Preface

CONTEXT IN MOBILE AND UBIQUITOUS COMPUTING

Advances in mobile and ubiquitous computing, wireless communications, mobile positioning and sensor technologies, have given a rise to a new class of mobile and ubiquitous applications and services that are aware of the context of application usage and adapt their behaviors according to that context with minimal distraction of the user.

Context-aware computing is a mobile and ubiquitous computing paradigm in which applications can discover and take advantage of contextual information (such as user location, time of day, computing and communication characteristics, nearby people, objects and devices, user activities and goals, etc.). Such applications are able to adapt their behavior, that is their functionality, content and interface according to the user's current situation with minimal intrusion. Context-aware computing is a new and rapidly evolving field and currently the focus of many recent research and development efforts. Pioneering work in context-aware computing was performed in the 1992 at Xerox PARC Laboratory and Olivetti Research, Ltd. (now part of AT&T Laboratories Cambridge), resulting in one of the first context-aware applications, *Active Badge Location System* (Want et al., 1992). Marc Weiser in his paper "The Computers of the 21st Century" (Weiser, 1991), predicted that the future computing would consist of small, interconnected computers, some integrated seamlessly in our surroundings (often invisible), and some worn by as, aiming to provide useful and effective services to the users according to their information needs and current situation. This started the vision of ubiquitous computing (also called pervasive computing) as the third wave in computing. Since then, many other researchers have studied topics surrounding context-aware mobile and ubiquitous computing and contributed to this field.

As human beings, we are aware of context, implicitly understand its importance and use it in our daily activities. We routinely use contextual information, such as, who is in our vicinity, where we are, or what is the time of the day, to modulate and adjust our interactions with other people or objects. In the same way that our gesture, activity or a word has different meanings depending on the situation and the context in which they are expressed, the user interaction with any IT application and service is influenced and determined by the situation/context in which such interaction occurs.

What is the context from the mobile and ubiquitous computing point of view? The definition given by Dey and Abowd (2000a) is the most cited one and refer to context as:

"any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves."

Chen and Kotz (2000) define following categories of context:

- Computing context includes network connectivity, communication bandwidth, and local computing resources such as printers, displays, memory capacity, processor speed, and so forth.
- User context includes user profile, location, preferences and people in the vicinity of the user, even the social situation.
- Physical context includes lighting and noise levels, traffic conditions, and temperature.
- Temporal context includes time of day, week, month, and season of the year.
- Context history is the recording of computing, user and physical context across a time span.

Some authors (Hofer et al., 2002; Prekop and Burnett, 2003) classify context in two dimensions: physical (external) and logical (internal). The physical (external) dimension refers to context that can be measured by hardware sensors, that is, location, light, sound, movement, touch, temperature or air pressure, whereas the logical (internal) dimension is mostly specified by the user or captured by monitoring user interactions, that is, the user's goals, tasks, work context, business processes, the user's emotional state, and so forth. However the context is defined and classified the main challenge in mobile and ubiquitous computing is how to provide intelligent context-aware applications and services, anytime, anyplace on any device, that takes into account the users' context and their current situation, increasing usability and effectiveness and minimizing distraction and needed attention.

CONTEXT-AWARE APPLICATIONS AND SERVICES

Many researchers and developers have explored context-aware computing and developed a number of context-aware applications and services to demonstrate and validate the enhanced usability, the flexibility, and adaptation of applications and services enriched with context-aware behavior. According to definition of Dey and Abowd (2000a) "a system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task".

Most of the mobile and ubiquitous systems now utilize some kind of context to perform their tasks; what makes context-awareness an essential requirement of these systems. Some of them are made capable of dealing with special types of context and are well-suited for specific conditions and requirements, for example, in navigation scenario. These systems handle context in an ad hoc way and are optimized for the situations they are used in without care about extensibility and flexibility. Although there have been many context-aware systems and applications tested over the last decade, most of them are still prototypes only available in research labs and in academia. One of the main drawbacks lies in the complexity of capturing, representing, and processing the contextual data, as well as adaptation of functionality, content, and interface of applications and services to defined context. These implementations have also lacked generality and flexibility in the sense that only a predefined set of context information has been utilized, with no allowance for customization or augmenting the scope of the information as the need arises. Yet the range of potentially useful context information and the ways of adaptation of mobile and ubiquitous applications to this information is limitless and unforeseeable.

