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Alerts in Clinical Information Systems: Building Frameworks and Prototypes

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Abstract. Alerts in Clinical Information Systems and CPOE are powerful tools for decision support. However, studies show that physicians override a large part of these alerts. Low specificity and high bandwidth of alerts lead to alert fatigue. Moreover, alerts seem to have usability issues as they are interrupting workflows and not always efficient to handle. This paper provides three different views on alerts: a system-based view, a human-computer interaction view and an organizational view. Based on this framework, we present a prototype of alert handling, which might ameliorate some of the problems with alerts.

Keywords. Clinical information systems; Medical decision-making; Alerts; Human-Computer Interaction

Introduction

Clinical information systems (CIS) are nowadays regarded as a necessity for the physicians in order to deal with the ever growing amount of clinical data. CIS are about to merge systems for medical data acquisition, systems for diagnosis and prescription in one comprehensive information system. The power of a CIS lies in providing facilitated access to medical data, but at the same in its ability to interconnect different sources of information and to provide support for interpretation.

A powerful way to take advantage of the interconnected medical data is to provide alerts based on stored medical information and predefined clinical rules. Alerts are a means to notify the physician of a possible adverse event. CPOE using alerting systems based on drug and laboratory information have proven to lower medication errors [1], especially in long term treatment [2]. Even if the positive effects of alerting systems are identified, the question persists how an alerting system should be best integrated in a CIS in order to improve best safety, quality and efficiency in medical care. The Swedish health organization Carelink (referred to in Pettersson et al. [3]) proposes a list

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of properties that alerts should have in order to address the requirements of an alert system. These different elements emphasize the fact that adding an alert functionality to a CIS does not guarantee for its efficient and safe use. Research has identified human factors [4] as well as systems acceptance [5] as important requirements for a successful integration.

In a literature review, Sijs et al. [6] identify that 49 – 96 % of alerts are overridden. The authors remark that an overridden alert is not equal to a medical error or even less so to an adverse event. A large part of alerts are either false positives (36.5% and 39% according two studies [6]) or true positive alerts, which are rated as not useful. When looking at the overridden true alerts, the authors identify a range of responsible human factors:

- alert fatigue due to poor signal-to-noise ratio as a result of high number of false positives or repeated true positives
- usability issues (e.g. misinterpreted or unnoticed alerts)
- disagreement with guidelines
- faith in physicians own knowledge
- lack of time

Further insight is provided by questionnaires [7] and focus groups [8], where physicians self evaluate the most important factors for a useful and easy use of alerts. According to these studies, drug related alerts are rated higher in terms of utility, than alerts on health state or disease state reminders. Physician's most fundamental requirement regarding human factors is the efficiency of the system. Alert overload can be detrimental to physician's performance in their daily work, not only because it can lead to errors by overriding true positive alerts, but also because the false alerts consumes physician's time and mental energy. Shah et al. [9] suggest a careful selection of alerts based on relevancy, severity, likelihood, and strength of clinical evidence in order to improve the acceptance of the alerts. Bates et al. [10] propose the "Ten Commandments for effective clinical decision support". A recurring issue is whether alerts should be active or passive. The prior have the drawback that they interrupt workflow, if they are not really specific and well timed. Passive alerts can be overlooked. Later in this paper we would like to provide a proposal for a prototype which aims to alleviate the dilemma.

In order to build the prototype, we would like to introduce three models of alert processing in CIS, each time changing the point of view. First, we look at alerts as an information process from the systems perspective. Second, we would like to address the interaction between user and alerting system from a human-computer interaction perspective. Finally, we look at the implications of alerts on an organizational level. This leads us to a prototype of an alerting system which aims to respect the implications on all three levels.

Building a Framework for Alerts

Regarding the systems perspective level, Calvitti and Lenert [11] propose a model of alert management, which defines three stages: (1) a detection state, where medical data is captured and classified; (2) the dissemination stage where the alert is transmitted to the concerned medical personnel and finally (3) the presentation stage, where the alert is presented to the user taking into account human factors. Hsieh et al. [12] propose an integrated feed-back system to evaluate the reasons of overriding behavior and

providing an interface to monitor the number and type of overridden alerts [13]. Subsequently reviewers would evaluate the feedback in order to ameliorate the system. In Fig. 1 we propose an own alert cycle, which takes into account the two aspects of an alerting system: the different stages in alert handling and the feedback loop for improving utility and usability of the alert system. According to this model, a complete alerting system is providing means for the definition of rules, the generation of rules, the management of rules, the alerting of the user, the evaluation of user actions and finally the correction of the alert. We argue that the application of this alerting system model would improve the specificity and the sensitivity of alerts.

