AN ANALYSIS OF CONTEXT-AWARENESS IN COMMERCIAL MOBILE SERVICES

Ana M. Bernardos, Daniel Marcos and José R. Casar
ETSI Telecomunicación, Universidad Politécnica de Madrid, Ciudad Universitaria s/n, 28040, Madrid, Spain

Keywords: Mobile data services, context-aware applications, location based services, mobile business.

Abstract: This contribution aims at analyzing context-awareness from a commercial point of view, studying how the utilization of context descriptors and features in mobile services has evolved during the period 2003-2008. The analysis is based on the information collected during a Technology Watch activity; this methodology has provided us with a large database of mobile services, built from monthly updates of mobile novelties and commercial launches. Services in the database have firstly been categorized regarding their functionalities, in order to get the big picture of the mobile ecosystem in this period of time. Afterwards, we have identified a list of descriptors (personal, physical or activity related) and features (related to resources discovery, management and communications and also to advances HCIs) which are usually identified in context-aware applications and systems prototypes. The use of these descriptors and features has been evaluated for each service and some trends have been detected. Our general conclusion is that nowadays few commercial mobile services can be considered "context-aware", although isolated features (mainly related to personalization) are perceived in many applications. Due to their functionalities, location aware services and mobile social networks are leading the use of context parameters.

1 INTRODUCTION

Simultaneously with the evolution of commercial mobile technologies and markets, a lot of research has focused on bringing to reality the paradigms that are supposed to sketch the future of mobility (Mohr, 2008). Ubiquitous and pervasive computing (Weiser et al., 1999) inspire the concept of ambient intelligence (ISTAG, 2001), a smart and sensitive scenario where context-aware applications (personalized and status adaptive services) make easier everyday activities (Schilit and Theimer, 1994).

To date, context-awareness has inspired many research prototypes in different application fields (museums, airports, hospitals, smart homes, etc., see Section 2). From an analysis on the evolution of commercial mobile services during 2003-2008, this contribution aims at shedding some light on how context-aware research concepts and features are being transferred into market applications. Our final motivation is to identify the hindrances (technical, privacy and business related issues) which need to be overcome to generalize the use of context information in commercial mobile services.

It is important to remark that this is neither a forecasting work nor a study on adoption and pattern of use study on mobile services. Both types of analysis are already common in (academic and corporate) literature. With respect to forecasting, there are some broad-scope proposals that aim at predicting the penetration and the traffic in cellular mobile networks –eg. (Arvidsson et al., 2007)- and also studies focused on niche services or particular markets –eg. (Funk, 2007). On the other hand, mobile services adoption is attracting great interest: for example, Kelleher (2007) analyzes four studies on this issue, Bouwman et al. (2006) goes deeper on barriers and drives that condition the services' use and Bina and Giaglis (2005) and Gilbert and Han (2005) analyze users' preferences taking into account their life styles, needs and demographical characteristics. Verkasalo (2007) studies the users' preferences from the analysis of the data traffic generation of a group of representative applications.

Using a complementary perspective to mobile data adoption studies, our contribution is firstly conceived to analyze the generation of mobile services. With this purpose, during the last five years (2003-2008), we have followed a Technology Watch methodology which has provided us with a monthly updated data base of new mobile services. In this contribution, we elaborate on the long series of

M. Bernardos A., Marcos D. and R. Casar J. (2008).
AN ANALYSIS OF CONTEXT-AWARENESS IN COMMERCIAL MOBILE SERVICES.
In *Proceedings of the International Conference on e-Business*, pages 177-184
DOI: 10.5220/0001910801770184

gathered data in order to show how mobile services and context-awareness presence has evolved.

The paper is organized as follows. Section 2 goes deeply into the concept of 'context-awareness' and gathers a review of its areas of application. Section 3 presents the methodological approach used in this study. From the empirical analysis, Section 4 provides a view of the mobile ecosystem, to frame Section 5, which elaborates on the level of "context-awareness" that current mobile applications have. Section 6 concludes the paper with some open issues for the generalization of context-awareness in commercial mobile services.

2 FROM LOCATION BASED SERVICES TO CONTEXT-AWARE APPLICATIONS

From the late nineties on, location has been the enabler of a number of commercial "precontext-aware" services, such as family finders, location based advertising, area billing, pervasive games, trackers, real time location systems (RTLS), etc. (Bernardos et al., 2007). After a complicated take off of LBS (Kaasinen, 2002), standalone navigation and tracking applications have nowadays become popular, partly due to some device manufacturers' efforts to promote the use of GPS enabled devices. Meanwhile, innovative mobile services related to Web 2.0 have shown up (it is the case of mobile social software or applications making easier content geotagging, for example) and some analysts expect them to contribute to widen the adoption of LBS.

