HDLalert – a healthcare DL alerting system: from user needs to implementation

Health Service DL Alerting: Users, Requirements and Design

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ABSTRACT
In the health domain, there are many circumstances where clinicians and patients wish to track changes in medical knowledge. However, existing 'news' or 'alert' services provide relatively limited means for selecting which information to receive. This results in clinicians and patients receiving information that is inappropriate, irrelevant or simply too voluminous.

In this paper, we detail alerting-relevant findings from several user studies incorporating both clinical staff (across several hospitals) and patients' perceptions. These findings demonstrate the importance of context, both in terms of the user's task and immediate environment. We introduce a novel alerting architecture that can provide a more finely tailored stream of alerts to the user, and provides further support to assist the interpretation of received material

Categories and Subject Descriptors
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General Terms
Design, Experimentation, Human Factors.

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Digital Library, Alerting, Healthcare, User Studies.

1. INTRODUCTION
In the clinical domain there is a growing importance placed on the use of current best evidence [25]. Evidence-based medicine highlights the importance of timely, accurate and concise information in healthcare professionals' decision making processes. Reddy & Dourish [24] confirm the importance of information being available at a glance to all members of a unit. They also identified that currently this is not supported by technology but by discussions with colleagues and the information they source. Similarly, patients increasingly discover their need to understand and actively deal with their health issues as is reflected by the huge amount of supports groups as well as initiatives such as the EPP of the British NHS. There is, therefore, an escalating need to improve the accessibility of reputable information sources.

We will now consider how available sources meet the demanding needs of the health domain. Web-accessible information sources present the potential to greatly advance learning capabilities regardless of users' location and time restrictions [1, 6, 9]. Digital libraries are a key example of such web-based resources. In comparison with traditional libraries, digital libraries (DLs) can provide specialized information in a format that is easily updated, with speedy searching and access facilities. However, web-based sources in general frequently fall short of expectations in their uptake and day-to-day usage [6]. One potential problem for clinicians as well as for patients is an awareness of what is available that is relevant and in which of the frequently changing sources it can be found. The tedious effort to repeatedly access and search these sources can be too time-consuming for the time-pressured clinicians. It is also beyond the expertise of many patients to evaluate the significance of the information regarding their condition. Another important problem is the complex and changing needs of different professionals and patients that vary according to their situations, i.e. the differing context of the users.

Digital library alerting services are a potential solution to these problems. Currently, these systems are time-consuming to set up and do not provide the flexibility to fit with their users' personal and situational needs which are constantly changing. This paper reviews the special health user requirements for such an alerting service. It then introduces an improved architecture of *health alerting services*, building upon a flexible generic alerting model.

2. BACKGROUND
This section commences in three parts: First we examine general influences on the adoption of digital library technologies. We then introduce alerting, and follow this with a discussion of alerting specifically in the health domain.

2.1 Influences on DL Adoption
Bishop's [5] study into digital library users' identifies that users can easily be deterred from using libraries and that poor awareness of library coverage prevents a full understanding of their potential. It has been argued that the reason for this is a need to have more comprehensive views of information within the context of related tasks and how that changes over time [2, 19]. Other work [4, 17] has explored how users can gain this through access to digital information while they are mobile (i.e. contextualizing the information to users' current time and place). However, most of these research directions detail searching and interpretation of digital library sources. Most systems do not relate well to user's temporal processes which start before

searching commences with the awareness and initiation of information requirements.

Todd et al [28] highlight the fact that nurses' current work practices (e.g. shift patterns, ward-bound duties) restrict their access to libraries and the internet. The difficulty some clinical professionals experience in accessing the physical library, and the push for evidenced based medicine, have resulted in different approaches to implementing digital library technology – such as remote DL access, computers on the wards and outreach information intermediaries. However, recent studies have identified that clinicians not only require timely high-quality information but that it fits with their own personal requirements and can be accessed when they have time (e.g. on-breaks) [18].

Most clinical alerting services are set up through specific publishers or digital libraries (e.g. British Medical Journal, Medline) whereby keywords are used to search titles or sometimes abstracts. However, the National Electronic Library for Health now provides clinicians with access to the Zetoc current awareness service, within the JISC Information Environment and eScience applications [3].

However, as demonstrated in [7], publisher-provided alerts give only limited support for selecting the notifications that the user wishes to receive. Furthermore, these systems also fail to support the user's context, providing the same information about a topic regardless of the user's abilities or environment. For example, health priorities frequently change in response to disease threats, between different medical areas and wards or when patients learn about long-term conditions. Finally, these systems are generally discrete, and fail to integrate with each other, leaving the user with a number of disjoint services with different controls, delivery methods and editorial styles.

