AUTOMATIC CONTEXT DETECTION OF A MOBILE USER

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Abstract: Mobile devices have obtained a significant role in our life providing a large variety of useful functionalities and features. It is desirable to have an automated adaptation of the behavior of a mobile device depending on a change of user context to fulfill expectations towards practical usefulness. To enable mobile devices to adapt their behavior automatically there is a need to determine the mobile user's context.

In this paper we introduce an integrated approach for the automatic detection of a user's context. Therefore, we summarize and discuss existing approaches and technologies and describe a service architecture that takes into account information from the interaction of the mobile device with communication networks and positioning systems, from integrated sensors, and planned behavior of the user from e.g his calendar or activity list. Additionally it considers the social network of the user to derive further information about his context and finally it takes into account his customs through a behavior model.

1 INTRODUCTION

The omnipresence of mobile devices requires the ability to adapt the device's capabilities. Simple implementations of this feature are already in place in most common mobile devices. So the user can limit the usage of the device's interaction features for example muting the ring tone, deactivating the network interface radio, etc. To simplify the configuration the settings are often grouped into configuration profiles, so the user only has to select a defined profile and gets a suitable setup for a situation. In real environments the context continuously changes and therefore it is desirable to support automatic detection of the user's current context. This would increase the usage comfort due to improved adaptability of the device. As an additional feature the current context of the user in combination with his current position can be used to improve the location based services by providing this information to the service.

In this paper we discuss existing and new approaches to determine a mobile user's context. We analyze their prospects, possible drawbacks and the technical requirements. The paper is organized as follows, in Section 2 we illustrate a simple example scenario from the domain of discourse to motivate our research. In Section 3 we give an overview of existing work in this area. Section 4 discusses the configuration space of a mobile device which should be adapted to individual context. In Section 5 we focus on existing approaches and introduce some new ideas to determine a mobile user's context and in Section 6 we describe the architecture of our idea of an integrated approach for context detection. Finally in Section 7 we summarize the results and describe our vision for future development.

2 SCENARIO

The following example scenario motivates the automatic detection of a user context and provides the reader with an overview of the arising problems.

Imagine a researcher who travels to a distant city (e.g. Milan, Italy) for a conference. Therefore, the researcher has to proceed along a chain of activities. So, he prepares for the trip at Sunday evening, goes to sleep, gets up at Monday 8:00 am, takes a shower and has breakfast with coffee, takes the bus at 9:12 am to the train station, arrives there at 9:34 am, waits until 9:46 am, takes the train to the airport, arrives at 10:34 am, checks in for his flight, gets a coffee, waits until 12:45 pm, boards the airplane, gets another coffee and lunch, and prepares the slides for his conference presentation. The plane touches down at 2:30 pm, he leaves the plane 2:39 pm, picks up his luggage at the baggage claim, leaves the airport, takes the metro, walks from the metro station to the hotel, checks in at the hotel, takes a shower, takes dinner

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at the hotel restaurant, drinks an espresso and joins to the initial meeting with the other researchers in a conference room. At this point we leave our fellow researcher and state that his context changed at least 20 times until this point.

The common researcher is very busy thinking about his research work, so it is very inconvenient for him to always keep the context setting of his mobile device up to date. But it would be preferable that the mobile device itself adapts automatically according to the situation. For example, disabling all radio systems of the mobile device during the flight, switching the device to silent mode and enabling visual signals (a flashing light) for incoming calls and messages during the meeting, but deactivating vibration alarm because the device is on the table and not in the pocket, switching to a louder ring tone and vibrating alert in the metro, changing the input mode from pen to finger touch and the output mode to speech synthesis and symbols while walking or driving. But also travel assistance like information about the exit station just before arriving there or information about the menu of the hotel restaurant at dinner time could be provided.

3 STATE OF THE ART

The state of the art for context detection is to use one kind of specialized sensor either attached to a person or located in several different places across so called smart rooms. For example (Karantonis et al., 2006) uses only one accelerometer to detect movement of the user. (Kern et al., 2003) use multiple identical accelerometers to detect activity context information. In most cases where different sensor types are used, each type of sensor detects a certain kind of context for a certain kind of purpose. Only very recent research works use more than one sensor type to recognize a single context, e.g. (Berchtold and Beigl, 2009), where an accelerometer and a microphone are used to recognize "knocking on the table in appreciation". Currently most research approaches, as (Ranganathan et al., 2004) and (Brdiczka et al., 2007), use pattern recognition instead of programmed rules to derive contexts from sensor information.