Simultaneously to LBS evolution, research in context-aware systems and services has gone ahead. Since the pioneers Active Badge or PARCTab projects, advances and challenges in positioning techniques, semantic context representations or software architectures for context-awareness have evolved and a great variety of application environments have been explored. By way of illustration, following there is a short list of some of them:

- *Context-aware mobile guides*: many initiatives (such as the breaking Cyberguide or GUIDE) have focused on the development of tourist *context-aware mobile guides*. Museums (e.g. Sotto Voce or Exploratorium projects) and exhibition centres (e.g. Hippie prototype, mExpress project or XGuide application) have also been inspiring environments. Augmented reality techniques are nowadays being combined with context-awareness to achieve a new user experience.
- Productivity applications for *working spaces* such as classes, campuses (e.g. ActiveCampus, Classroom 2000 or eClass projects) and offices (e.g. Context-Aware Office Assistant).
- *Fieldwork applications* for environments where recording and filtering data are prior tasks, such as laboratories (e.g. Labscape) or archaeology areas (e.g. the Context-aware Archaeological Assistant).
- *Smart homes* are highly pervasive scenarios with sensors, actuators, wireless networks, etc. (Meyer and Rakotonirainy, 2003); in particular, there is a growing interest in applications aimed at supporting daily living activities and well-being (especially of elderly and disabled people) (e.g. Wireless Wellness Monitoring and Howel projects).
- *Health care environments*, such as hospitals - Bricon-Souf and Newman (2007) contains a survey- or even operating rooms (Agarwal et al., 2007).
- Horizontal applications such as *memory aids, location annotation* software (e.g. GeoNotes) or *context-aware telephony* (callers are provided with context information about the receivers (Khalil and Connelly, 2006)).
- Other challenging areas of application are *context-aware mobile learning* (e.g. Mobilearn project), *context-aware mission critical support* (e.g. Siren project for firefighting) or *ubiquitous mobile gaming* (e.g. Botfighters).

Context-aware services share requirements with general mobile ones (eg. with respect to usability and interaction mechanisms, device requirements - screen sizes or power consumption-, network speed, etc) but, the same as location based services, are especially dependant on:

1) **Stable location mechanisms.** Location is a relevant descriptor of context that is used as a filter in most context-aware applications. The quality of the location estimation has a direct impact on the user experience. So, reliable, transparent and latency-controlled location mechanisms are still needed to offer an acceptable user experience. To date, GPS (and its variants, such as A-GPS) is the most used positioning mechanism outdoors. But GPS does not perform well indoors, where the multiplicity of networks make possible to configure diverse solutions. Roaming among different positioning technologies is a challenge to be solved.

2) **Reliable privacy management.** Context-awareness means acquiring and handling identity, real time location or activity data. Users must be

aware of which personal data are being managed and have control over the acquisition mechanisms. The combination of security, pseudonym use or cloaking zones may confer the user with a sufficient feeling of control.

3) **Sustainable business models: clarifying the "ownership" of context data.** Mobile operators are nowadays handling a lot of personal information (such as rough cell-based location data) and providing third partners with the tools to access it. At the same time, hardware manufacturers are equipping mobile device with autonomous sensors (eg. GPS or NFC readers), capable of acquiring context information directly from the device. Some of them are also partially shifting their revenue sources to the provision of applications that use the acquired parameters. These two different approaches to context-data acquisition may determine the development of context-aware services.

"Fully-compliant" context-aware applications seem to be in a prototype stage yet. But some mobile services are already intensively using some context descriptors. In the next pages, we intend to analyze to which extent context-awareness is implemented in current commercial mobile services and how it has evolved in the last few years.

3 METHODOLOGICAL APPROACH

Technology Watch, according to the Standard UNE 166006-EX, is the continuous process of obtaining and selecting information from a scientific and technological environment, in order to turn it into useful knowledge by analyzing and spreading it, so that organizations can take advantage of it and make better decisions by being ahead of changes.