2.2 What is Alerting?

An alerting service informs its users about changes they are interested in. Information about these changes is provided by *publishers*, e.g., digital libraries or Electronic Health Records (EHRs). Publishers send messages about changes to the alerting service. Changes of interests may be alterations to a patient's medication, which is entered into the EHR. The interests of users are defined in *profiles*. These profiles are registered with the alerting service. Incoming change messages are filtered by the alerting service according to the user profiles. Whenever the alerting service identifies information that matches profiles, the respective users are alerted by a *notification* [10], see Figure 1.

2.3 Alerting Services in Health Environments

There are several areas where alerting services have been applied in the health domain. A number of systems are used for emergency care and for the monitoring of laboratory results. Examples are a real-time clinical alerting service for intensive care units [8], a system supplying wireless clinical alerts for physiologic, laboratory and medication data [26], a system for wireless clinical alerts in a surgical intensive care unit [16], a system for real-time notification of laboratory data requested by users through alphanumeric pagers [22], a laboratory results alerting service for ambulatory and hospitalized patients [14], CLEM a clinical event monitor [29] as well as the Columbia-Presbyterian Medical Center clinical event monitor [13].

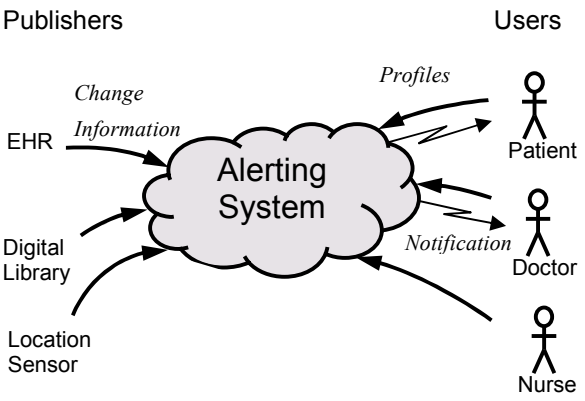

Figure 1: Alerting Service Overview

Another group of health-focused information systems are workflow systems. Examples are a clinical reminder system for ambulatory care [31], a careflow management system for chronic patients [21] and a framework for clinical test request protocols, PLAN [30]. Some decision support tools provide reminder functionalities, such as the paediatric diagnostic reminder tool ISABEL [23]. Alerting is also provided in disease surveillance systems, such as RODS (Real-time Outbreak and Disease Surveillance) [20].

These systems share several severe drawbacks: First of all, these clinical systems are not intended for patient use or support, and are highly tailored to the specific task for which they were originally designed. Many rely on receiving technical (numerical) measurements from instruments, which map poorly onto the textual analysis required for alerts in libraries. Also, the profiles that define when an alert should be sent inherently have a simple structure. They rely on the relative sparsity of notifiable changes or on a few selecting options to limit the number of alerts received by the user. In DL contexts, greater flexibility is required to support large volumes of heterogeneous data. Similarly, the tasks supported in a DL are also fluid with complex information needs.

3. HEALTH SUPPORT USER STUDIES

This section reports the results of our user studies regarding information and alerting needs of clinicians and patients.

3.1 Alerts for Clinicians

Alert service related findings were sourced and re-analysed from four studies conducted within the healthcare domain over a 4-year period. In-depth interviews, focus groups and observational studies were conducted with 125 clinicians (e.g. nurses, junior doctors, consultants, surgeons, occupational therapists, psychologists, nutritionists etc.) library and health information personnel, managers and IT department members. Study 1 and 2 looked at two comparative hospitals (i.e. city-based and provincial), Study 3 appraised the use of outreach librarians while Study 4 evaluated a patient health call centre.

Clinicians' awareness of what was in digital libraries and mechanisms to support there usage (e.g. alerting services) was identified as very poor. However, a project placing information intermediaries within clinical teams was found to support increased awareness of digital resources and their relevance to clinicians needs. Intermediaries attended team meetings and ward

rounds, recording queries and searches in situ or actively proposing searches.

"*(The information intermediary) would sort of raise the flag and she became very good also at predicting and anticipating ... a clinical question*" (Consultant).

Clinical intermediaries provided flexible support for digital information sources by raising awareness and initiating future requirements. It is argued that alerting systems that could support clinicians in this way would be invaluable.