One of the current theoretic challenges is to find a standardized description and definition of context. (Dey, 2001), for example, gives an operational definition of context whereas (Henricksen and Indulska, 2005) defines conceptual models for context-aware applications. A survey of context modeling approaches is given in (Strang and Linnhoff-Popien, 2004), but often researchers use their own definitions.

In the last years the uncertainty aspect of context detection got more and more attention because with pattern recognition methods the detection is never entirely certain and applications can use a context detection service better if they get real time information about the quality of the detection. Examples of work in this research area are (Berchtold and Beigl, 2009) and (da Silva et al., 2006).

4 DEVICE CONFIGURATION

The device configuration space consists of all possible configurations of a given device. To effectively manage this configuration space of a device profiles are used which are preset configurations combined with a suitable name.

Some of the settings from a device configuration space are listed here to help the reader get an impression of configuration possibilities of a mobile device. For example, as output modes the user can choose among icon or text based representation of a content, or even voice synthesis. Furthermore, for the textual and graphical output the text size and screen direction (portrait or landscape) can be configured, and for voice synthesis the volume and perhaps a few additional characteristic parameters can be adjusted, e.g. speaking speed, the pitch and timbre of the voice or the gender of the speaker. As input modes the user can choose for example among a microphone with voice recognition, a touch screen (finger or pen mode), or the traditional key-pad. There are also many additional settings, e.g. microphone and touch screen sensitivity, etc. As general behavior settings the user can configure the ring volume, ring tone, screen brightness, earphones volume, and so on.

5 CONTEXT DETECTION APPROACHES

Today the predominant way to adjust a mobile device to a changing context is that the user configures a set of different profiles for his device in advance and later selects the suitable profile for his current context. If the context changes very often it is inconvenient to make such adjustments manually. Thus, it is desirable to automatically detect the user's context and adapt the configuration of the device accordingly. In the following we briefly discuss several approaches to determine the context of a user.

5.1 Planning

A very simple approach to context detection is to deduce it from the digital calendar, that contains all the events and trips the user has planned. Each event may consist of several activities. Since the classical calendar functionality is provided by many mobile devices, especially smartphones, the scheduled events and trips are already available for further processing. Therefore, the actual time is used to determine the corresponding event from the user's digital calendar. The actual context of the user can be deduced from the description of the event, e.g. meeting, flight, etc.

5.2 User Behavior Model

This approach is based on the assumption that user behavior is to some degree consistent. So, for example the user goes to bed at almost the same time every day and he has lunch at a specific time. From this we derive that user behavior can be defined as the correlation of time, space, activity and context. Consequently, the user behavior can be deduced from his past, by observing former behavior tuples and matching them to the current situation (Sama et al., 2008) (da Silva et al., 2006).

5.3 Radio Signals

Mobile devices are able to interact with several communication networks and there exist several approaches to derive the precise position of a mobile device from the interaction with these communication networks, like GSM (Kunczier and Anegg, 2004), UMTS/3G (Kos et al., 2006), and WLAN (Jan and Lee, 2003) (Krempels and Krebs, 2008); all of them providing localization estimations with acceptable accuracy.

The context of a mobile user can be derived from his position. For that purpose the geographical position must be processed by a *GIS (Geographical Information System)* to obtain additional information about the user context, e.g. street name, building name, or name of a point of interest. From the type of building, e.g. train station, the user context can often be derived directly. If the localization accuracy is high the user context can also be determined in a more detailed manner, e.g. if the user is in a restaurant or in the business lounge inside the train station. This additional information can be used to detect time shifts or schedule deviations in conjunction with plan based context detection, as discussed in section 5.1.

5.4 Sensors

The majority of todays mobile devices have a number of different sensors at their disposal. Most of them are only built in to serve for one or two special applications but they also can help to determine the user's context.

Accelerometer. The accelerometer not only measures acceleration of the device but also how the device is tilted. It is possible to match the movement pattern of the device to certain situations, such as the device is in the user's hands, laying on a desk or held to the user's ear. While in the user's pocket it is also possible to decide for example if he is walking, running or sitting down (Karantonis et al., 2006).

Camera. The camera's use for detecting user context is limited because most of the time when automated context detection is needed the mobile device is in the user's pocket, but sometimes it can be used for image recognition (Luley et al., 2005). For example it can help to determine wether the mobile device is in a pocket or not. It also helps to recognize the lighting conditions of the surrounding even if you use this information only to adapt the brightness of the display. It is possible to use 2D barcodes and the camera to get information about a location that is equipped with them. The public transportation system in the city of Berlinfor example is using them on bus stops. If people scan the bar code they get a hyperlink to a timetable with real-time bus schedules.