To achieve flexible, scaleable, and effective development of context-aware applications and services a more generic framework is needed. Such a generic framework should include and provide advanced methods, tools and techniques for:

- Context sensing and acquisition,
- Context modeling, representation and storing,
- Processing, aggregation and reasoning of contextual data,

- Context-aware application adaptation,
- Integration of context-awareness into service-oriented architectures
- Security and privacy of context data,
- Knowledge discovery and mining of historical context data, and
- Design and development of context-aware applications and services.

The method of context data sensing, capture and acquisition is very important when designing context-aware systems because it defines the architectural style of the system and also the capabilities of context-aware services offered. Depending of context data types defined within the particular context-aware application domain, the set of contextual data must be acquired through various sensors, either physical, logical, or virtual and represented and stored in an appropriate data store (Baldauf et al., 2007).

To efficiently manage context data and integrate it in context-aware systems the appropriate context model must be developed. The context model is needed to represent, store, and exchange contextual information in the most convenient form. To develop flexible and useable context modeling constructs that cover the wide range of possible contexts is a challenging task. Strang and Linnhoff-Popien (2004) summarized the most relevant context modeling approaches, which are based on the data structures used for representing and exchanging contextual information in the context-aware systems. The main approaches include key-value pairs, XML-based models, graphical models, object-oriented models, logic based models and ontology based models which variously fulfill requirements of the context-aware systems, such as simplicity, flexibility, extensibility and expressiveness.

To provide high-level context information from raw sensor data, such data must be appropriately processed. The data processing is responsible for transformation, reasoning and interpreting contextual information and representing it at a higher abstraction level more useful for particular context-aware system or service. Context-reasoning represents the process of deducing new and relevant information to the use of application(s) and user(s) from the various sources of context-data. For example, the exact GPS position of a person might not be of value for an application but the name and type of the room the person is in, brings greater meaning to the system. Also, if context-aware systems depend on several different context data sources, to provide useful and high-level contextual information to the other systems' components the raw context data must be aggregated and composed to generate information that is more important and advantageous to the application.

The main challenge in design and development of mobile and ubiquitous applications is the adaptation to context and context changes (Adelstain et al., 2005). Adaptation to context and its changes might happen in middleware (system), in the application level, or both. The adaptation of context-aware applications can be performed on three aspects: a) the functionality of various components (services) in the mobile application, b) the data (content) that are delivered to the application can be adapted, and c) the user interface and the ways of user interaction with the application. There is a need for concepts, methods, and tools to achieve effective and seamless integration of adaptation in design and development of context-aware applications.

Service-oriented architecture represents advanced and popular approach for the building and the rapid prototyping of context-aware mobile applications and services (Baldauf et al., 2007). Different functionalities of context-aware systems are encapsulated as low coupled services with context acquisition, context management and context adaptation roles. Usually the central services gain context data through distributed context provider services, process and aggregates it and offers it in high-abstraction and usable form to the application services. Such context-aware mobile services are located on top of the architecture, and retrieve and use contextual information to adapt their behavior according to the current and/or past context. As sensors in a distributed sensor network may fail or new ones may be

added, a discovery mechanism to search for and find appropriate sensors for sensing context at runtime is important. The context-aware system must provide mechanisms and capabilities to enable discovering of new context information services using different forms of querying and lookup mechanism. Such dynamic mechanisms are important, especially in mobile and ubiquitous environments, where available sensors, the context sources, as well as their capabilities and structure, change rapidly. Also, context information obtained from context provider service in such an architecture can affect the various stages of the service provision process for example to enhance service discovery or service composition. The main challenge here is how to achieve autonomous orchestration of atomic or composite context-aware services of a service-oriented architecture into higher level services based on context information and available QoS parameters to offer adapted and more usable services.

The important aspects of context-aware mobile systems and services are security and privacy. As context may include sensitive information on people, for example, their location, their activity, the history of their context information in the form of their profile, and so forth; it is necessary to have the opportunity to protect privacy. Therefore, concepts and mechanisms are needed to express policies, to define ownership of context information and access rights for different users.

Context-aware mobile applications and services must also provide access to historical context data. The context-aware systems must provide capabilities for storing and maintenance of a context history and the facilities to query historical context data. The context histories may be used to establish trends and patterns in context changes and predict future context values by using knowledge discovery and data mining techniques. Managing and mining historical context data provides the ability to implement intelligent and highly adaptable context-aware systems and services. Furthermore, based on data mining algorithms, contextual information can be predicted to proactively provide a certain set of context-aware services to the user without his/her explicit intervention or request.