However, current mechanisms (i.e. DL alert systems, notice boards) increase the likelihood of information overload through poor personalisation of alerting services (e.g. alerting to full content pages). They were also noted as requiring a lot of time to support these activities, time that clinicians frequently noted that they just did not have.

"*Everyone is so busy there is simply never a moment in the day when you think – ahhhh what should I do now.*" (Surgeon)

3.1.1 Press Alerts

Patients' information requirements were identified as often initiated by press, family or friend induced fears.

"*Because there is a lot of information out there in the media and in the press. People hear about it and they call us because I think they're worried about it, or they think it's going to affect them. I mean we certainly have a lot more health alerts than we ever had*" (Health information officer)

It was also noted by clinicians that they were being forced to become more aware of current press issues, both to allay patients' fears and to find out what position was being taken by their professional body or their hospital. Nursing staff reported that it would be useful to have a resource that captured these changing issues and related them to current evidence, organizational and national health perspectives. The findings highlighted the need for press-alerts that would link recent press articles on a particular subject with related current research and professional articles and then collate them for the user.

3.1.2 Flexible Resources

The immediate benefits of updated, locally relevant, day-to-day clinical information (e.g. policies, procedures, induction data, guidelines, and protocols), electronically stored and quickly retrievable, were recognized. Clinicians, however, require more than simple electronic representations of documents. These information sources would be invaluable if, subject to appropriate authentication, they could fulfil specific user needs, provide local knowledge and prompt updating requirements.

"... how to care for a wound point 6 ohhh yes I have to use this type of dressing and where are they kept ohhhh right they're kept under there" (Nurse)

Users also detailed the need for flexible libraries of organisational information (e.g. job title, role, contact details, schedules and diaries) that would then link into communication media such as email and ultimately the electronic patient record and evidence based medicine resources.

3.2 Alerts for Patients

Further findings are also presented from an online-survey, which was undertaken in order to identify the requirements for a patient-centred mobile alerting system. The survey lasted for two weeks in February 2005. It was based on a series of interviews taken in a university clinic, participant-evidence from actively following condition-relevant newsgroups (over several years prior to the research study) and several use-case developments. The survey was directed towards patients, doctors, nurses as well as computer scientists employed at IT departments of clinics. In this analysis, we refer only to those participants who are patients.

3.2.1 Education Information

Participant-evidence from taking part in condition-related newsgroups has shown that patients want to be educated about their condition. This issue becomes extremely pressing, whenever a change in their condition has taken place such as a change in medication or the necessity to undergo an operation. This information is confirmed by the high number of patient support groups on the internet that have been set up during recent years, e.g. yahoo alone offers 11934 illness-related support groups.

This observation was confirmed in the online-survey, which was undertaken in a mixed-approach. Both quantitative and qualitative data was analysed [15]. In the quantitative part 43/60 (71%) patients wanted to be alerted about educational material.

This was further refined by the qualitative data detailing things they would like to be alerted about, for example:

"New clinical studies" (Patients)

A few of these patients were interested in scientific information. Others were led by specific complaints and direct support for diagnosis and treatment.

"*What to look for in emergency situations of the disease (i.e., something to tell me if a given symptom will go away on its own, or is worthy of a visit to the hospital)*" (Patient)

Thus, the result of this qualitative part was that alerts would have to be personalised as different people are interested in differing issues. E.g. some are more interested in research results whereas others want to have more straight forward advice about their condition. Thus, the context determines what alerts are needed.

3.3 Summary of User Requirements

In this section, we have identified a number of user requirements for alerting in heath digital libraries. In the course of discussing these requirements, we have demonstrated that there is a wide variety of material that users may wish to track. The needs of a consultant are very different from those of the patient they treat or of nursing and other clinical staff. These differences are often reflected in the form of material that a specific user wishes to read.

However, particularly for medical staff, their current environment or clinical demands have a strong influence on their information needs. Coarse-grained alerting services that provide many alerts on a broad topic are unlikely to supply the targeted, timely information that they require. Patient's needs are no less complex – responding to one source of health news, they may wish to discover related material that 'makes sense' of clinical material in terms that they comprehend and have practical value for their day-to-day life.

4. SYSTEM REQUIREMENTS

Given our user studies outlined above, we have arrived at a number of requirements for a health alerting service. To

illuminate these, we will first introduce three simple use scenarios to clarify some uses of such a service, (see Figure 1).

