There is more to Context than Location

Environment Sensing Technologies for Adaptive Mobile User Interfaces

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Abstract

In this paper we analyze the usage of sensors to improve application of ultra-portable mobile devices, such as personal digital assistants (PDAs), wearable computers, or mobile phones. Ultra-portable devices are characterized by being operational while on the move, and have in common that they are used for different tasks as well as in varying environments and situations. We discuss the concept of context to capture conditions in the usage environment of mobile devices, stressing that there is more to context in mobile computing than location. We motivate key application domains for exploitation of context-awareness, and propose to use environment-sensing technologies for automated context recognition. As example implementation we describe improvement of a PDA user interface based on orientation-sensing. Finally, we propose to use combined sensors for recognition of higher-level contexts beyond specific physical conditions.

1 Introduction

Over the last years, small and mobile devices have become more common for support of users in their work environments and everyday life. To distinguish these devices from mobile computers such as laptops, we use the term ultra-mobile devices:

<u>Definition</u>: *Ultra-mobile devices are computing devices that are operational and operated while on the move.*

Commercially available ultra-mobile devices comprise most notably personal digital assistants (PDA), handheld PCs and mobile phones. These devices are designed to support users in different environments and different situations. We propose that user support can be improved significantly if the devices have knowledge about the environment and situation of their usage, for which we use the term context.

Context in general is defined as the "interrelated conditions in which something exists or occurs". Most things in life - private or professional - happen in a certain context. That means that most tasks users perform are not isolated from the interrelated conditions. Contexts can be considered at different levels of abstraction. At a higher level of abstraction we consider for instance “*in a meeting*” as context. An example for a lower level context is “*it is cold”*. Knowledge of context, that is context-awareness can be exploited for adaptation to the environment, and most notably adaptation of user interfaces to given conditions in a specific situation. As to yet, though, context-awareness is hardly applied in mobile user interfaces. As in computing in general, the only context commonly used is the set of applications the user is working with.

An obvious context to exploit in mobile applications is location. Most mobile computing research though has rather gone into hiding location rather than exploiting location [1], focussing on facilitation of “desktop computing away from the desktop”. Nonetheless, there are successful applications of location-aware mobile computing, most notably navigation systems based on GPS sensors (e.g. [2]). Other examples are the NaviCam [5] and active badge systems [1, 3, 8]. Going beyond location very little research on context-aware mobile computing has been published [6]. Yet, we would argue that location is but one dimension of context, as further discussed in the next section. Following that discussion, we will address the issue of using sensor technology

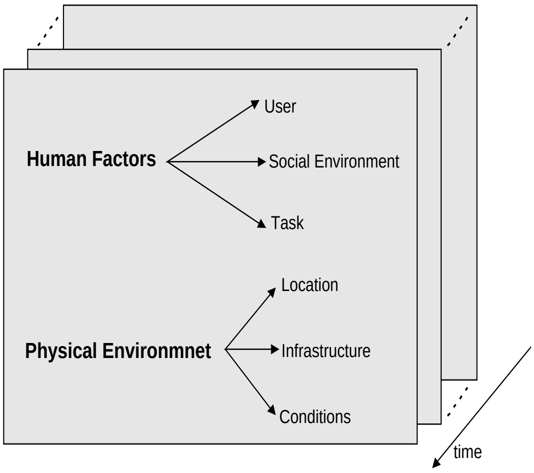

Figure 1: Context Classification

for facilitation of context-awareness, and discuss an example implementation of a context-aware mobile user interface.

2 Context

To structure the concept of context, we propose two general categories, human factors and physical environment, with three subcategories each. Orthogonal to these categories, history provides additional context, as shown in Figure 1.

