CaBN: Disparate Information Management through Context-Aware Notifications

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***Abstract* — Keeping track of information from multiple sources leads to attention management challenges. We propose CaBN, a context-based notification system which alerts users of information from disparate sources such as e-mail and calendar events. The system determines the best way to deliver a notification by comparing the priorities of the incoming information and ongoing user tasks. Leveraging tradeoff of human attention for optimal task utility, CaBN aims to be a mobile and central information source to mitigate the problems of information fragmentation and attention management.**

Keywords* — *Context-aware notification systems, information fragmentation, attention management, mobile

I. Introduction

As designers, we recognize much of the information users handle widely varies both syntactically and semantically. All these different forms of information have unique structures and are designed to hold a specific type of information. Coupled with this problem is the fact that a lot of this information can be distributed across multiple devices, leading to information fragmentation. Some information may be accessed and maintained on a certain device while the same may happen for another information type on another device.

A crude solution to dealing with fragmentation is to set up devices such that information is delivered to the user instead of forcing the user to check each possible source. For example, fragmentation can be experienced with PDAs being used as e-mail clients and cell phones to retrieve voicemail. Because both information sources reside on different devices, a user may request the devices alert them of new e-mails or voicemail. However, the delivery of these alerts takes a toll on a user's limited attentional resources—causing unwanted interruptions to their ongoing tasks. Such devices, functioning as notification systems, need to be designed to deliver information by accurately supporting attention allocation in dual-task situations.

What happens when information sources are combined together to combat information fragmentation? A single device could potentially cause enormous amounts of interruptions as a result of competing information sources. This crucial challenge illustrates a key relationship between attention management and information fragmentation.

Our work is based on integrating disparate information sources and managing attentional resources. To accomplish this, we make use of the *attention-utility theme* that defines the tradeoffs in overall utility that occur based on allocation of attention to various tasks over time [12]. Attention is controlled using a toolkit of methods that maps notifications to acceptable levels of interruption that seek to maximize attention-utility tradeoffs. We present Calendar-Based Notifications (CaBN), a notification system designed to deliver personal information in this prioritized fashion. Key to this system is its ability to gauge ongoing activity priority and incoming information sources by using rules to deliver appropriate notifications.

II. Background

CaBN was developed to address the problem of information fragmentation and information overload while accommodating the increasing use of mobile devices and the need for constant access to information. This section describes these issues in depth and highlights several similar research and development efforts.

In today's world, information is increasingly being fragmented by location, device and software application. This can make it difficult to use and update that information [7]. Fragmentation can also further disrupt people's daily lives as they are required to switch and transfer information between devices/applications to work on multiple tasks simultaneously [10, 17]. Systems have been developed that integrate information management tasks to combat this problem. For example, Ducheneaut and Bellotti have proposed augmented email clients to support other tasks such as scheduling and file management [3]. However, these types of systems do not directly address the problem of how best to manage the influx of information while still completing daily tasks.

One cause of information fragmentation and information overload is people's natural disposition and need to perform multiple tasks simultaneously [13]. This results in the need to develop systems that best manage people's limited attentional resources as they work on multiple tasks [1]. These systems, known as *notification systems*, function in dual-task situations to provide users with needed information for secondary tasks while the user is working on a primary task [11]. There have been several efforts to model how these resources are managed in such secondary systems [6, 4, 11]. For example, McCrickard et al. define these systems in terms of the *interruption* a notification causes to a primary task, how well it supports accurate and efficient *reaction* to a notification, and how well it supports long-term *comprehension* of the information it provides [11]. Such critical parameters, or IRC values, are used to guide the development of systems that best manage people's attentional resources while providing the most possible utility. Franke et al. propose an approach to model these resources in terms of pre-interruption—where the user prepares to transition from a main task to an interrupting task, mid-interruption—where the user's focus changes to the interrupting task, and post-interruption—where the user returns to and reorients to the original task [4].

The increasing need to remain mobile while having access to information has given rise to a multitude of portable devices such as PDAs, cell phones and laptop computers. Notification systems developed for such systems need to be aware of and sensitive to the context in which the user is currently situated. For example, a cell phone should vibrate if a user is in a meeting or class, but should ring if the user is riding in a car or the subway. Sawhney and Schmandt have developed an audio-only wearable interface that provides information from a number of sources including email, voicemail, news services and calendar events [16]. Notifications are delivered based on the importance of the information and the current user context. Context is calculated from message priority from e-mail filtering, usage level based on the time since the last user action and the likelihood that the user is currently engaged in a conversation based on an analysis of the auditory scene. Others have proposed similar automated approaches to determining user context and information importance that rely on things such as external sensors, predictive models derived from user behavior [8, 9]. Another way to determine context is through location-tracking [14, 15] or on explicit user-defined rules for information importance that result in more predictable notifications [2, 5].