As already introduced, an alert can also be viewed as an interaction between user and the system. In fact, an alerting system can be reduced to the physician's interaction with the display, keyboard and mouse. Using these tools the physician is building a representation of the physical world (e.g. patient's health status). The physician can respond to this information in the real world and/or by entering feedback to the system. This interaction loop is described in Norman's human-computer interaction cycle [14]. As we all know from our own experience, the interaction with a computer system can be flawed. On one hand, the displayed information can be unnoticed or misinterpreted or, on the other hand, wrong information entered by erroneous assumptions or by simple mistyping. Reason's model addresses these different qualities of errors when he speaks of slips, lapses and knowledge based errors [15]. In order to find a way to reduce errors on this cognitive level, we would like to refer to Rasmussen's model of decision making [16]. According to his model, human decision making can be modeled as bottom-up problem identification and a top-down process of problem solving. In the context of this work we would like to limit to the problem identification. From a users perspective the first step is to be alerted of the occurrence of an abnormal situation. This level of decision making addresses the skill-based level of decision making, as it concerns automated processes. In a further step, the user would account for the given information. This level is called rule-based as it concerns internalized rules, like identification of an illness based on a pattern of symptoms.

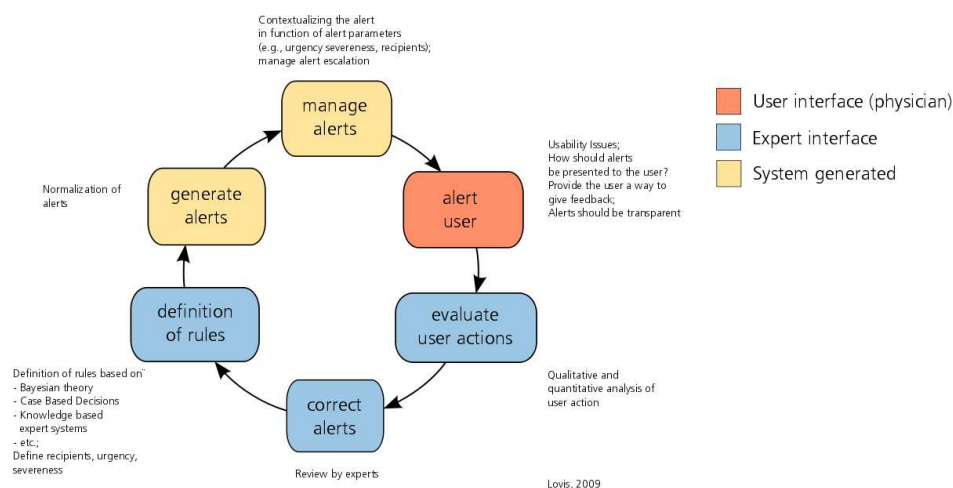


Figure 1: Alert circle in Clinical information system

In a third step, the physician identifies the problem and matches it to the physical world context. At this level, the physician does not apply predefined rules, but addresses higher level conceptual functions in order to solve the problem. Typically, a physician would consider ethical aspects of a problem or institutional goals and redefine or adapt rules accordingly. This level of reasoning is called the knowledge-based level.

We expect that the application of an alert system according to the decision levels will reduce alert fatigue if the level of information is adapted to the physicians information need. Also, such a cognitively engineered alerting system should improve the acceptance of the alert system as it provides an active mode of information seeking (or passive mode when using the systems perspective according Shortliffe [17]).

Regarding the view from an organizational level, we would like to introduce Kuuti [18] and the activity theory approach. According Kuuti, a system can be described on three levels: the technological, the conceptual and the work process level. His main critic is that a system only based on human factors methodology, hence a conceptual approach, is likely not to take into account the work process level. He would argue that the evaluation of medical reasoning in laboratory settings would not suffice to grab the complexity of work situation (being under time pressure and interacting with other health care providers). According to the activity theory, an actor is therefore not interacting with the computer alone, but the computer is merely a tool for reaching the physician's goal. In the terminology of the activity theory, the goal is to transform an object to an outcome. In this perspective, an alert would be a (supporting) tool suitable to transform (heal) the object (sick patient) to a desired outcome (cured patient). As a physician is in most cases not working alone, the system should additionally provide means to support rules (e.g. medical guidelines), the community (enabling communication between health care providers) and division of labor (provide a way to organize work between them). In order to design a new alerting system, all of the aspects of activity have to be taken into account. Carayon et al. [19] propose a similar approach, when they talk of a "work system" that has to be considered when exploring the work activities of health care providers. The authors point out that the prescribed task is not necessarily equal to the activity the physician is actually performing. Medical tasks are context specific and predefined rules fail to replace physician's decision as they do not take into account the larger context. Overridden rules are therefore likely and should be made possible.

Building a Prototype

The following proposition is based on the models we have discussed so far. The prototypes are functional design, which implies that they are conceptual and neither complete nor detailed. Prototypes are a way to model the user point of view. However, we will point to technology and organizational implications as required.

First, a prototype for alert systems should apply not only to alerts in CPOE, but to the CIS on the whole. From a user-centered perspective, the interface should use unified processes and displays for the same type of information. However, we propose to display alerts, which are related to the current task in the patients record itself, whereas non-specific alerts (e.g. concerning another patient) are shown on the same display but outside the patient's record. To counter the detrimental effects of work interruptions, we propose stackable alerts that do not interrupt work flow. New

concepts of user interaction in Rich Client Applications (RCA) make it possible to go beyond the idea of popping up windows. Using a stack of alerts (as shown in Fig 2), the physician has an overview over the open issues and can address them when best suited. An exception of the uninterrupting paradigm is raised when an open issue is preventing the physician from finishing his/her current task. In this case, the system would not allow terminating the task (e.g. clicking OK) before handling the open alert.

