Three Dimensional Context-Aware Tailoring of Information

Author information

Abstract

Purpose The paper explores the notion of context in ubiquitous computing. Personal Information Managers exploit the ubiquitous paradigm in mobile computing to integrate services and programs for business and leisure. Recognizing that every situation is constituted by information and events, context will vary depending on the situation users are in. The paper aims to show the viability of tailoring contextual information to provide user with timely and relevant information.

Design/methodology/approach – An experiment was conducted with testing on a group of real world users. The test group used the application for approximately half a day each and performed a number of tasks

Findings – Results from the conducted experiment show the viability of tailoring contextual information to provide user with timely and relevant information. Among the questions in the questionnaire the users were asked to state whether or not they would like to use this application in their daily life. Statistically significant results indicates that the users found value in using the application in a daily life.

Originality/value – The novelty in this work is a new exploration and implementation of context by integrating three dimensions of context: social information, activity information and geographical position.

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1. INTRODUCTION

Integrating multiple dimensions into a mobile application context is a desideratum often talked about but seldom achieved in practice. In the information communication era we use increasingly advanced technology and we are getting used to be able to acquire the information we want almost anywhere, anytime – a paradigm encapsulated by ubiquitous computing technology. Moreover, as the mobile phone has become a personal accessory it has continuously increased its role and importance in daily life[1], with industry

producing increasingly advanced devices with a rising number of sophisticated functions. In this context, Personal Information Managers (PIMs) [2] have become increasingly popular. A PIM is a mobile device running a complicated operating system and often containing: phone capabilities, camera, calendar, text editor, spreadsheet, document reader and a range of other utility applications. In addition to carrying a PIM or other advanced mobile phone with us almost all time, making links between our daily activities and registered information are increasingly common place. This can range from plotting appointments and tasks in a calendar to automatic information exchange between mobile devices, synchronising, uploading information to web 2.0 sites like Flicker or Facebook, and base station communication. Indeed in our everyday life we face hundreds of different situations and settings every day, and extracting context from ubiquitous applications can potentially have a great influence on the daily use of such mobile devices.

We focus our efforts on integrating context in a mobile phone application realized in a PIM. The uniqueness of this approach is that the prototype merges three independent areas of context into one definition and computation of the user context. Individually, these areas of context have been tested, but never in combination as described in this paper. Additionally, the system developed immediately takes advantage of this information when retrieving and presenting information to the user. To the best of our knowledge, this approach has not been explored previously, and PIM-based integration of location, activity and social information thereby aims to utilize these three different segments of context in earlier unexploited ways.

2. CONTEXT-AWARE COMPUTING AND PIMS

The use of context [3] in the design of applications (or when trying to communicate findings to a research field) is a possible solution to avoid vagueness and misinterpretation, if used correctly. Accordingly, developers and researchers see that context is one important factor when designing new applications. With PIM devices becoming increasingly widespread and in daily use by a large population, this opens interesting possibilities for development. Such applications would potentially be used daily by people in their homes or at their workplace, especially bearing in mind that people carry mobile devices and thereby the application, with them almost 24 hours a day. Several research contributions have looked at

aspects of context being integrated in desktop [4] and mobile applications [5],[6] Similarly to research trying to define context as a term, in this work the definitions of context and the way it is implemented varies considerably. In addition, these applications rely on people sitting down in front of the computer in order to use them. One such example is an application developed by Zhou et al. [7] at the IBM research centre. Here the users' sequential interaction history and their interests form the basis upon which the next step of search for information is built. This is implemented and tested as a desktop application, but the implementation only focuses on 1-2 areas of context.

Others have looked at context implementations used in mobile applications. For example, Ludford et al. [8] looked at the use of context to provide useful information to the user on their mobile phone. In their work, context is based on the location or (and) time of the day. This partly makes use of daily available context information, which however it is not instantly fed back into the system as parameters in information retrieval. Efforts have also been made to make use of context as a tool for supporting business travellers in[9]. The definition of context here as the users' planned activity in combination with the location is quite interesting. This because it generates quite a lot of information about the user, but information is of reduced interest if we have no way of making use of it. Zhou et al. [7] have also demonstrated the use of context sensitive information for the real estate business. These are just two examples out of many and one could only imagine many other possible scenarios. On an overall basis, though, the use of context in applications is often missing. Moreover, the definitions of context tend to be vague and single dimensional. This focus should be changed, since automated PIM applications which take into account the total context of the user would possibly be able to not only support the everyday tasks of the user but also improve efficiency and ease the work of the user by automatically tailor information to the users' needs or adapt the application to the users' current setting.

