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How About a MATe for Awareness in Teams?

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Abstract. While guests in the office or a phone call can be pleasant surprises, in the wrong moment they may be disrupting a time of focused work and concentration. A lack of coordination between colleagues at the work place can lead to unwanted interruptions and result in an inefficient and unpleasant workplace. MATe (Mate for Awareness in Teams) is a pervasive, ambient intelligent computing framework charged with the task of preventing unwanted interruptions and improving social interaction at the workplace of knowledge workers. We present a survey of employees at a university in order to identify the attitudes of knowledge workers towards interruptions as well as their opinions on a pervasive system surveying and analyzing their behavior. Based on the results of this survey a prototype has been developed using an ontology written in OWL as a knowledge representation and logic-based reasoning to infer the users' status and interruptibility.

Keywords: Pervasive computing, context awareness, interruption management

1 Introduction

Supporting social interaction while preventing unwanted interruptions may be achieved by creating awareness of each other's activities. MATe, a pervasive ambient intelligent system, supports this task. Digital doorplates can be set up to display status information of office owners and record messages from visitors. Information about coworkers and messages can be queried and displayed on a variety of devices. MATe supports the self-directed coordination of co-workers corresponding to their work as well as their physical contexts [16].

The paper is organized as follows. Section 2 introduces related work by presenting surveys done for similar projects and describing related projects that have been evaluated. Section 3 describes the survey done for MATe and presents the results. In section 4 we briefly describe the prototype of MATe that has been designed based on the survey results. Section 5 offers a short discussion of the prototype and an outlook on future work.

2 Related Work

Context aware assistance at the workplace through use of pervasive tools has been approached in several works. Hudson and colleagues [8] created a model to predict the interruptibility of knowledge workers. As a first step, the feasibility of such predictions was studied through a Wizard of Oz experiment. As a second step, sensors were deployed and the system was tested under real life conditions. While their results only provide data for a certain category of office workers they achieved a promising rate of 75% to 80% correct predictions.

Knox and coworkers have created Scatterbox, a system delivering messages at the right time to the right device depending on a user's context and interruptibility [11]. The research group itself was used as a test group for the implemented system. A follow-up study with 9 students over 20 days was conducted. The participants stated that context aware message delivery was convenient but demanded a different way of thinking about messages [11]. Evaluation of both tests was done by collecting data during the test and by conducting interviews with the users before and after the test.

Cheverst et al. explore the use of digital office door displays with the HERMES-System. It allowed people to place messages on a display outside of their office via e-mail, SMS or manual input on the display. It also allowed visitors to leave private messages for the owner [2].

A more elaborate and in-depth review of work related to the MATe system can be found in Ruge et al. [15].

When analyzing the related work, it became obvious that the first step in creating a pervasive system tailored to the needs of knowledge workers to prevent unwanted interruption and facilitate interaction should be to identify the needs and attitudes of future users. To determine attitudes towards interruptions itself and towards computerized support systems, to understand the effects of interruptions in the work environment and to find strategies to avoid unwanted interruptions, we conducted a survey at several computer science research groups at the University of Lübeck.

3 Survey

The survey consisted of two samples. The first one included 5 researchers at the Institute for Multimedia and Interactive Systems (IMIS) where MATe is developed. The second sample consisted of five researchers from four other research groups at the same university. This study design was chosen to determine whether the results can be generalized to other groups of knowledge workers or whether they are specific to the primary group of users.

All participants were asked the same questions about their (1) working environment, their (2) attitudes towards interruptions, their (3) tactics in avoiding interruptions, and their (4) feelings towards a pervasive system assisting with the coordination of workers. A description of the samples and the main results of the survey can be found in Table 1.

Table 1. Description of the samples and main results

	IMIS	Others
Research Groups	1	4
Persons	5	5
Age	40.6 (29-55)	26.8 (25-30)
Persons per office	1	2.4 (2-3)
Try to avoid interruptions	yes 3; no 2	yes 1 no 4
Avg. interruptions per day	20 (7-35)	18.3 (6-43)
Avg. time lost	90 min (60-150)	45 min (30-60)
Sources of interruptions	Persons at the door (10)	E-Mail (8)
per day	Instant messenger (5)	Persons at the door (3)
	Phone (3)	Phone (3)
		Instant messenger (3)

3.1 Results at IMIS

All research assistants at IMIS are working in single occupant offices. Due to the architectural design of the building, doors are often closed. All offices are located in close proximity to each other and are equipped with phones and computers. Most subjects use instant messengers during work. Asked how information and data used for work reaches them, they answered that they considered electronic and conventional mail to be the most important channels. Informal ad hoc conferences or scheduled conferences are of equal importance.

