next section, we describe a system which can reduce the need for synchronous communication in the perioperative domain.

2 Event Processing Technology

The main characteristic of implementations of an event-based or event-driven architecture is that it has the ability to *detect* events and react *intelligently* to them. An *event* is a change in *state* that merits attention from systems [TYP+09]. In an event-driven architecture, we can identify 4 main concepts, Event producers, Event consumers, Messaging backbones and Event processors.

[TYP+09] Introduces an analogy, ”the central nervous system” in order to explain the characteristics of the architecture:

- Nerve cells fire signals to the brain
- The brain interprets the signals and reacts
- The reaction can be to gather more input in order to be able to interpret the signal
  - Use sight/optical nerve
  - Process input and compare to the mental data store
  - Conclude (and initiate new reactions)

As for the events that are generated, these can be divided into the following basic patterns[Lu01]: Simple events (e.g. machine is turned on/off), Event stream processing (e.g. location information) and Complex events (multiple events under multiple logical conditions such as a stock ticker). However, none of these patterns is able to deduce *why* an event has occurred, only *that* it has occurred.

3 Overcoming the Challenges

In the sections above, we have given a number of definitions of health informatics and given an overview of the different communication strategies. Summarised, the challenges that we need to address consist of: multidisciplinary, non-deterministic behaviour, human in the loop/humans form part of the information systems, implicit information, non-captured information, modelling, improving quality of healthcare, developing interventions which can improve upon existing information and communication systems. Also, rather than names, roles are being used. It does in general not matter who does the job, as long as the person is qualified. This presumes that direct addressing of individuals based on names is not an effective way to go.

All this indicates that healthcare is a complex domain both in terms of work procedures and communication between stakeholders, and that creating a supporting system needs to address these facets. In addition there is stringent legislation in place in order to ensure that medical/patient information is kept secure. Other than that, the domain also has very many legacy systems that are not built to cooperate with other systems. Event-based architectures can help overcome the latter problem, but if an application based on such an architecture is successful depends on more than technology alone.

As depicted in the objectives of the COSTT project mentioned in the introduction, we do not propose to build a system that makes decisions *for* people, but rather a system that *helps* stakeholders make to qualified decisions based on extra information which previously was not available in an asynchronous manner.

In the perioperative domain, interruptions in the form of (often) phone calls are part of daily life. Medical stakeholders are adjusted to coping with these interruptions, though studies show (e.g. [Al05]) that many of these interruptions would have been unnecessary if the initiating part would have been aware of the situation of the other stakeholder. Examples are that the question did not require an immediate answer, and asynchronous communication would have sufficed, or the question was about something that could have been known in advance based on situational awareness, for example “is the patient on his/her way to the operating theatre?”.

The perioperative process is a dynamic process in which unforeseen events require a constant and flexible adaptation of planned work. In order to properly conduct and coordinate their work, actors involved in this process must be continuously aware of the current state of affairs and deviations from the plans. Many information sources are currently in place to support the achievement of this awareness, e.g. conversations with colleagues, paper-based charts, the electronic patient record, the operation planning system and status indicators of equipment in use. The problem with these sources however, is that they are not easily accessible for all authorized and relevant actors and the events available through these sources provide a fragmented view on clinical reality.

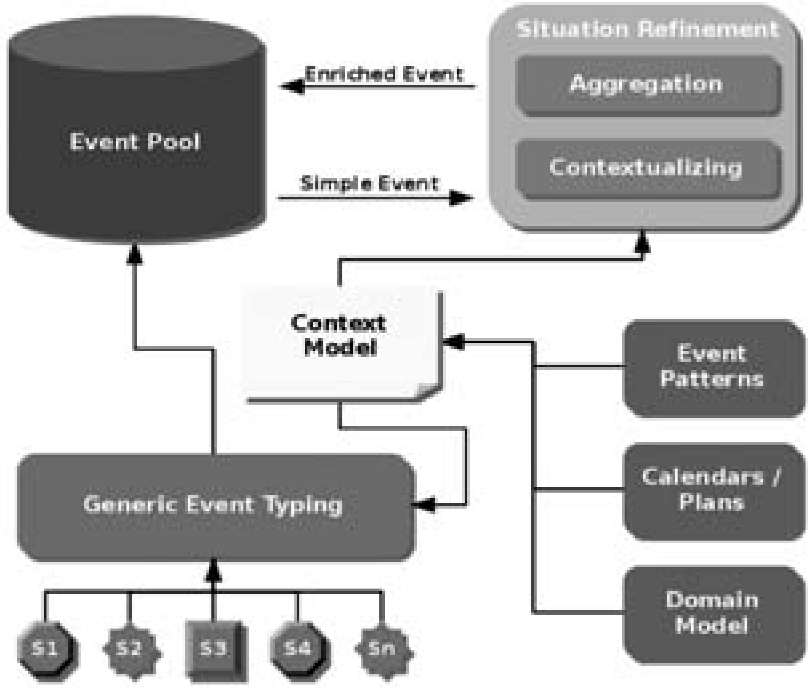

Figure 1: Draft Event Middleware

To overcome the fragmented view, one needs to combine information form multiple sources. The information is divided into real-time digital data stemming from sensors and a context model with among others patterns based on observations in the domain, access to calendar and planning systems, etc and the domain model tying all this together.