Towards this goal, Dey and Abowd [10] state that if we understand context fully in a given environment and setting, we would then be able to better choose what context-aware behaviours to sustain in applications. This could lead to more realistic applications and thereby applications more meaningful to users. This is also exemplified by Edwards [11] when he uses context information to build an application. In his application different layers represent different sources of information and they can be

reused in later settings. Edwards argues that context is a major part of our daily life and computing with support for sharing and using contextual information (context-aware computing) would improve user interaction. Indeed when viewing people rather than systems' as consumers of information a new infrastructure is needed. Another approach to create context-aware applications is Zhiwen et al. [16] in their context-aware media recommendation system. The media recommendation applications is a similar approach to what descried in this article in the sense that several aspects of context is exploited. However, a big difference is that Zhiwen et al. base the approach on an ontology approach.

Rounding up, we can conclude that although researchers and developers have tried to implement context in applications, they struggle with how to use the term and their definitions of it vary. If we look at attempts to take advantage of context in mobile phone applications, the results are even poorer and interpretation of context information in such applications is few.

This paper focuses on the use of context in a mobile phone application via its integration in a Personal Information Manager - PIM. The uniqueness of our approach is the use and integration of context information in an earlier unexplored way. As described, previous work has looked at context in mobile applications, all with their own context definition. What makes our approach exclusive is that the implemented prototype merges three different areas of context into a definition and computation of the whole user context. Additionally, the system immediately takes advantage of this information when retrieving and presenting information to the user. To the best of our knowledge, this is until now an unexploited approach. This is the precise focus of this paper, which concentrates on the multi dimensional association of location, activity and social setting on a PIM representing a new realization of context in mobile applications.

3. DESIGN

3.1 PIM Application design

This application presents information relevant to the users' context. To be able to do this, system design and functionality are split into three main modules, each of which generate context-aware information. This enables

the precise definition of elements and thereby tailoring of information to be displayed according to the users' needs. One of these main modules handles activity, one handles social context and the third handles the geographical location. The input from all three sources together provides the foundation for the user context computation. By this operationalization of context and context-aware concepts we are able to create a user context. This user context is the foundation upon which the application takes action to present information to the user (Figure 1). We now proceed to provide further details of each of the three modules involved in our PIM application.

Take in Figure 1

3.2 Social Context Module

This module computes the foundation upon which the social context is determined. Social context will naturally differ tremendously based upon each situation and for each individual. Still, it is possible to use one social context in common by several people by choosing concepts that are interpreted the same by most people. This is achieved through building a taxonomy scale of concept terms illustrated in the table below.

Table 1: Taxonomy of social context

Categories:	**Leisure**	**Work**	**Travel**
Sub categories:	Shopping	Meeting	Train
	Cinema	Preparation	Car
	Spare time	Own time	Tube
	Food	Travelling	Foot
	Culture	Phone meeting	Transport

Building on the description of activities from Prekop and Burnett [12] information of the social context in the application are stored and meta-tagged as Pocket Outlook activities / appointments. These tags are based on the above taxonomy and are implemented for the user through extending the standard Pocket Outlook category interface by programming in the Pocket Outlook Object Model. Thereby the user can enrich (tag) the activity with category tags through a familiar interface and thereby greatly

increase the familiarity of the system. The following screenshot shows this interface.

Take in Figure 2:

3.3 Geographical Location Module

This module calculates location based on input from the internal GPS in the device. Through configuration of the internal communication port (COM port), communication with the GPS receiver is established. When a valid connection through the GPS device to a GPS satellite occurred it returns a String with longitude and latitude coordinates to the application. The input String from the GPS is then parsed and the actual location retrieved by inspecting the longitude and latitude coordinates. These coordinates are then mapped to a specific zone (in our case, Oslo, Norway). Currently the city for testing, Oslo, is divided into 16 zones based on the city regions [13] as described in official maps that outline the size and border of the zones. As the user is moving, information about current zone is updated and stored in the application.

3.4 Activity Module

This module communicates with the Microsoft Pocket Outlook storage on the mobile device and retrieves appointments and activities. The module accesses the Pocket Outlook storage directly and also listens to system events in this storage.