Unannounced visits of coworkers in the office happen frequently while phone conversations or phone conferences are not frequent. While spontaneous social interactions are considered to be an important social factor by all participants, most do try to shield themselves from interruptions at certain periods. Participants estimate that they are interrupted (on average) 20 times per day. The most common sources of interruptions are phone calls, instant messenger messages and visitors.

Most strategies for avoiding such unwanted interruptions include Post-it notes on the office door or just not reacting at all to knocking at the door or the phone ringing. If the subjects do not want to be disturbed, they stop checking e-mails. Those who use email notification alerts ignore them or switch off the notifications for that period. Most believe, however, that small notifications about a received message are not interruptive.

Participants state that the reason for the interruption (topic) and the person interrupting are the two most relevant factors when judging whether an interruption is worthwhile. Urgency and duration of the interruption are of less importance. Asked how much time they lose from unwanted interruptions the reported time period varies between 1h and 2.5h ($\overline{x} = 1.5$h) per day.

Most participants believe that an interactive doorplate, which displays their current activity, would be useful to reduce the amount of interruptions. Furthermore most participants believe that it would already be useful to simply display "do not disturb" on the doorplates instead of displaying the occupants' activities.

The survey clearly shows that the subjects are not interested in a system that forces them to carry out additional work like setting the doorplates' status information manually or otherwise cater to the needs of the system. On the contrary, the system has to disappear into the usual everyday work-flow. It also reiterates the concern for privacy that users of such systems have. Several participants are only comfortable with a system where they understand which data is acquired for which purpose and who can access it.

3.2 Results from other research groups

In all other groups surveyed the researchers worked in offices inhabited by two or more persons. Most of them worked with an open door (despite a comparable architectural design). The offices are likewise equipped with phones and computers. The research assistants use instant messaging. Some use micro blogging services in addition. These services are then kept open constantly.

Only one out of five participants sometimes tries to avoid interruptions. Even though interruptions average at about the same level as at the IMIS ($\overline{x} = 18.3$), the estimated time lost due to these interruptions is only half the time (45 min.) compared to IMIS. Mail is less important as a mean of communication compared to IMIS but it is still the most important way to communicate. Unannounced visits at the office are on average more relevant than at IMIS but the relevance is spread widely between the different research groups.

Just as the means of communication show vast differences between the research groups, so do the sources of interruptions. While for one participant one third of all interruptions are from the phone ringing, for all other participants the phones do not cause relevant distraction. Altogether e-mail clients, visitors and the phone are considered to be accountable for most interruptions. Notifications about received messages are considered interruptions by three out of five participants.

In judging which interruptions are worthwhile the participants have different opinions. Some consider the duration of the interruption to be the most important factor, while others think that urgency or the person who is interrupting is the best criterion to judge the importance of an interruption. Only two out of five believe that presenting the occupant's activity on a doorplate would reduce the interruptions, but four out of five agree that a "do not disturb" sign would.

3.3 Discussion

Reported introspective beliefs in a survey should always be taken with care. In contrast to the introspective believes of most of our participants, Cutrell and colleagues [3] found empirical evidence that even small notifications can be very disruptive, depending on the performed task. The notion that social contacts are necessary for a productive and positive climate at the workplace is consistent with other studies [7].

All things considered the chosen study design of the survey is limited and does certainly not support the attribution of causes for differences found in between the groups. We are aware of the fact that there are competing explanations for most of the reported differences. One such might be different adoption styles of modern communication and cooperation behavior due to a considerable age difference ($\overline{x}_{\text{IMIS}} = 40.6$ years versus $\overline{x}_{\text{others}} = 26.8$ years) between the sample groups. But the same effect might be as well caused by the difference in the number of persons per office.

The most important outcome with regard to the design of the MATe prototype is that there are differences in workflow and priorities in between the different research assistants. Independent of whether the reported introspective believes are objective, reliable or valid or whether the inter-individual differences could be explained differently, the differences suggest that the system has to be highly adaptable to the users' needs and adjustable to their workspace environment.

4 The MATe Prototype

Turning the results of an analysis into a prototype is a creative and rarely a linear process. We therefore usually follow an entangled approach that combines User-Centered System Design (UCSD, [12]) and Feature-Driven Development (FDD, [13]) to be able to deliver prototypes early and in doing so keep the development process close to the user's needs (see Figure 1 [14]).