All these interesting challenges in the context-aware mobile and ubiquitous computing field have inspired the research and development community to develop many important solutions and achievements, and to report and present them in the scientific and professional publications, at workshops and conferences. Several context-aware frameworks and systems are designed and developed with some or all these functionalities in mind to enable simple and efficient development of context-aware applications. The prominent examples reported in the literature are (the list is not exhaustive):

- *Context Managing Framework* presented by Korpipää et al. (2003)
- Service-Oriented Context-Aware Middleware (*SOCAM*) project introduced by Gu et al. (2004)
- Context-Awareness Sub-Structure (*CASS*) presented in Fahy and Clarke (2004).
- Context Broker Architecture (*CoBrA*) (Chen et al., 2003)
- *Context Toolkit* (Dey and Abowd, 2000b)
- *Hydrogen* project (Hofer et al., 2002).
- *CORTEX* system based on the *Sentient Object Model* (Biegel and Cahill, 2004)
- *Gaia* Project (Roman et al., 2002)

But many open, research and development issues are still remaining. Context-aware computing is a research area that is still growing and evolving and every related study and research work contributes to richness of this field. The objective of this book is to provide throughout insight in advanced concepts of context-awareness, such as context-aware application adaptation, context management, context privacy and protection, context-awareness in service-oriented architectures, and the application of context-awareness for enhanced usability in specific application domains. The understanding of these concepts ultimately leads to more effective design and implementation of mobile and ubiquitous applications and services

that can access accurate, high quality context information on the fly in highly dynamic environments and adapt their functionality, content and user interface/interaction accordingly.

BOOK OBJECTIVE AND AUDIENCE

The book relies upon a huge research in context-awareness domain during past decade which establish fundamental context-related definitions and principles, methods for context sensing and acquisition, context modeling and storage, as well as development of context-aware applications based on context frameworks. This book follows this line of research and development by presenting and describing up-to-date research and development issues in the context-aware computing community.

As such, the book covers advanced aspects of context-awareness and up-to-date topics in context management, development and adaptation of context-aware applications and service, context-aware security and access control, incorporating context-awareness in service-oriented architectures and describes how to achieve enhanced usability and personalization of context-aware applications in some actual domains such as ambient intelligence, E-Learning, infomobility, Semantic Web, and so forth.

By presenting timely and relevant information to the context-aware mobile and ubiquitous computing field, the book is expected to argue the readers that being aware of context is a key factor for enhancing usability and adaptation of contemporary mobile and ubiquitous applications and services.

The book appeals to a broad computer science and computer engineering audience. It is considerably valuable to researchers and developers in mobile and ubiquitous computing, by covering advanced aspects of context-awareness and concepts in design and development of context-aware applications and services. The reader will be able to get in touch with new and comprehensive research issues the context-aware research community is dealing with today. The book is expected to serve as guidance for researchers, software developers and practitioners in this reach and fruitful research and application field, toward making context-aware computing a full reality.

BOOK ORGANIZATION

The book consists of 16 chapters, organized into five sections. A brief description of the chapters follows.

The first section of the book presents concepts, principles and strategies for development of context-aware applications adaptation.

Preuveneers et al. (Chapter I) present the fundamental concepts of their component-based methodology and complementary context-aware adaptation framework, and discuss how the framework handles the various kinds of adaptation along multiple levels of abstraction (*content*, *application*, *framework*, and *network*). After having discussed the basic concepts of our adaptation framework, they evaluate some of the benefits of their integrated adaptation approach based on a set of QoS requirements.

Chaari et al. (Chapter II) propose a comprehensive and open strategy that guarantees the adaptation of applications to context on three facets: (i) the services offered to the user, (ii) the multimedia contents returned by these services, and (iii) their presentation to the user. They have validated this strategy by developing a platform that guarantees applications adaptation to context by using Java, OSGi and Web service technologies to implement this platform. They present a successful test of their adaptation approach on a home healthcare application concerning dialyzed persons.

Daniel (Chapter III) characterizes the design of context-aware Web applications, describes a conceptual, model-driven development approach, and shows how the peculiarities of context-awareness require augmenting the expressive power of conceptual models in order to be able to express adaptive application behaviors.

The second section of the book deals with different aspects of advanced context management, regarding the adaptive framework, distributed context and context-aware database querying methods and techniques.

Roussaki et al. (Chapter IV) elaborates on mechanisms that address advanced requirements including support for distributed context databases management; efficient query handling; innovative management of mobile physical objects and optimization strategies for distributed context data dissemination. These mechanisms establish a robust spatially-enhanced distributed context management framework that has thoroughly been designed, carefully implemented and extensively evaluated via numerous experiments.