3.5 Architecture

The application prototype is designed in accordance with the layers principle, thereby separating the different main parts of the system. The figure below shows the main building blocks of the application prototype. Excluded from the figure are the supporting modules e.g. GPS communication, data transport, permanent storage access etc.
One important part in the application is the computation of user context. This computation needs to be done each time the user has moved (more than 40m) or when there is a change in appointment. One exception from this is when the user is in a busy state i.e. in a meeting and the current activity is marked with a tag indicating no disturbance accepted. The

actual computation is based on the three dimensions of social-, activity- and geographical information. If information exists for an ongoing activity with the collected social information at the current location, this information is presented.

Take in Figure 3:

4. PIM Application prototype

An application prototype was developed using C# and implemented in a Windows Mobile 5.0 environment on a HTC 3600 PDA phone [14]. The phone is running on a Samsung 400 MHz processor with 128 MB ROM and 64 MB SDRAM. The phone has large communication capabilities with the ability to communicate over GPRS, EDGE, 3G, WLAN, GPS, IR and Bluetooth [9]. To be able to acquire this information, the application has made method calls to the PIM storage area using the available Pocket Outlook Object Model (POOM). This interface allows for retrieval and manipulation of information from the storage. To constantly have this information updated, the application listens for events that are generated when an activity ends and a new one is started.

4.1 Prototype PIM application

The developed application realises several needs, all of which combine to integrate a three dimensional view of context in a modern PIM application:

A) *Context, activity collected from PIM storage:*
Take in Figure 4 below shows how social context, represented as activity information, is retrieved and displayed to the user. To be able to acquire this information, the application has made method calls to the PIM storage area using the available POOM. This interface allows for retrieval and manipulation of information from the storage. To constantly have this information updated, the application listens for events that are generated when an activity ends and a new one is started.

Take in Figure 4:

B) *User context must be computed and contextually relevant information presented to user:*

The underlying computation of context is the core module of the system. This module is responsible for coordinating the presentation of information to the user. This is done on the basis of context computation, which is carried out:

- At system start-up
- When the GPS registers a new valid position and the user has moved a minimum of 40 meters since the last stored position

Take in Figure 5:

– When activities change so that a system event is generated and triggers the process. The whole process from event generation until new event is presented to the user is illustrated in the sequence diagram (Take in **Figure 6**).

C) *If instructed, intercept all incoming events and afterwards produce summary of blocked events:*

There might be instances where the user can be in situations where disturbances are unacceptable. One such occasion might be in a business meeting. In such occasions the social context can be the weighting factor forcing the application to suppress an event which otherwise would have been generated based on location and activity. If the user is in this particular context, the application will also suppress incoming SMS messages. When the user is freed from the busy state s/he will want to know what s/he has missed. At that stage, the application will therefore produce a summary of events to the user (Take inn Figure 5).

Take inn Figure 5:

The application needs to comply with Microsoft Compact Framework:

This requirement is an underlying premise for the whole application development. If this is not taken care of, the application will simply not run. All source code components are run both in a Microsoft Windows Mobile Emulator and on the PIM device, both powered by the Windows Mobile 5 operating system.

4.2 Computation of context in PIM

The integration of multiple dimensions into one mobile application context exclusive to a particular user in a particular situation is the unique concept of this application. To be able to better describe the actual computation of the user context and be able to describe the inner composition of the algorithms, the following variables are used: α describes social setting, β describes location and γ describes current activity. The function f of context can then be described as follows:

$Context = f(\alpha, \beta, \gamma)$
$\alpha = \{c_i \mid i = 1\text{-}5\}$ *(As described in section 3.2)*
$\beta = \{p_i \mid i = 1\text{-}16\}$ *(As described in section 3.5)*
$\gamma = \{a_i \mid i = 0 - n\}$ *(As described in section 3.4)*

Based on this algorithm we can apply rules for each situation and thereby have the system act differently in each unique situation. In a given situation context can be composed as follows:

$$Context = f(\alpha, \beta, \gamma)$$

$$\alpha \in \{c_{i,j} \mid i=1\text{-}3, j= 1\text{-}5\}$$

Where $c_{i,j}$ is all elements of the context activity matrix (Table 1 of section 3.2). For instance, $c_{2,4}$ would represent travelling on work related activity.

$$\beta \in \{p_i \mid i=1\text{-}16\}$$

Where p_i is one of the city zones of Oslo, as described in section 3.5

$$\gamma \in \{a_i \mid i=0\text{-}n\}$$

Where a_i is a possible activity / appointment in Outlook, as described in section 3.4, figure 7 illustrates the concept.