Microphone. The microphone has many possibilities to detect the user context. It is easy to measure the volume of the background noise and adapt the volume of the audio alarm or the speakers accordingly. It is also possible to identify places based on the characteristic background noise. For example (Ma et al., 2003) were able to recognize with background noise only if they are located in an office, at football match or at the beach. They were able to differ between ten location with an overall accuracy of 91.5%. It should also be possible to use voice recognition to detect how many people are in the surroundings and who they are.

Compass. Some mobile devices have a built in electronic compass, because GPS can only give a position but no direction information. The electronic compass gives information about the movement of the user and can be used to compliment the data from the accelerometer and GPS.

5.5 Near Field Community Interaction

We see a promising area for further development in the sharing of context information with other users. Since applications for instant messaging and social networking became available for many mobile devices a user can share all the information with respect to its position and context with the people connected to him in his social network or through his instant messaging contact list.

To derive the user's actual mobile context from the context of the connected people in his social network we assume that he has either a similar or an identical context as his colleagues and friends.

We suggest that the mobile context of the user could also be derived with the help of a majority vote from the actual contexts of his near field community. A straight forward way to implement a near field community service is to advertise the user if one of his colleagues or friends is in the same cell of the mobile network, the same WLAN access point range, or even in the same train, building, plane, etc. After the advertising the mobile device can accept the new context as its current context or can use it to determine a similar context by combining the advertised context with other relevant knowledge.

6 INTEGRATED CONTEXT DETECTION ARCHITECTURE

As mentioned in Section 3 existing approaches only consider a certain aspect or technology to discover a user's context. Thus, we propose that a combination of several approaches is desirable to offer an overall adaptation to a mobile user's context. We also propose that detection of a mobile users's context should be provided by the mobile device as a service, so that all applications can have access to the context information and can adapt their behavior accordingly. In Figure 1 we show an architecture of a Context Detection Service which comprises all aspects of context detection mentioned above and computes a suitable context that is provided as a context description for other applications for further processing.

The integration approach of the Context Detection Service is based on a three layer architecture. The data or signal source layer consists of the available sensors, radio network interfaces, the built in clock, and or even the connection interface to the user's community. The source layer provides information in form of data or signals which comprise the information layer. This information needs to be transformed to defined knowledge so it can be processed by the Context Detection Service. The transformation of information to knowledge is done by additional Information Processing Services which match the information events from the source layer to knowledge tags with the help of suitable patterns defined in the Pattern Repository.

The most significant criteria to determine one's mobile context seem to be his geographical location, the current time, and his planned activities. On one hand all these criteria have a direct impact on ones context and on the other hand the corresponding technologies, like calendars, location based directories, and time dependend schedulers are already part of prevalent mobile applications.

For the detection of the geographical location, technologies such as GPS or UMTS, GSM, and WiFi networks are available to easily determine geographical locations and thus it should be considered as one of the main parameters for the context detection service. But the coordinates of a geographic location alone might not be sufficient to determine the context, since it does not provide any descriptive information regarding the corresponding place. So the detected location must at least be enriched with more details from a map or yellow-pages service to become more useful in terms of context detection, e. g. by adding descriptive knowledge tags like cinema, restaurant, airport, etc. to the detected location.

An identified description tag of the surroundings, e.g. airport or even an office inside the airport, has a static character with respect to the temporal dimension, since the context of a user can change over time even if he stays at the same place. In an office inside the airport for example the context might be *office work* in the morning, *tutorial* in the afternoon, and in between several coffee breaks. One possibility to draw more precise conclusions about the actual user context is to make a correlation of a description tag with the planned acitivities of the user. Therefore, we take into account appointments from the user's calendar and planned activities from his TODO lists in combination with the current date and time to detect his activity context for the given location description tag. Another possibility to refine the actual user context can be achieved by using noise patterns recorded by the microphone to distinguish among e.g. quiet office work, a coffee break, or a presentation, etc.