The challenging adaptation of the context model to the needs of a specific user group as well as the necessary alterations in the office workspace makes it difficult to apply this approach for the development of the MATe prototype. We therefore had to operate less agile in comparison with our usual projects. To compensate for this we put a lot of effort in keeping the context modeling flexible to allow for easy adaption later on. Before presenting the building blocks of MATe in subsection 4.2 we thus give a brief overview of the state of the art of interruption handling in pervasive systems to demonstrate how we based our context model.

4.1 Context Modeling

To develop a more comprehensive understanding of what we expect from a system like MATe we used the survey and our personal knowledge of the work

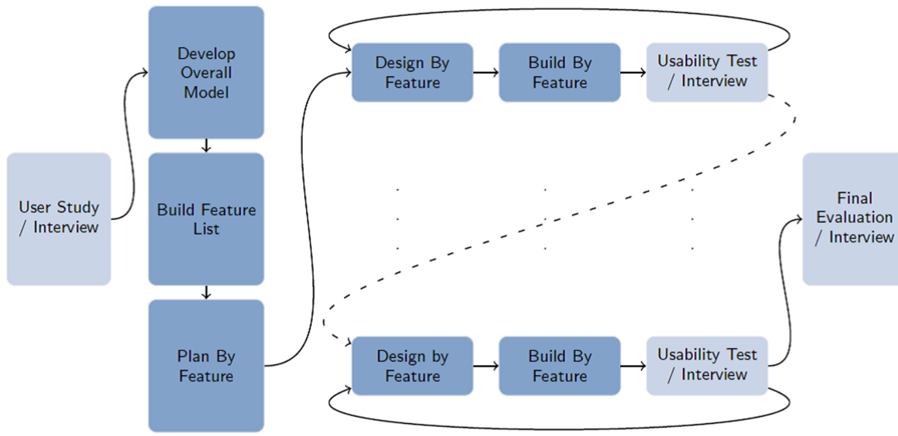

Fig. 1. Entangled UCSD-FDD Process Model [14]

environment at the institute to create scenarios. The primary concern is to "preventing unnecessary interruptions" and (at the same time) "supporting wanted interactions" while dealing with uncertainties and even conflicting data. These scenarios provided a natural understanding of our goal. The scenarios also made apparent that a model of the users context had to be available to the system to provide the demanded services.

Given the results of the empirical study, our modeling of a users' context has to include not just the work environment but the individual needs of the users. At the same time the model should conform to standards and benefit from previous research in the area. We have previously conducted a review of pervasive systems and interruptions [15]. Some relevant conclusions concerning the modeling are repeated here, focusing on the SOUPA Ontology by Chen et al. [1], the ONTONYM-Ontology from Stevenson et al. [18], and the CONON system by Wang et al. [19].

The SOUPA Ontology [1] is designed as a standard ontology for pervasive computing environments using OWL. It draws on the FOAF ontology, the DAML-Time ontology as well as other well established ontologies to create an easy to understand representation of relations, people, places, times and other features relevant to pervasive computing.

ONTONYM [18] is another ontology using OWL-DL to model the context of knowledge workers. The aim is to provide context for pervasive systems like Scatterbox [11] to accomplish context sensitive message delivery. Like SOUPA it uses classes to model the principal dimensions of a users context like people, spaces, sensors and time.

CONON [19] uses user defined context rules to create an implicit context in addition to the modeled low level context. The context itself is also modeled in OWL.

All three systems have in common that they use classes of an OWL or OWL-Like model to describe places, objects and users as well as sensors. OWL-properties specify the characteristics of entities of those classes.

The Basic Ontology For Work Information Exchange (BOWIE) was developed to represent the workspace of the user and exchange information about it across the system. It models all persons, rooms and objects as well as sensors and thus keeps with the design established in previous research.

Sensors are used to represent the characteristics of an entity. As described below, we use the term sensor in a very broad sense ranging from RFID readers sensing RFID-labeled personal items to calendar plug-ins sensing scheduled events. Entities have no properties except their relation to sensors and an identification, instead they are surveyed by sensors that have a value, thus: instead of a birthday being the property of the person, the date is the value of the birthday sensor surveying that person. This makes the model completely adaptable to the specific sensors and data available and useful to the work environment while respecting the users wish for privacy and to not gather information without clear purpose.

To expand the ontology to understand the different way people work the ontology rule language SWRL is used, defining rules of behavior for those sensors modeled in the ontology. For one person the rule may specify that he is not to be disturbed when the system places him in the context called "meeting" while others may not share that rule. A learner is to gather responses from users and change the rules to accommodate the users' needs. Using these rules to establish an implicit context above the modeled structure is also used in CONON [19].