Figure 8: Detailed context computation

Let us assume the following scenario: A user is approaching the the railway station and the system identify activities and position before it actively computes the user context and identities what information could be relevant. The following steps are carried out:

1. The users' activities are constantly monitored by the application and rules for possible context match are employed. In this figure

the user approaches the train station and triggers a context computation.

2. The system needs to acquire information on which it will base the computation. It first collects the users social setting which in the situation is travel by train.
3. Next it verifies the users' position, and in our example s/he is placed in Zone number two, at the railway station in the city centre.
4. The application communicates with Microsoft Outlook through the POOM API and extracts the upcoming appointment. For our user here the appointment is transportation to the stadium where s/he is going to watch a sports game.
5. Based on the three acquired context parameters the system tries to apply the computation rules using the algorithm to see if there is any match. For our user here such a match exists and the action taken from the system is to automatically set the user in contact with the ticket reservation office at the stadium.

5. Evaluation and discussion

5.1 User evaluation

Evaluation of the developed prototype was accomplished by having 15 persons between the ages of 21 and 38 use the application for approximately half a day each. Users had to physically move between different geographical locations while performing simulated daily activities

When each test candidate started, s/he was given a document with a list (Table 2) of activities / tasks that had to be entered in the Microsoft Outlook calendar on the device.

Table 2 List of activities to be entered in Pocket Outlook

Subject	Location / Zone	Start	Categories	Comments
Train at central station	2	12:00	Travel, train	
Shopping at Oslo City	2	+20'	Leisure, shopping	
Meeting at company X	1	+20'	Work, meeting	Sensitivity private
Sightseeing in Old Town	1	+20'	Travel, foot	

Tour at Munch Museum	4	+20’	Leisure, culture	
Coffee break at St. Haugen	5	+20’	Leisure, food	
Shopping in Bogstadveien	5	+20’	Leisure, shopping	
Travel from Frognerparken to Solli plass	3	+20’	Travel, transport	
DNB Nor Solli plass	3	+20’	Work, meeting	Sensitivity private
Government	2	+20’	Work, preparation	
Central train station	2	+20’	<None>	Route stop

This was accompanied by a map showing five
of the Oslo city zones used in our experimental evaluation and detailed route (Figure 8).
that the participants should follow. A short user manual on how to operate the mobile phone was also handed out.

Take in Figure 9

All activities entered into the calendar were meta-tagged by the users with a social context category. After this s/he would start moving according to the route and along the way the application would keep track of current and upcoming activities as well as current position. When position and activity matched, the application also checked the social category before taking appropriate action. If the user was in a context setting available for receiving information, this would be pushed by the device. Otherwise, if the user was in a busy mode, or otherwise not to be disturbed, the device would cache all events and incoming SMS’s thereby leaving the user alone. Once the user returned to normal mode, a summary of missed events would be displayed.

5.2 Questionnaire

Users had to complete an evaluation questionnaire after the testing (Table 3).

Table 3: Questionnaire

1	The information provided by the reminder system correctly matched my current location
2	The information provided when I was "Sightseeing in old town" was incorrect.
3	The summary of blocked events I received after appointment "DNB Nor Solli plass" was useful
4	The system provides duplicated information
5	I liked the fact that the application is integrated with Outlook
6	The reminder system is useful
7	I would use this application in my daily life

In all questions in the questionnaire, the users were asked to state whether they agreed or not to each statement. The possible answers were: *Strongly Disagree (SD), Disagree (D), Mildly Disagree (MD), Mildly Agree (MA), Agree (A)* and *Strongly Agree (SA)*. Each possible answer from *SD* to *SA* was mapped to a number from 1 to 6, respectively, and the responses thus received were analyzed using a T-test (Table 4). We will in the following sections elaborate on the implications of our evaluation exercise.

5.3 Results

User responses to the evaluation questionnaire are summarized in Take in Figure 6 below. The feedback from these questions would be able to give at least partly answers to how the application behaved. The most important thing in a context related application is that the information displayed actually matches the current user context.