The challenge lies not only in the technical capabilities of combining multiple event sources into a meaningful set representing a real life event, but also in acquiring sufficient domain knowledge to understand the meaning of the atomic events and supporting systems in addition to typical patterns. As mentioned before, the non-deterministic nature of healthcare makes the domain very hard to model, as all kinds of deviations to a “typical” workflow can occur and are even considered normal.

In the COSTT project, different challenges are address by different researchers with relevant backgrounds. Focusing on but one of the challenges alone will not lead to a complete and usable system in the end. The focus of the first author lies in the situation refinement. In short, this is the logic behind the aggregation and contextualisation of atomic events into more semantically rich composite events that represent a “real life event”. The concept is described in [Wi09], [WT10] and shown in Figure 1.

3.1 The Notion of Quality

Inspired by the SQI (Signal Quality Index) of a Bis monitor, where the system not only views a bispectral index indicating the brain activity of the patient[2], but also shows the signal quality index indicating the reliability of the first parameter on a percentage scale (0 means not reliable at all, 100 is perfect reading). The value of this quality parameter is as much of a triggering factor for anesthesiologists as the actual reading. Depending on the combination of the two parameters, one may decide to take action.

In a similar way, when combining digital events from different sources with different qualities that all impact the value of the aggregated composite event (and also taking into consideration the spatial and temporal variations of the events) the composite, contextualized event will have a varying quality. The contextualized event depicts a "real life event", though based on the variations in the quality of the underlying atomic events and even the context model and other secondary information sources, the "trustworthiness" can be upgraded or downgraded as new information fitting the pattern is detected. Then, "the human in the loop", one of the HI factors, can decide whether to act upon the information or not. And as the stakeholder is aware of the situation around him/her, synchronous communication is no longer needed in order to find out that is going on. Though, when the quality parameter is inadequate for the situation, one can still resort to that type of communication to verify the situation.

4 Discussion and Conclusion

The hospital is high risk environment, and the derived events representation of the environment and especially the quality of the representation can contribute to improving patient safety. Quality is critical, if you can't trust the quality of the derived events, potentially patient can be endangered, other systems are in general less critical.

Another aspect of quality is getting the right (amount of) information at the right time, and *when* one needs the information is a quality context parameter. However, caution should be taken when distributing information. Social media in the private atmosphere (meaning a non-business setting) is non-critical. "Leaking" of information can be unpleasant, though in a hospital such leaks can be illegal as it can contain patient information.

The above pertains to a healthcare professional community; however, the type of situation refinement can also be introduced in other communities. It can help answer questions such as: Where are the people, what are they doing? When can I expect an action to be ready? When does the next task start? Is someone nearby whom can assist with a specific task?

[2] On a 0-100 scale a bispectral index of 0 indicates that the patient is brain-dead, 40-60 means narcosis and 100 means the patient is fully awake

Also in a social setting it might be nice to know if one can interrupt the receiver. In most messenger systems, it is possible to indicate a status, however, experience shows that the actual status in general does not represent the real status of the person. Many messages do not require direct attention.

One of the differences between a social and a hospital setting is that one in general addresses a pre-set group or an individual in a social setting, whereas the role of a person is much more important in a hospital setting. Targeting a role could in a sense be compared to a user profile rather than an individual. This concept could be used for targeted marketing based on the “needs” of the receiver.

When semantic models are created to commence situation refinement, and for example can use artificial intelligence/case based reasoning is implemented in order to detect patterns based on historical data, or gather additional information from pseudo-static sources such as calendar or planning systems (in general: systems external to the system being used).

In order to create a contextualised event, one needs to analyse which events occurring in the domain are of relevance and how (with which additional information) these can be semantically enriched in order to provide more meaning. Detecting patterns in order to better be able to merge events from multiple sources, reasoning for missed events, reliability of inferences, etc. And not to forget, the notion of quality; let people reason upon the outcome of an inferenced result, and not a computer system.

Remember that nature cannot be fully described by rules. It is simply too complex and diverse. Rules are simplifications, and simplifications can become a risk when the right context is unknown. Therefore, situational awareness also includes metadata surrounding the actual message, and as mentioned, should include a sense of quality of this information.

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