4.2 Implementation of MATe

According to Jones et al. [10], using few sensors may be enough to successfully determine a users' context. As we did not know beforehand which sensors would be best suited in our case, we used XMPP (a lightweight protocol widely used in instant messengers) to support easy addition of new sensors. The MATe prototype as shown in Figure 2 uses the following sensor types: (1) a "DropZone" in every room where users can place a specific personal item that they usually carry around all the time to determine a users' location, (2) instant messengers for status information, (3) online calendars for status and location information and (4) sensors monitoring a users' computer activities (e.g. application in use, URLs currently accessed, etc.). All sources of information are connected via the central service of MATe, the Awareness Hub, which coordinates the routing of information based on the status of the user. The Awareness Hub is connected to sensors and other devices using XMPP.

Determining a users' status is the task of the reasoning coordinator, which draws on context data stored in an OWL-ontology. OWL has been chosen because it has emerged as a quasi-standard for ontologies thus being the first choice regarding reusability.

Using logic-based reasoning and learning techniques to deduce a users' context from aggregated sensor data helps to make the application invisible to the

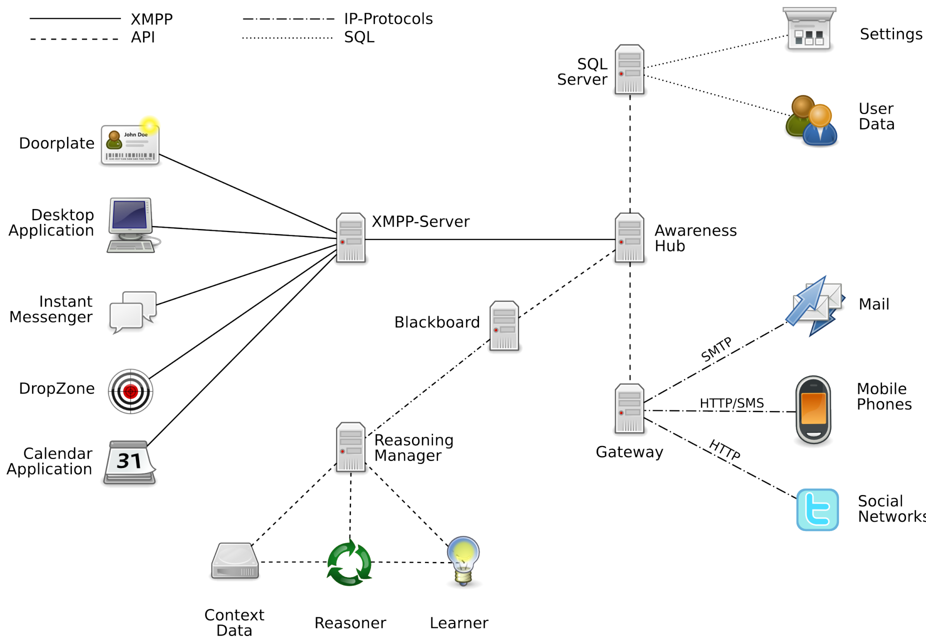

Fig. 2. The MATe System

user as requested in the survey. The inferred context is to be displayed on digital doorplates (see Figure 3) at office doors and optionally on social networks or instant messengers. All these data sinks are updated by XMPP messages from the Awareness Hub. For more information on the MATe prototype and its potential application for other domains see Ruge et al. [15] and Schmitt et al. [16].

5 Discussion

An important lesson learned from the development of the system described here is that a user-centered design process is beneficial for the design of ambient, context-aware systems. This holds not only for the development of the knowledge model, as described before, or the development of the hardware. It also, and probably most importantly, holds for the feature sets the proposed system should have. In our original inquiry we focused on minimizing unwanted interruption and designed the empirical study to gain insight into how knowledge workers deal with interruption of their work process. Within the user-centered design process it quickly became obvious that a much more important aspect is the facilitation of wanted interactions in a manner that they are as little obtrusive as possible.

Fig. 3. Prototype for the MATe doorplate

5.1 User-Centered Design

When we look at the empirical findings, it becomes clear that a variety of methods for dealing with unwanted interruptions already exist: closing the door, ignoring phone calls or knocking on the door. So one remaining question is: what benefits can a complex ambient system give that such technology-light solutions do not? Then again, the empirical findings do support that there are acceptable interruptions: inquiries for information interrupting persons could have easily gained themselves is not accepted as a reason for interruption, but what about inquiries for information that are essential for the interrupting persons work and which could not have easily been found out about?