III. CaBN Goals

Information in CaBN is integrated into a single device as a direct reaction to the problems associated with information fragmentation [7]. While CaBN's design is modular enough to add new information sources, the two initial sources of information the system handles are e-mail and calendar events. E-mail is regarded as a critical method of communication with others. Because e-mail can be used to pass on such a wide variety of information, it is a key source to include in this system. Calendar events provide insight into the daily tasks that need to be performed. Such information is important to users who constantly need to be reminded of which tasks they must attend to. We strive to deliver this information to users through our system by managing attentional resources. Specifically, we had two goals for the design of this system: prioritizing both contextual and incoming information from disparate source, and comparing and delivering the information using the most appropriate notification method.

A crucial primary step to delivering information is prioritizing within dual-task situations. The primary task, or context, and the secondary task, the incoming information, are both associated to predetermined priorities. In the case of e-mail and calendar events, both e-mails and calendar events are incoming information sources. Calendar events also act as a context source, providing insight into the current activity.

McFarlane et al. determined interrupting tasks can be handled by rule sets [13]. We use the same method by deriving priorities for both the contextual and incoming information from filter rules. Users create filter rules, consisting of a set of criteria, to match any piece of information to an assigned priority. This allows the user to create filters for both contextual and incoming information. We use these priorities as a basis to understanding how notifications should be delivered.

The delivery of information itself to the user is crucial to understanding how CaBN works. A comparison of the contextual and incoming information priorities provides insight into how to balance the user's attentional resources. When both incoming information and ongoing calendar events are matched to filters, the competing priorities of each provide insight into how the incoming information should be delivered. Each possible combination of priorities is associated with a specific notification method. Notifications change based on timing, visual, and auditory characteristics which are classified as appropriate for each possible situation. The objective is to reduce the need of the user to attend to different information sources and divert their attention only when it is appropriate to do so.

IV. Notification Methods

Each filter rule includes a priority level assignment ranging from 1 to 5, where 1 is the lowest priority and 5 is the highest. The notification matrix is a simple solution to determining the best possible notification delivery method based on priority levels (see TABLE I). Each resulting value in the matrix corresponds to 1 of 5 different notification methods (see TABLE II).

The four corners of the matrix reflect distinct notification delivery choices designers made. When the context (calendar events) and information (e-mail or calendar event) priorities are both low priority, the notification method is either nonexistent or fairly subtle. The same is true for high context and low information priorities. On the other hand, when high priority information is received in low priority contexts, the notification is highly interruptive. In situations where both the information and the context are high priority, the notification is somewhat interruptive.

TABLE I
THE NOTIFICATION MATRIX

		Context Priority				
		5	4	3	2	1
Information Priority	5	3	3	3	4	5
	4	2	2	3	4	4
	3	2	2	3	3	3
	2	2	2	2	2	2
	1	1	1	1	1	1

The rationale for this matrix is derived from previous research. Franke et al. used a similar method to determine notification methods based on possible interruption and current tasks [4]. The choice of notification methods in the four corners of our matrix, the extreme possibilities, closely resembles the notification characteristics chosen by Franke et al. for similar conditions. The only difference is in the highest incoming and contextual information priority condition. While we choose to deliver a mid-level interruption, Franke et al. choose the lowest possible form for the same conditions. We choose to balance both information and context rather than giving less weight to the information priority.

There are several notification methods that can be used to deliver the information in an appropriate manner. We intentionally tried to make the notification methods as distinct as possible to underscore the need to prioritize information. TABLE II illustrates how each method alters the interruption level to attract a user's attention to varying degrees.

When a notification object with a notification priority of 1 is determined, the device does not explicitly notify the user of the information. A priority of 2 defers the notification to the end of an ongoing event. In this method, a visual notification is delivered to the user, causing minimal interruption (see Fig. 1). In such a case the user may immediately be aware of the incoming information. The next priority level increases the amount of visual change by repeatedly flashing, causing increased interruption in the periphery during an event. The 4th priority level introduces a one-time auditory alert to attract the user's attention during the event. The highest priority level continuously repeats the auditory alert until the notification is acknowledged by the user during the event.

TABLE II
THE NOTIFICATION METHODS

Notification Level	Notification Method
1	None
2	Continuous slow visual movement displayed at the end of the current event.
3	Continuous fast visual movement displayed during an event.
4	A single beep and continuous visual movement.
5	Beeping at regular intervals and continuous visual movement until acknowledgement.

Fig. 1 A notification occurring to alert the user of an incoming e-mail.

The notification methods have been chosen based on prior work on the attention-utility theme and the IRC framework to quantify the interruption level on a 0 to 1 scale, with previous research revealing that appropriate interruption levels can be identified with an 18% margin of error [2]. For this reason, we chose 5 different priority and notification levels to achieve complete coverage of the 0 to 1 continuum within the IRC framework.