In order to match the different levels of decision making, we propose an alert system which is based on the model of Rasmussen. In a first step, the physician is alerted about a new issue with a short phrase (in stackable messages as mentioned before). The physician can immediately respond to the alert by dismissing, postponing or showing the alert. The type of permitted action is based on the nature of the alert.

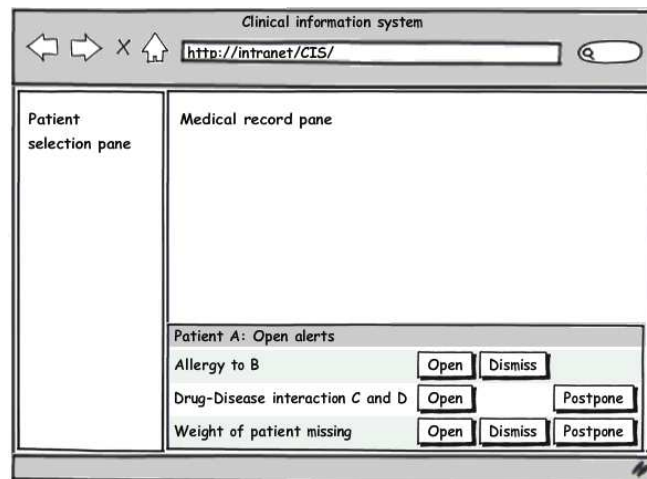


Figure 2: Stacked alerts for skill based reasoning (elements are unproportional in order to make them readable)

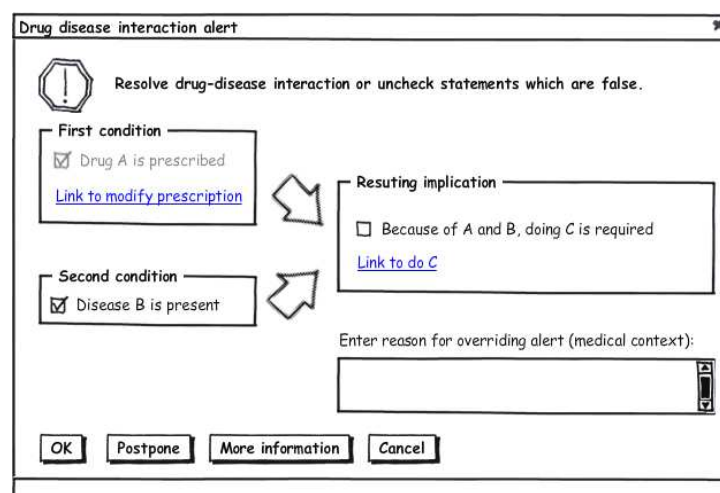


Figure 3: Pop-up window with the rule-based version of the alert

An alert has to be classified by attributes such as urgency and severity. When opening the alert, the physician is presented a rule-based view of the problem (Fig. 3). In this view, the physician can invalid a given condition, correct a condition or challenge the given conclusion. This would allow implementing a normalized procedure for feedback for overridden alerts. Still, it has to be considered that an alert is based on a presumed activity in a certain context. The system should be flexible enough to allow the physician to enter information, when the context is different than predicted. A free text field enables the physician to explain the different contexts. User feed-back and system-generated information should be added, in order to provide even more detailed context. Finally, we propose to add a third level of information for knowledge-based decision making. In an additional screen, the physician can consult detailed information of the given rule when required (e.g. summaries of scientific papers) in order to judge whether the given rule is applicable in the given context.

Discussion

We presented three different views on an alerting system. The models value lie in the comprehensive view they provide: a view from the systems perspective, a view from the user-computer interactions perspective and a view from the organizational level. Based on these models, requirements of an alerting system can be more easily defined.

The prototype we presented is in a preliminary stage. The intention is to demonstrate an alert system, which aims to address some of the current problems of alerts in CIS. We face the problem of lacking specificity and high bandwidth by providing an integrated feedback-system. This feedback system will require an interface for reviewers and experts who define the rules. By using non-interrupting alerts in a stackable mode, we try to ameliorate the problem of work interruption by alerts and alert fatigue. Finally, we argue that an alarm system should be adapted to cognitive theories of decision making. Physician's active information seeking, going from a short notification, to rule-based explanation and finally to extended knowledge based information should provide physicians more control over the system and improve system acceptance.

Certainly, the alert system is preliminary and far from being ready to be deployed in a hospital. However, a first prototype makes it possible to test the alerting system using usability test. The goal is to confront physicians with the new alert system in case based scenarios [20]. Iterative design will help to get the system closer to the needs of the physicians and the whole institution. Additionally, there must be careful consideration on how to integrate the system in the larger context of a hospital. In an activity theory approach, it has to be acknowledged that CIS and alerts, even if they are a powerful tool, are part of a much larger system. Work situations are dynamic and should be observed in the real context of work [21].

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