The human factors are structured into three subcategories: information on the user, on their social environment, and on their tasks. Information on the user comprises for instance knowledge of habits, mental state, or physiological characteristics. The social environment is characterized by proximity of other users, by their social relationship, and for instance by collaborative tasks. Finally, tasks define goal-directed activities, or on a higher-level of abstraction general goals of users. Regarding the physical environment, we distinguish location, infrastructure, and physical conditions. Location can be regarded absolute (e.g. GPS-coordinates) or relative to other objects (e.g. inside a car). The infrastructure describes the surrounding computing and interaction environment, for instance devices that mobile application can adapt to for e.g. improved access. As third category of context regarding physical environment we propose physical conditions, such as level of noise, brightness, vibration and so on; these conditions can be fixed (e.g. outside temperature) or changeable (e.g. light conditions inside a room).

To gain an understanding of the current context knowledge of previous contexts is very helpful. Patterns of user-activity can be matched with a context history to provide additional information to calculate a new context.

3 Application Domains

Context-awareness, that is the facility to establish context, can be exploited in many application domains. With respect to applications of ultra-mobile devices, we have identified three domains of particular interest:

- Context-aware communication: provision of communication while on the move is a key application of ultra-mobile devices, most notably of mobile phones but also of PDAs and emerging technologies such as wearables.
- Context-aware application selection: ultra-mobile devices such as PDAs and wearables are designed to assist their users with all sorts of tasks; context-aware selection of appropriate assistance applications would extend assistance capabilities and improve ease of use.
- Context-aware UI modes: ultra-mobile devices are supposed to be operational in largely varying situations, imposing varying requirements on human-computer interaction, and hence adaptive user interfaces.

Context aware communication

Information overload has increased, as easy and cheap means of communication have become more widely available, especially based on Internet technology. Furthermore the automation of communication, such as mailing lists, increased the information and communication load on the user. Different researchers have already investigated these topics (e.g. [4]), mostly considering user profiling based on evaluation of application usage patterns. Regarding applications of ultra-mobile devices, context-awareness ans in particular awareness of the real-world environment can be exploited for context-based information and communication filtering. Examples of such applications are a context sensitive todo-list or different modes for information/communication delivery appropriate in a given situation.

Context aware application selection

The size of the UI for most handheld devices is very limited and the navigation through numerous menus and sub-menus is usually awkward, so that automated selection of applications becomes highly desirable to improve ease of use. Based on context-awareness, applications likely to be required could be identified:

Context	*Application most likely*
Walking to the bus station	Bus schedule
In a shop	Shopping list
In a telephone box	Phone numbers

Context-aware application selection may be implemented in different ways to improve ease of use. It may go as far as invoking selected applications automatically, or it may be used to simply ease access to applications that are likely to be required, for instance by putting a handle for direct access on the screen.

Context Aware UI modes

For stationary computers it is well known how to construct an ergonomic user interface. The input and output modalities are already determined when a computer is installed, in accordance to the preferences of the user and the usage environment of the computer. For ultra-mobile devices this task is much more difficult, as they are used in different contexts, as pointed out above. For optimized human-computer interaction, the UI should be adapted to the context. An example is the usage of a device like a PDA or a wearable on the move. The size of the font and the display mode should be adjusted to requirements imposed by the environment, for instance lighting conditions and vibration. Another interesting aspect is adaptation is for example context-aware recognition of handwriting in pen-based mobile devices, as handwriting on a moving train is quite different from handwriting at a desk! Further, privacy settings in devices can also be adapted to contexts such as *it is crowded*.

4 Sensor Based Context Awareness

The trivial way to sense context is to ask the user in what context he or she is, but we will not consider this case here. Another common method to derive information about certain parts of a context is to monitor application usage of users.

Another approach to acquire context information is to make the environment smart, so that it can supply context information to mobile devices and applications. Examples of such systems are active badges [1, 8] or locust swarm [7]. On a larger scale the GSM network infrastructure, or even on a global scale the GPS system establish smart environments that provide context information to mobile devices. Most of these examples use location, which is only one aspect of context, to enhance their applications and devices [2, 5]. Further, some context information can be derived from communication among devices, for instance co-location, user proximity, and available infrastructure.