Zebedee et al. (Chapter V) describe a robust and adaptable context management system achieved by adopting the autonomic computing paradigm, which supports systems that are aware of their surroundings and that can automatically react to changes in them. They present an implementation based on widely accepted standards, specifically Web services and the Web Services Distributed Management (WSDM) standard.

Li et al. (Chapter VI) present the latest context-aware querying techniques developed in the data management field in order to enable effective design of context-aware database query processing mechanism. They outline six ways to query context directly, and provide a categorization about how to use context in querying traditional databases. The approaches of handling imperfect context in context-aware database querying are also described.

The third section of the book is concerned with service-oriented computing in the mobile and ubiquitous settings and how to develop and seamlessly integrate context-aware mobile services in service-oriented architectures.

Jacob et al (Chapter VII) extend the notion of context-aware services by considering service composition approaches, and present a middleware aiming at the autonomic and context-aware provision of services in mobile peer-to-peer networks. In this regard special attention is paid to a semantic blackboard concept to cache and disseminate context data and a context-aware service composition approach in terms of the identified trends and challenges.

Eikerling and Mazzoleni (Chapter VIII) present a methodology based on model-to-model transformations to be applied at different stages of the service lifecycle. Starting from a conceptual model, these models reflect characteristic properties of the mobile service under development such as context information. For the implementation, a middleware suite then is used which comprises a set of constituents which significantly simplify and shorten the mobile services development cycle. They demonstrate the concepts in terms of mobile business-to-business field services in which through the methodology and tools the dynamicity can be enhanced.

Dietze et al. (Chapter IX) propose Mobile Situation Spaces (MSS) which enable the description of situation characteristics as members in geometrical vector spaces following the idea of Conceptual Spaces (CS). Semantic similarity between situational contexts is calculated in terms of their Euclidean distance within a MSS. Extending merely symbolic SWS descriptions with context information on a conceptual level through MSS enables similarity-based matchmaking between real-world situation characteristics and predefined resource representations as part of SWS descriptions. To prove the feasibility, they provide a proof-of-concept prototype which applies MSS to support context-adaptation across distinct mobile situations.

Raibulet (Chapter X) proposes an adaptive solution to enable identification of the available resources and services and indicates which resource is the best one to execute a service. She proposes an approach which models the adaptation knowledge through reflective entities, qualities and properties, the management of the adaptation knowledge through views, the decision support through strategies, and the management of the functional and non-functional elements through managers.

The fourth section of the book deals with important topics of context-aware communication, security and privacy in mobile systems and applications, which are essential prerequisites for wide use of context-aware services across the wireless Web.

Lofeudo et al. (Chapter XI) present their own hardware and software platform built to communicate and position mobile devices in an efficient way. They describe the design and implementation of their software/hardware combination, which is designed to provide a balance between network bandwidth, power consumption and roaming capabilities. They also present an example showing how the hardware is combined with their sensing layer to develop context-aware applications.

Gomez et al. (Chapter XII) present the use of context information for authentication and access control in ubiquitous and mobile environments as a way to reach a higher level of flexibility and adaptability of the systems' security. The authors propose and describe different new techniques to ensure access control, and compare them to the state-of-the-art.

Ali-Eldin et al. (Chapter XIII) deal with two challenges in incorporating privacy in context-aware services. The first one is to improve privacy architectures with a trust functionality and the second one is to integrate this refined privacy architecture in larger service- oriented architectures (SOAs).

The fifth section of the book presents application of context-awareness for enhanced usability and personalization of mobile and ubiquitous applications in specific application domains.

Joly et al. (Chapter XIV) depict their vision of "Social Ambient Intelligence" based on the review of several uses of semantic technologies for context management, adaptive human-system interaction, privacy enforcement and social communications. Based on identified benefits and lacks, and on their experience, the authors propose several research leads towards the realization of this vision.

Paganelli and Giuli (Chapter XV) provide an analysis of existing studies in the field of context awareness research targeted to the infomobility application domain. The authors propose an evaluation framework for infomobility services based on the elicitation of context information items and high-level requirements. The framework is applied to some relevant state-of-the art research works among personal navigation systems, infomobility service integration frameworks and context-aware location-based communication platforms. Evaluation results are discussed in order to highlight open research challenges in the infomobility application domain.

Tsianos et al. (Chapter XVI) put focus on identifying human factors that relate to users' performance in Web applications that involve information processing, and a framework of personalization rules that are expected to increase users' performance is depicted. The environments that empirical results were derived from were both learning and commercial; in the case of E-Learning personalization was beneficial, while the interaction with a commercial site needs to be further investigated due to the implicit character of information processing in the Web.

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