From 2003 to date, a Centre for Technology Diffusion in the UPM, CEDITEC, accomplishes a Technology Watch Programme in 'Wireless Technologies and Mobile Applications', which includes the generation of a monthly newsletter and a technology watch report on this issue. The watch process starts with the selection of critical information sources related to mobility, more than 60 sources ranging from technical publications to mobile market focused weblogs, also including general press. Afterwards, a methodical process of data collection allows expert filtering to elaborate a selection of the most relevant information in the month: news, reports, publications, patents, products and also an average selection of the 15 newest and most representative mobile services found in that period of time.

This way, our time-indexed database gathers information of 735 mobile services, from May 2003 to March 2008. As the technology watch process has not been to collect every new service, but the most representative or new, the quantitative analysis happens to be done on critically filtered data. Besides, the services are mainly focused on European and North America markets (as it is difficult to directly access Asian information sources, due to language restrictions).

In this contribution, the services' information has been submitted to further analysis, considering the aspects of user experience, technology evolution, business case, and contextual functionalities developed in the following sections.

4 BUILDING THE BIG PICTURE OF THE EVOLUTION OF MOBILE SERVICES

In this section, we comment on the mobile ecosystem evolution between 2003 and 2008, the considered period of analysis. The objective is to provide the reader with a general (not complete) picture on how the situation has changed in the last five years, supporting our statements with some results of the analysis of the collected data.

a) Entertainment and self content generation together with information services has driven the production of mobile applications.

To analyze what the present offer of mobile services is and how it has evolved during the last five years, we have inferred a functional classification on the stored data. It is composed of 12 categories; we consider that a potential category becomes a formal one when it groups 20 services as a minimum. The classification is as follows (note that some services may match more than one category):

- *Location and tracking:* of people or mobile assets (94 services).
- *Information:* news, weather reports, etc. in addition to eLearning and language translation services (130).
- *m-commerce:* mobile payments, financial services and m-ticketing (62).
- *Browsing and searching*: in the Internet (41).
- *Connectivity and communications:* including VoIP, SMS, MMS, IM or videoconference (96).
- *Applications and productivity:* e-mail applications, document formatting, and remote access to computers or mobile phones (47).
- *Security and safety:* data security and surveillance applications (20).

- *Entertainment and self content generation:* photos, video, music, and games downloading, creating, publishing and sharing (155).
- *Personal information management:* calendars, reminders, customization, settings (78).
- *Social networking* (49).
- *Mobile experience enhancers:* new interfaces, content adaptation, voice to text conversion, 2D codes reading (72).
- *Miscellanea* (32).

Most categories include some subtypes of services which share the final objective but differ in their functional implementation. It is the case of multimedia content and information services. Both have driven the commercial production of mobile applications in the last years (accounting for 21% and 18% over the total).

The other main categories are connectivity and communications (13%), location and tracking services (12.7%) and personal information managers (10.6%).

b) Towards mobile 2.0: downloading, but also sharing and uploading contents.

"Mobile 2.0" is the way to refer to the convergence between the social web (or Web 2.0) and the basics of mobility (personal, localized and always-on). From a practical point of view, Mobile 2.0 *is about connecting your phone to download your favourite podcasts, read your RSS feeds, do a one-click image upload to an on-line photo management and sharing application, consult the location map while on the road, tag your streamed videos or update your moblog*.

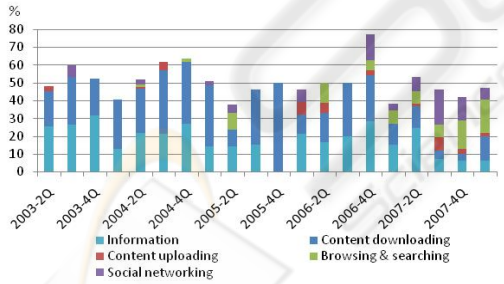

Figure 1: Evolution of content services (percentage of services within the total of each quarter).

Using Mobile 2.0 applications needs broadening the type of user operations, going beyond simple downloading. This trend is somehow shown in Figure 1, which describes the evolution of content services according to our data. To compose Figure 1, we have divided the services in the "Entertainment and self generation content" category between "downloading" and "uploading" applications.

It is noticeable that during 2003-2005, the content offer was mainly focused on data downloads, whereas from 2006 on, an increasing trend in services supporting the creation and sharing of mobile content is detected. At the same time, the presence of other categories, almost undeveloped before, are intensified: it is the case of browsing and searching or doing social networking.

c) A technological view: enhanced networks and sensing mobile devices.