Table 4: T-Test results

Question	Mean Response	T-Value	P
1	4.80	8.088	0.000
2	2.47	-1.054	0.310
3	3.73	1.585	0.135
4	2.73	-0.654	0.524
5	5.47	12.854	0.000
6	5.20	12.602	0.000
7	3.93	3.287	0.005

From Table 4 we can see that all answers display a positive bias (Questions 2 and 4 are in fact negative statements about the application, therefore the negative bias here, reflects positive user statements). In question 1, 14 out of 15 answered that information displayed did match

their current location and the responses are statistically significant. This would indicate a correct computed context and correct displayed information on an overall basis. For question number two, 11 out of 15 respondents were negative to that the information being displayed in one appointment was incorrect. This indicates that 11 got, at least partly, displayed correct information and four had incorrect or no information displayed. There is thus a strong bias towards negative answers, a few (4) positive answers and no middle values (MA / MD). This polarization of results however leads to the data for this question not to be statistically significant.

Take in Figure 6:

The application's ability to block events (question three) and present the information later at a more appropriate time for the user was also measured. The test group is divided in their answer but a majority of 10 of out 15 thought of it as useful. This answer is also likely to be influenced by personal preference.
Another element important to take notice of in a system providing information is duplicate messages (question four). In this experiment, although 10 out of 15 persons state that the application does not provide duplicate messages, almost the whole scale of possible answers are used and again explains why responses are not statistically significant.

As described, the application prototype is adaptable to different scenarios and user settings, but a context dependent application needs to be tailored to the users' need when being deployed for a real life setting, e.g. the initial categories and their weight need to be configured. This can be solved using a wizard following the installation of the application on the mobile device. The reason for this is that the application currently does not have the ability to adapt from the users action, nor is it particularly easy at present to choose information services to be displayed to the user automatically. This is in accordance with the findings of Prokop and Burnett [12] which state that it is very difficult to determine environmental information sources. Almost every source of information would need to be tailored or have a custom interface written in order to be able to deliver its services to the application. When these issues are taken care of, the user experience might improve and increase even more the positive trend in answers to question six and seven. Moreover, as shown by Zhou et al.[7], information tailoring is an important task to help users interpret data. Our

application focuses on tailoring by having minimal information displayed at the same time, when new messages are shown, thereby easing the users' interpretation.
Currently calendars and applications based on these do not take multi contextual information into account ([15] and [1]) as they often only reproduce the information already available there. Thereby, this can at worst lead to incorrect display of data and at the best a reproduction of data in a new interface. Our developed PIM application greatly differentiates from this by only displaying information based on the computed user context, given by the three factors social context, location and activity / appointment. Earlier approaches that have made use of calendar data from Pocket Outlook, often end in using Pocket Outlook data together with a simple timeline (i.e. [3]). In our approach, the use of Pocket Outlook data is extended to not only retrieve and display the data, but also to add extra meta-information to the appointments. Results from question five show that all respondents stated they liked the integration of the developed PIM application with the Outlook calendar. This is important because it shows they had no problems with entering an appointment in one application, and having information displayed in another application (the prototype).

In the evaluation exercise, generation of information was tightly connected with the actual task at hand and participants were asked to judge whether or not they found the application useful (question six). Our results show that all 15 users involved in the evaluation thought the application gave useful value. This would indicate that the reminder system is an application with practical use for the users. One other side of usefulness is the behaviour of the device and the application. Therefore each was asked to evaluate these parameters as well in question six.

As a final question, after the test, the users were asked to state whether or not they would like to use this application in their daily life. As the t-test shows, the results for this question are statistically significant and one should note this indicates that the users found value in using the application in a daily life.

6. Conclusion

Context and context-awareness have long been acknowledged as important and have generated considerable research effort. However,

integration into PIMs has so far been limited and the perspective has often been single-dimensioned. In this paper the design, implementation and evaluation of an application prototype which integrates context / context-awareness into a PIM from a novel three-dimensional perspective combining social-, geographical- and activity information has been presented. User evaluation of the proof of concept displayed a strong positive bias, highlighting its potential usefulness and applicability. Based on the developed prototype, we have shown the viability and usefulness of our approach and we do believe that tailoring information in the manner described in this paper takes the PIM concept one step further towards the ideal of providing tailored and timely information to mobile information users everywhere.

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