In addition, the importance of social interaction at the workplace, both as a goal in itself and to aid collaborative work, seems to justify interruptions. Unfortunately, our study design focused on the person being interrupted, and information about the need for and acceptance of interrupting other persons can only be inferred.

In the user-centered design process of the overall MATe system, the focus shifted gradually from avoiding unwanted interruptions to support wanted interactions in a way that fits the needs of all persons involved. So the initial goal – giving other people awareness about when a person is not to be interrupted – was amended with a different goal – giving other people a hint on when and how to interact with other persons while minimizing the impact on the person interrupted.

In this sense, the system described in this paper is much more a general awareness system than an interruption management system. Dourish et al. define awareness as "[. . .] an understanding of the activities of others, which provides a context for your own activity" [4]. For MATe, context is twofold: on one hand, MATe infers the context any given user is in – what activity are they in, are they interruptible or not. On the other hand, MATe is a context provider for the colleagues of this user. In the words of Gutwin et al., MATe provides "Informal Awareness" – "[. . .] the general sense of who's around and what they are up to

– the kinds of things that people know when they work together in the same office" [6].

Connecting the development of the MATe system with its users provided us with the valuable feedback that it is not only important not to be interrupted, but that is of maybe even greater importance to know when and how to interact with a colleague or a group of colleagues. Further research is needed to evaluate the performance of the implemented system in this respect, as well as to guide further development.

To evaluate the MATe prototype we follow a multi-method approach. To determine whether MATe's reasoning subsystem can compete with state of the art systems, we intend to use the data set from Fogarty et al. [5] as a benchmark: will MATe be able to predict the users' interruptibility with comparable or better accuracy? Furthermore a limited field test with only a few offices is prepared. We plan to use Wizard of Oz elements to be able to field-test the use cases and acceptance of the system with the given reasoning accuracy before applying the necessary structural alterations in the whole office space. The main goal is to find out whether MATe is not only able to prevent unwanted interruptions but at the same time able to significantly improve social interaction within the team.

Parallel to that process, software and devices are created that will offer knowledge workers in the research group the possibility to overwrite and correct the derived awareness information of the MATe system by simple interactions. This information can then be used to teach the system to fine tune its derivation rules.

5.2 Further Development of MATe

The MATe system is under constant development. For the time being, there are two main lines of development efforts. First, we are transforming the MATe system into a general framework for the design and implementation of awareness systems. Second, we are introducing new types of sensors and actuators into the MATe system.

By abstracting away those aspects of MATe which are tied to the office worker domain it will be possible to make use of the underlying architecture in other application domains. Application domains under consideration are ambient assisted living scenarios and interactive museum guides, amongst others. The resulting framework is called MACK (Modular Awareness Construction Kit [17]), and MATe is one application making use of this kit.

Part of this development effort is the implementation of a modular communication framework inside MACK. For the time being, MATe employs different reasoners for different questions. While we in this paper primarily look at interruption management, we have other reasoners for different types of questions. One reasoning component is responsible for locating a given user in the environment (in his office, in a meeting room, away from the campus). Another reasoner chooses the best channel of communication for direct messages based on interruptibility information and the inferred location of the message receiver. These reasoners are for the time being very basic production systems. All reasoning components are tightly coupled with the awareness hub, which makes the system inflexible with regard to adding new or alternative reasoners or modifying existing ones.

To better handle this situation and to make it easier to interact with the interruption management provided by the work presented here, the different reasoning components will be loosely coupled with the awareness hub by a simplified blackboard [9]. This component is already depicted in the architecture diagram in Figure 2. The blackboard architecture will also make it easier to integrate machine learning components.

The development of new actuators and sensors happens both user centered and technology driven. As the results of our empirical study show that many users consider it enough to show the interruptibility status, and not the ongoing activity. To cater for these users, we have developed an ambient door lighting system. This system uses a simple traffic light metaphor and illuminates one of the four glass elements typically found in the office doors of the computer science building. Depending on the interruptibility status, the doors will emit either a red, a green or a yellow glow on the outside. The meaning of the yellow light will be determined based on user feedback.

Another component which is to be added in order to facilitate giving feedback to a machine learning system is the DeskCube. The DeskCupe is a combination of actuator and sensor: as an actuator, it can display the system's assumptions about the user's current activity on LED matrix displays on its six sides. As a sensor, it allows the user to give feedback to the system by turning the cube to a more appropriate activity if the inferred activity is not correct. Although primarily driven by the technological need to give feedback to the system, the cube takes into a account the user wishes to not having to use an additional device for setting for example the interruptibility status: active use of the cube will hopefully improve system performance, but is not necessary for using the system.

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