There are two key points regarding technology that shape the changes of the mobile ecosystem during 2003-2008: a) mobile devices have evolved from traditional mobile phones to smart devices with increasingly embedded technology and b) the communication infrastructure is not based on cellular technology any more. Cellular communication networks have enhanced their performance and availability, but alternative technologies have shown up and increased their penetration rate.

With respect to mobile devices features, Figure 2 illustrates an approximated timeline on how new technologies have been embedded into mobile devices. The arrows point out the early introduction of a technology in a commercial phone in the general market, although its technical availability may be previously detected and its availability as a commercial common feature may not have happened until several months later.

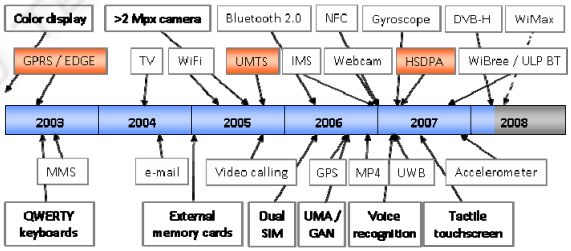

Figure 2: Approximate timeline of technologies in mobile devices.

On the other hand, a very general picture of communication infrastructures shows that:

- Cellular networks have increased their data rate, through UMTS/WCDMA technologies (384kbps) and its enhanced versions: HSDPA (14.4Mbps), HSUPA (5.6Mbps), HSPA+ (42 / 11.5Mbps) and the next LTE – 3GPP Release 8 (>100 / >50Mbps).
- Growing production of standards: WiFi (IEEE 802.11g, June 2003; next IEEE 802.11n in 2009); WiBRO (TTA, late 2005), WiMAX (ITU, October 2007), LTE (GSA, January 2008).

- Great take off of WiFi networks, with 89% growth of WiFi business Hotspots (those located in airports, hotels, retailers, etc.) over H2 2007 (iPass, 2008).
- Fixed to Mobile Convergence (FMC) has been a well-known strategy of some operators, adopting UMA and IMS in order to provide better indoors mobile coverage.
- Enhancements in location technologies: E-911 in USA, market-driven deployment of location based services in Asia-Pacific zone (DTI, 2004), growing integration of GPS receivers in mobile devices all around the world.

d) Business: mobile service providers shift from operators towards software companies.
Generally, the development and commercialization of a mobile service implies the interaction of a number of stakeholders. Obviously, the value chain (or network) composition is very dependent of the final service. For example, location based services value chains are generally complex: in the case of an A-GPS mobile location server, it is possible to identify at least ten roles doing their part to build the final service (Bernardos et al., 2007), and it will be the mobile operator the one offering and billing the service. On the other hand, a Bluetooth based social application, offering discovery of peers and communications will only require an application provider and, indirectly, a handset compatible provider. In this case, the user will get the application directly from the service provider website, and will be not charged for using it.

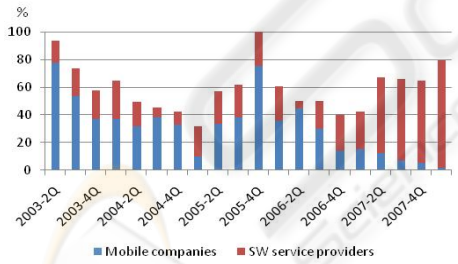

Figure 3: Comparison of mobile services' providers.

On the whole, operators start to change their walled-garden strategies (Wieland, 2007) towards more open ones, in part to incentive data traffic through popular 2.0 applications and to let the users browse in a more familiar way. Well-known web services providers that have mobilized their applications (p.e. Google, Yahoo! or Skype) are acting as users' attractors to mobile data services.

From our analysis of data, we get the following picture (Figure 3): mobile operators started dominating the provision of content and services to mobile devices, whereas in the last six quarters this market has surrendered to Internet software service providers.

5 CONTEXT-AWARENESS IN COMMERCIAL MOBILE SERVICES

5.1 A List of Context-Aware Features

From the classification of mobile services proposed in Section 4.1, the reader might conclude that many of the considered services are not context-aware at all. But some of them –although far from being truly context-aware applications– could have some 'context-aware' features; intuitively, it is the case, for example, of those services grouped into the 'location and navigation' or 'social networks' categories.

Measuring the context-awareness level of a mobile service is not an easy task. For our analysis, we have identified a number of basic questions that a context-aware service should be able to answer:

1) Who the target entity/user is and what does it/he/she want/like? Some services will need to handle personal descriptors, these understood as identity, profile, preferences and group membership related issues. Personalization and services' adaptation to the user's profile are key for many applications.