S1) A patient would like to be send educational material, whenever his condition has changed, e.g. when starting on a new medication. This he would define in a profile as "send educational material when patient's condition has changed" (cf. Sect. 3.2.1).

For this kind of profile the alerting service would filter the EHR and whenever an entry describing a relevant change has been found, the patient would receive appropriate educational material in a notification from the alerting service.

S2) A doctor would like to be notified with relevant research results, whenever there is an important new press release and it is likely that his patients will make inquiries about this topic: "send related research results when a new press release is published" (cf. Sect 3.1.1).

Here, the alerting service has to filter a Digital Library in order to find out more information relevant to each new press release. When relevant documents have been found, the doctor is then sent relevant research results, together with the original press release.

S3) A nurse works in several units of a hospital. In these units they have differing treatment guidelines for certain conditions, it is difficult to keep track of. Therefore the nurse wants to be reminded about the respective guidelines whenever he changes unit "send treatment guidelines when clinical unit has changed" (cf. Sect. 3.1.2).

A location sensor can supply the alerting service with the position of the nurse. Whenever the nurse moves from one unit to another, the nurse will be supplied with the appropriate treatment guidelines.

Returning now to the earlier user studies, one novel challenge in providing alerting services in the health area is the variability of language between professional and patient. Differences may also occur between disciplines. Though humans cope well with such barriers, computers do not. Thus, any alerting service will have to be open to supporting matching between technical and 'common' terms, or even between natural languages (cf. S1, S2).

This language barrier reflects a deeper difference in knowledge. Clinicians not only have a wide and comprehensive technical vocabulary but they also possess a systematic understanding of how the human body behaves and reacts. Useful literature for them will leverage these strengths in making diagnostic decisions, and directing the course of treatment. For a patient, though, these tools are absent, and material will often be of a practical, directive form. Furthermore, variability between patients will be large – from pro-active individuals who seek to understand their conditions fully to those who 'only want it fixed'. A comprehensive system will thus not only perform textual matches, but also consider the form and purpose of the material to be Responding to the current environment – be it differing clinical and/or management practices and priorities (cf. S3), temporal terms of disease progression or time of day are also considerations. Finally, some material such as electronic health records that need appropriate processing to ensure that the current context is properly captured.

Together, these factors create a demand for a complex filtering architecture. We will now introduce our current architecture and illustrate how it matches these demands.

5. ARCHITECTURE

To meet the requirements discussed in the previous section, we have designed a new health digital library architecture HDLalert. The prototype of this architecture has been developed around the established Greenstone Digital Library, and its Alerting Service. These two components have been joined through additional event-based components. In this section, we will describe the structure and operation of this new integrated medical DL system, and demonstrate how it matches the requirements described above.

5.1 Design

The overall HDL architecture is shown in Figure 2. Different compositions of systems can be created through connecting the components of the system in varying ways. In the figure, we illustrate the creation of a supplemented alerting service, with each alert received being enriched with links to relevant material. Incoming alerts have key phrases extracted through the *extractor* module. This data is then passed into the filtering system with the user's profile for the appropriate additional documents to be selected. Clinicians define their interests in *profiles*; the *thesaurus* replaces or enriches the original term with a translation (see our previous work in [7]). Matched documents are forwarded to the user with the original alert through the final, notification module. We will now describe each of the four component elements in more detail.

Common to each of the alerting scenarios introduced earlier in this paper is the requirement for the matching of content of one document against a set of other documents. For example, in the press alert scenario, one wishes to match important terms or phrases from the press text against documents in a supporting digital library. However, one requires a more selective match than by simply comparing all the text in the example document - key features of the example document need to be identified and extracted, and then those matched against the expert corpus. In our architecture, this process is performed by the extractor component.

The extractor component may be realised through different implementations. There are many circumstances where specific extractors would be required. For example, press alerts are usually distributed in plain text form or with only simple markup, whilst EHRs may be stored in complex database or XML formats. For accurate retrieval, the input content needs to be correctly processed, to avoid false positives amongst other problems. One such false positive could be matching a warning about medication interactions for a drug no longer being administered to the patient.

Secondly, we noted the problem of differing languages used by different users - clinicians and patients, for example. For this to be addressed, we use a thesaurus that facilitates the translation of key terms in one form of language into the equivalent terms in another. In Greenstone, we have long used multi-lingual thesauri for supporting cross-language retrieval. In HDLalert we utilise this same technology within the same human language. For example, clinical text highlighting the presence of "glucose" will retrieve patient-centred documents about "blood sugar".