V. CONCLUSION AND FUTURE WORK

The CaBN notification system was designed to address the issues of attention management and information fragmentation while maintaining mobility and ease of access. Attention management is addressed by controlling the flow of information to the user. By using filters and priorities, CaBN reduces the amount of information that is presented to the users. Instead of presenting information as it arrives, CaBN selects the most appropriate time to display the information depending on the user's context. This ensures that users are presented with the right information at the opportune time and not overwhelmed with the information flowing in.

Fundamental to this ability is the use of the matrix. Currently, the matrix can not be changed and its use relies upon how well the filters have been set up by the users. We recognize that some users may need to change their filters if they do not achieve the desired results. Adding functionality to accept user feedback regarding the assigned priorities in the filters can alleviate this problem. Thus, the basic model of the matrix can remain static, but the users will still experience better results through more accurate filters.

To address the problem of information fragmentation the CaBN architecture allows for easy addition of many information sources into the system. This extensible architecture, although not yet tested with other sources, makes it possible to assimilate all the information from various sources and display it to the user through a single channel.

Our implementation of CaBN uses a PDA which provides easy mobility and access to the information. Future efforts will focus on supporting other networking-enabled portable devices that people use. For example, the CaBN client could be implemented on a cell phone so that notifications are delivered through text messages. In addition, we will work on supporting additional information sources such as voice mail, RSS feeds and instant messaging. Although we have not conducted a formal user evaluation of the system yet, we realize the effectiveness of the CaBN system lies in the accuracy of the logic unit in calculating the notification priorities. Future evaluation work will examine effective creation of filters, usability of the CaBN client, and effectiveness of the notification methods and matrix.

Our ultimate goal is to maximize the productivity of information workers through appropriate personal information management strategies as defined by the attention-utility theme. The work described in this paper represents an important step in analyzing this domain by identifying levels of interruption and methods for achieving them. Further study will seek to expand this method set, empirically validate its utility through user testing, and create applications that leverage its benefits.

References

1. P. D. Adamczyk and B. P. Bailey, "If not now, when?: the effects of interruption at different moments within task execution," In *Proceedings of ACM SIGCHI*, pp. 271-278, 2004.
2. C. M. Chewar, E. Bachetti, D. S. McCrickard, and J. Booker, "Automating a Design Reuse Facility with Critical Parameters: Lessons Learned in Developing the LINK-UP System," In *Proceedings of CADUI*, pp. 236-247, 2004.
3. N. Ducheneaut, V. Bellotti, "E-mail as habitat: an exploration of embedded personal information management," *Interactions*, 8 (5), pp. 30-38, 2001.
4. J. Franke, J. Daniels, and D. McFarlane, "Recovering Context After Interruption," *Cognitive Science Society*, 2002.
5. M. Guppenberger, and B. Freitag, "Intelligent creation of notification events in information systems: concept, implementation and evaluation," In *Proceedings of ACM CIKM*, pp. 52-59, 2005.
6. E. Horvitz, C. Kadie, T. Paek, and D. Hovel, "Models of attention in computing and communication: from principles to applications," *Communications of the ACM*, 46 (3), pp. 52-59, 2003.
7. D. R. Karger and W. Jones, "Data unification in personal information management," *Communications of the ACM* 49, (1), pp. 77-82, 2006.
8. E. Katsiri, "A Context-Aware Notification Service," In *The First Workshop of Location Based Services*, 2002.
9. N. Kern, and B. Schiele, "Multi-Channel, Context-Aware Notification on Wearable Devices," In *Ubiquitous Computing Workshop on Design*, 2002.
10. G. Mark, V. M. Gonzalez, and J. Harris, "No task left behind?: examining the nature of fragmented work," In *Proceedings of ACM SIGCHI*, pp. 321-330, 2005.
11. D. S. McCrickard and C. M. Chewar, "Attuning Notification Design to User Goals and Attention Costs," *Communications of the ACM* , 46 (3), pp. 67-72, 2003.
12. D. S. McCrickard, C. M. Chewar, J. P. Somervell, and A. Ndiwalana, "A Model for Notification Systems Evaluation—Assessing User Goals for Multitasking Activity," *ACM Transactions on Computer-Human Interaction*, 10 (4), pp. 312-338, December 2003.
13. D. C. McFarlane, and K. A. Latorella, "The scope and importance of human interruption in human-computer interaction design," *Human-Computer Interaction* 17 (1), pp. 1-61, 2002.
14. J. P. Munson and V. K. Gupta, "Location-based notification as a general-purpose service," In *Proceedings of WMC*, pp. 40-44, 2002.
15. M. Sampat, A. Kumar, A. Prakash, and D. S. McCrickard, "Increasing Understanding of a New Environment using Location-Based Notification Systems," In *Proceedings of HCII*, 2005.
16. N. Sawhney and C. Schmandt, "Nomadic radio: speech and audio interaction for contextual messaging in nomadic environments," *ACM Transactions on Computer-Human. Interaction,* 7 (3), pp. 353-383, 2000.
17. S. Whittaker, V. Bellotti, J. Gwizdka, "Email in personal information management," *Communications of the ACM*, 49 (1), pp 68-73, 2006.