2) Where the user is? Location is a physical descriptor that usually provides significant knowledge about the user's context. Location acts as a situational filter that is influenced by the positioning system accuracy. Being the basis of navigators and trackers, location availability is making possible some innovative services such as mobile locative social software, pervasive games or geotagged content making (photos, blog posts, etc. may be georeferred).

3) How the user is? Environmental and biometric data use. Apart from location, context-aware services may use other physical descriptors to describe the environment where entities are plunged (this may be useful, for example, for environmental and agriculture surveillance applications and domotics), or even to monitor their biometric parameters, in order to infer information about the target entity physical state.

4) What is the current user's activity? Not independent of the previous issue, information about the current activity and logical state (presence or connectivity, for example) of a target entity may

complete the inferences about its situational condition. Features such as presence announcement and state dissemination or availability notifications are considered in this point.

5) What does the user intend? This feature is related to personal or professional activity data gathering, under the shape of calendars, schedules or notifications, or behavioural patterns.

6) Who/what is near the user? In certain applications, building a social group based on proximity issues with defined privacy levels and collaboration policies is the service's leitmotif. Context-aware services combine physical and situational data with the management of preferences and interests, creating social networks which promote direct interaction among peers. Apart from discovering people, discovering and interacting with daily objects through wireless location (WiFi or BT based systems, for example) and proximity technologies (such as NFC or RFID) is also possible.

7) With whom the user may communicate? Applications which are focused on enabling peer communications make possible the formation of proximity-based groups.

8) How are the user's interaction mechanisms? Context-awareness aims at facilitating daily living and interaction with the environment. In the last years, mobile devices have increased the number of embedded sensors they have. Accelerometers, cameras, gyroscopes, etc. enable more intuitive interfaces: pointing an object to get information about it or using a 2D sensor reader to make easier the information search process also increase the development of mobile context-awareness.

Table 1: A list of context-aware features.

	CONTEXT-AWARE FEATURES
PERSONAL	
1	Identity and profile management
2	Preferences and group membership management
PHYSICAL	
3	Positioning capabilities
4	Environmental or biometric data acquisition and management
ACTIVITY	
5	Connectivity and presence information
6	Activity data gathering and storing
RESOURCES MANAGEMENT & COMMUNICATIONS	
7	Nearby resources discovery
8	Resources management and allocation
9	Peer to peer communications
INTERFACES	
10	Sensor-assisted HCIs

Elaborating on these questions, Table 1 gathers some features enabling context-awareness. From their combination, mobile services may be built: features 1, 2, 3, 5 and 7 may be identified in a mobile social software application, while a sport monitoring service may need to handle characteristics 1, 3, 4 and 6.

In the next Section we analyze the implementation of these features in the stored data.

5.2 Some Results

- Limited but detectable use of context-aware features. 20% over the total of analyzed services are using personal descriptors, only 8% are employing physical parameters and managing resources and communications, while 5% of the services are using activity descriptors. At least one of the considered features appears in 47% of the 735 services. Around 49% of these services are just implementing one of the features; in fact, only 9.4% employ more than four context-aware characteristics.

- Upward trend in personalization and emergence of sensor-assisted HCIs. Discarding the incomplete series of 2003 and 2008 and aggregating the rest of the services in two biannual periods (2004-2005 and 2006-2007), Figure 4 shows a general increase of context-awareness.

Personalization (identity and profile, preferences and group membership) appears as a general trend. Real time information about the user connectivity (logical state) is also increasingly used. On the other hand, peer to peer communications have crossed the barrier of mobility in the second period of time. Almost 16% of the new mobile applications also manage location descriptors. Finally, services using new interfaces have significantly augmented in the period 2006-2007.

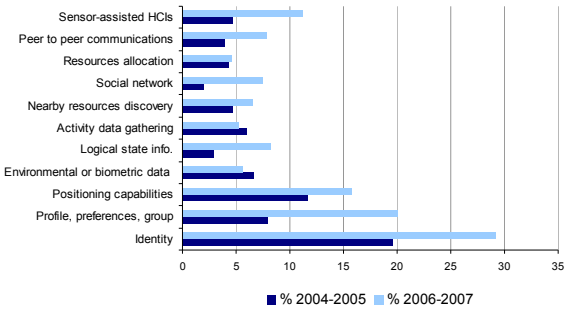

Figure 4: A biannual comparison of context-awareness implementation in mobile services. Percentage over the total production in the periods of analysis (300 services in 2004-2005 and 304 services in 2006-2007).