Once both extraction and translation has been achieved, filtering is passed to the established matching systems of either the digital library (for matches against reference documents) or alerts (for matches against new material) as required. In [7, 12] we demonstrated that a digital library and an alerting service can use

a common syntax. Therefore, we can abstract above both static collections and dynamic streams of content. The rich filtering languages introduced in [10, 12] support a wide range of functional requirements.

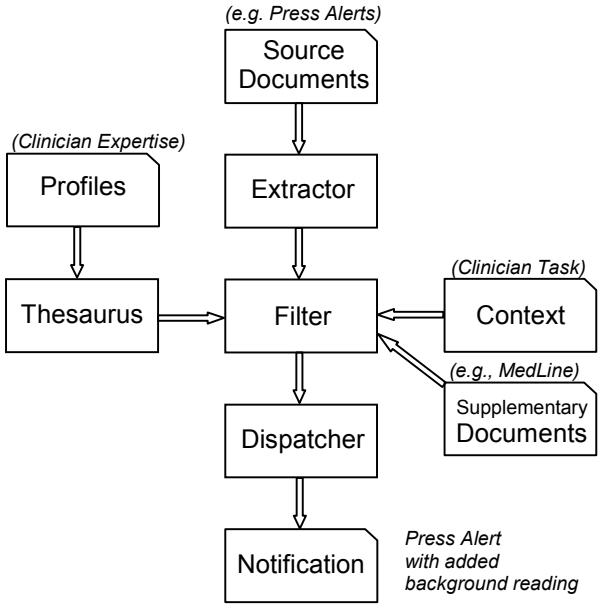

Figure 2.: An Architecture for Health DL Alerting

Our architecture presented here adds an additional element to the filtering system; it also adjusts the output of the filtering process depending on the user's current context. Again, this element is modular and can be realized in different ways; it feeds rules and data to the filtering system to be used in the filtering process. For example, in the case of a DL that delivered different information depending on the physical location of the user, the context module would supply positioning information to ensure that any material selected was appropriate for a nurse's current ward.

Finally, the information is forwarded to the user through the notification module. Again, this can be implemented in different ways – in some cases, this may simply send notifications by email, but in others it may choose from a variety of different methods depending on the criteria sent forward from the filtering engine – e.g. the patient's ability to see or hear.

It is important to note that the proposed alerting service only provides information. It does not, of itself, provide decision support. Our experience is that such systems are poorly received by clinicians, and in any case are usually irrelevant to patients.

5.2 Example

To illustrate our architecture, we sketch its operation for enriched press alerts for clinicians (see italics in Fig. 2). Clinicians describe their information needs in profiles. The profiles are supplemented with terms from the thesaurus as required. New press alerts are received from news databases, and passed into the system. Each press clipping is then processed by a keyphrase extraction system to identify clinical terminology. The system filters the terms according to the clinicians' profiles. If a match is found, the system now searches a number of medical DLs (e.g. MedLine) to discover material relevant to the press article. Additional context is also used to improve the selectivity of the material (e.g. for the clinician's domain of expertise). Finally, the press clipping is sent to the user, accompanied by references to relevant journal articles selected from MedLine.

5.3 Alerting Service Design Summary

We have introduced the HDLalert alerting architecture, and briefly illustrated its application to an enriched alerting service for clinicians. Our novel architecture differs from existing health alerting services in supporting fine-grained matching using the proven alerting technologies of the Greenstone Alerting Service (GSDL-AS) [7, 12], which can also be implemented over a variety of DL systems. Furthermore, it extends the advantages of GSDL-AS by introducing supplementary material to alerts and also facilitating selection across different reader groups through the use of a thesaurus.

6. CONCLUSION

In this paper, we identified the need for alerts in health DLs. Though some existing systems provide coarse-grained alerting, this fails to meet the requirements of clinicians and cannot support the needs of patients. Furthermore, the user requirements for health alerts are diverse: Different types of information are required to support different tasks. Alerts themselves could be simple messages or more complex packages detailing the new information and supportive background material.

Therefore, we argued that a new system is required that provides a richer and more fine-grained service than exists at present. We introduced a new alerting architecture for health DLs that is built upon innovative but established DL tools. These reliable elements can be combined in different ways through the same architecture to achieve the varying alert forms that our users required.

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8. Contribution

Doris Jung provided the technical material on alerting services and the review of alerting for patients under the supervision of Dr. Hinze. Anne Adams supplied the remainder of the user studies. George Buchanan contributed the HDLalert architecture, with further technical input from Annika Hinze.

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