An additional way for context detection are moving patterns of the user (e.g. riding a bus, a train or a bycicle, walking, running, not moving etc.) that can be detected with the help of sensors available in the device, e.g. accelerometer, compass, or even a microphone. Those patterns can be used alone or even in combination with other identified context description

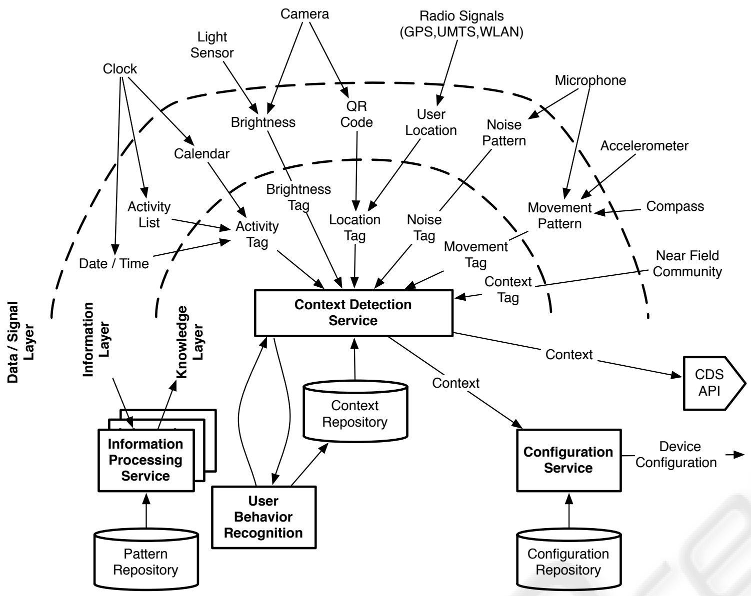

Figure 1: Context Detection Service (CDS) Architecture.

tags to derive a certain device configuration.

The Context Repository containts context defintions consisting of a context name and a list of required context description tags provided by information processing services. Everytime when all the required description tags of a defined context arrive in a well defined time interval at the Context Detection Service, the corresponding context is matched and provided as output for the Configuration Service or for context sensitive applications on the Context Detection Service Application Programming Interface (CDS API). The context descriptions provided by the Context Repository consist of a list of description tags $< T_1 >, \ldots, < T_m >$ derived from the signals of the input sensors of the source layer describing a well defined user context $Context_1$. A list of context detection rules from the Context Repository could be:

$$\begin{array}{ll} (< T_{1,1} >, \ldots, < T_{1,m_1} >) & \Rightarrow Context_1 \\ (< T_{2,1} >, \ldots, < T_{2,m_2} >) & \Rightarrow Context_2 \\ \ldots & \ldots \\ (< T_{n,1} >, \ldots, < T_{n,m_n} >) & \Rightarrow Context_n. \end{array}$$

The Configuration Service selects a suitable device configuration description from the Configuration Repository for a detected context and applies it to the mobile device to adapt its behavior to the corresponding context of the mobile user. For example for a given $Context_1$ a suitable configuration will be $Configuration_1$, for $Context_2$ it will be $Configuration_2$, and so on.

$$\begin{array}{ll} Context_1 > & \Rightarrow Configuration_1 \\ Context_2 > & \Rightarrow Configuration_2 \\ \ldots & \ldots \\ Context_n > & \Rightarrow Configuration_2 \end{array}$$

Finally, the Context Detection Service can refine a context description rule by comparing the larger set of the identified context description tags with the description tags of a certain rule that deduced the actually detected context. However, these tags characterize also a user's behavior providing the possiblity to update or renew the defintion of the context rules in the Context Repository.

7 SUMMARY & OUTLOOK

In this paper we discussed different approaches to automatic context detection and proposed an integrated service architecture which can combine information from the different approaches. We think this is necessary to gain a precise view on the user's context which is the main preposition to developing context-aware mobile applications. As a fundamental for an integrated service the context information from the data or signal source layer is transformed into knowledge which can be interpreted by the context detection service and then be provided to mobile applications running on the device or as basis for the device configuration. The selection criteria for the most suitable context detection approaches should be on the one hand pervasiveness of the underlying technology, e.g. UMTS and WLAN networks of the radio signal approach, and on the other hand the obtainable accuracy for the derived user context. Todays mobile environments are characterized by highly available, pervasive mobile communication networks, mobile calendar based job itineraries, and mobile devices with high computational power. Under these preconditions it is recommendable to combine it with radio based approaches in UMTS/GSM networks for the detection of the user's current geographical region. A rough context of the mobile user can be deduced therefrom in combination with the event and activity list from his calendar. This rough context can be refined with the help of the radio based approach in WLAN infrastructures that the user will enter, cross, or leave. To determine the context of a mobile user in an automated way it is necessery to process knowledge from several sources and services. Thus, there is need for common ontologies for the description of the context concept, knowledge description tags characterizing a defined context, and even the events provided by the signal layer. The next implementation steps for the proposed context detection architecture are the definition of a suitable context ontology and the interaction design of the discussed components of a Context Detections Service.

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