- LBS lead the group of precontext-aware services, together with information,

communications, personal information managers and social networks applications. Figure 5 compare the implementation of different context-aware features based on the categories presented in Section 4.1. It shows that Location and tracking services are the most personalized and activity aware ones. Personal information managers do not lag behind with respect to these two features, although in general they do not include location as a descriptor. On the contrary, information services are increasingly using positioning as a filter. Mobile commerce services do not use activity data but are personalized and sometimes related to the user location. In general, "entertainment and self content generation" services are scarcely considering the use of location.

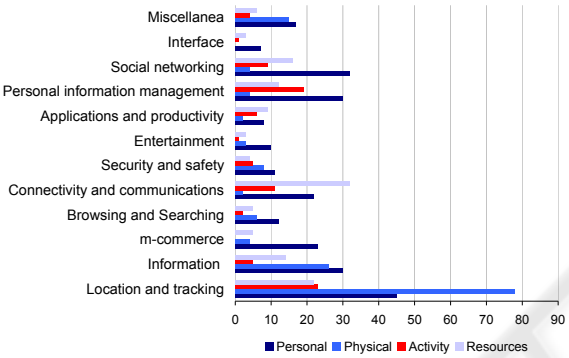

Figure 5: Number of services for each category that implement personal, activity, physical and resource related features.

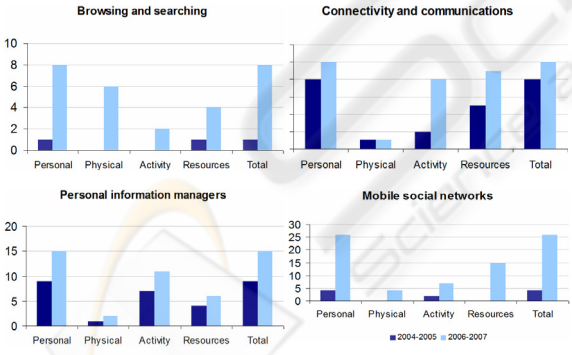

Figure 6: Evolution of context-awareness in the periods 2004-2005 and 2006-2007. Data for some of the categories identified.

When analyzing what kind of services includes resources discovery and management capabilities, the "Connectivity and communications" category is the one which aggregates the greater number of applications, followed by the "Location and tracking" and "Social networking" categories. As it can be noticed, most of the services handling resources are limitedly using physical filters such as position, with the obvious exception of "Location and tracking" category.

6 CONCLUSIONS

This work explains the results of the analysis of a large database of mobile services, systematically updated during the period 2003-2008. Apart from giving a general view of mobile services evolution, we have focused on studing to which extent context-awareness is implemented in commercial mobile services. With this purpose, we have identified several context-aware descriptors (personal, physical or activity related) and features (capability of managing resources, establishing P2P communications or implementing advanced HCIs), and evaluated their implementation in mobile services.

- In general, few commercial mobile services can be considered fully 'context-aware', although isolated features have been detected in about half of them.
- Personalization -this understood as the capability of handling identity, preferences and group membership information- is the context-aware feature that most applications implement. Physical and activity descriptors' use lags behind.
- Mobile services are increasingly incorporating the use of context-awareness, although there is not a breaking point in the period 2004-2007. Again, personalization is the most significant trend.
- Context-aware features have been detected in services of all the functional categories. Anyway, services in the following categories "Location and Navigation", "Social networks", "Information" and "Personal information management" are showing the highest levels of context-descriptors' use.
- Mobile 'social networking' applications may be considered as highly context-aware. They have remarkably appeared during 2006-2007 and are intensively using personal descriptors while discovering and managing resources. Location-based filtering is also included in some mobile social services.
- The integration of sensors such as gyroscopes or accelerometers is making possible new interaction mechanisms with the environment. Sensors assisted HCIs proposals have noticeably grown in 2006-2007.

Nowadays favourable boundary conditions - progressively more connected environments, evolved mobile devices (with new communication capabilities, more usable HCIs and embedded sensors), "literate" users and more established data markets – seem enough to make context-aware services enter in the commercial offer. This "context-awarezation" of mobile services has already started, even if there is still a long way to go.

ACKNOWLEDGEMENTS

This work has been financed by the Spanish Ministry of Education and Science under grant TSI2005-07344 (COLOCAME) and by the Government of Madrid under grant S-0505/TIC-0255 (MADRINET).

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