Another option for implementation of context-awareness in mobile applications is to equip mobile devices with environment-sensing capabilities. This is quite in contrast to smart environments as it rather smartens up mobile devices than their usage environment, providing for context-awareness in any environment. For the remainder of the paper we will focus on sensor-based context-awareness with description of an example implementation and consideration of sensor-based recognition of more complex contexts.

5 An Orientation-aware adaptive PDA User Interface

In this section we describe a small project that was carried out to demonstrate some of the given ideas on a very basic level. Considering the basic context *device orientation* we show that employing an extremely simple sensor can have significant effect on the human computer interaction.

Displays often have a rectangular shape with different length and width. Therefore it is possible to display documents and objects in landscape or portrait. For a stationary computer (e.g. a workstation with a 21” screen) this is less important – a document can be displayed in both ways with good quality on the screen. But considering handheld devices with very limited screen real estate the orientation can be of significance for the user. Looking at handheld-devices with pen-interface, some of them offer the functionality to switch the display orientation mode.

An example of such a computer is Apple’s Newton MessagePad which has a screen of of 13 x 9 cm. The operating system supports to switch

Figure 2: Using the orientation-aware device in different modes.

the orientation of the display in all four directions. This feature is built in but as far is we know, it is hardly used. The main question that arose was “how can the device sense what orientation the users wants”? Considering the usage of ordinary (paper) documents we saw that people take a sheet of paper landscape or portrait – whatever suits them more in that situation. Switching from one mode to the other occurs just by turning the page. In our implementation we build this usage paradigm into the Newton MessagePad by enhancing it with a simple orientation sensor, based on two mercury switches. With this simple extension, the screen orientation is adapted to device orientation whenever a stable change in orinetation is sensed.

Using a web browser on a PDA it often occurs that there are pictures that do not fit inside the display due to the used aspect ratio. The conventional way of dealing with this is to scroll to see all of it. With orientation-awareness, users get a simple and easy way of changing between portrait and landscape users just by turning the PDA so that the picture aspect ratio and the display orientation match best, see Figure 2. Another example where orientation-awareness can enhance the usability of PDAs is a spreadsheet application. The user can by simply turning the device displaying either more rows or more columns, whatever is more appropriate for the current data.

6 Sensing more Complex Contexts

The above described example demonstrates that simple sensors can improve usability of mobile devices. Our further research though aims at sensor-based recognition of higher-level contexts, such as *in a meeting*. One approach to recognition of more complex situations is machine vision, based on rather expensive camera technology and image processing. In contrast, we aim at recognition of more complex contexts by combining different rather simple sensors from which cues can be obtained, from which in turn more complex contexts can be derived using AI technologies. We are currently investigating this approach in ESPRIT project TEA (Technology for Enabling Awareness, EP26900). First experiments investigate recognition of different situations in an office environment and of recognition of travel context, in particular modes of transport, considering applications in mobile telephony and in personal digital assistants. Beyond TEA, we consider use of bio-sensor to obtain further context about the user. The user acceptance of such intrusive sensors is not yet determined, but our experience is that people react quite reserved towards this issue.

There are still more open issues regarding recognition of complex context to than answers. Our research focus is on the following issues:

- What kinds of sensors are essential to recognize complex contexts?
- How much (or rather how little) intelligence is required to recognize complex contexts ?
- How can the construction of complex contexts from simple contexts be automated?
- Where are the limitations for context-awareness?

Another host of questions arises around the change in usage paradigms that may be facilitated by sensor-based context-awareness.

7 Conclusion

Context-aware adaptation is an essential concept for ultra-mobile devices. Devices that are used in different situation can be significantly enhanced when they can obtain context. To structure the approach we classified the term context. We showed that context has many dimensions and is more than just location. For recognizing contexts we proposed the usage of sensors. In a case study we showed that it is useful to recognize simple contexts such as orientation with sensors. Beyond we considered the issue of recognizing more complex contexts and proposed combination of simple sensors and a two-step recognition approach, which we currently investigate in ESPRIT project TEA.

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