MOBILEAUDIT
A Tool for Contextual Knowledge Management

Olaf Thiele, Hartwig Knapp and Martin Schader
University of Mannheim - Department of Information Systems
68131 Mannheim, Germany
thiele, knapp, martin.schader@uni-mannheim.de

Nicolas Prat
Essec Business School - Information and Decision Systems Department
Avenue Bernard Hirsch, B.P.50105 - 95021 Cergy cedex, France
prat@essec.fr

Keywords: Mobility, knowledge management and context-aware computing.

Abstract: In many professional activities, the ability to retrieve and store knowledge in a mobile situation is crucial. This need, together with the progress of mobile devices, has led to the emergence of mobile knowledge management. In this paper, we propose a context-aware knowledge management architecture for mobile environments and apply it to an auditing use case. We developed the MobileAudit prototype using the proposed architecture. MobileAudit enables environmental audits according to US as well as European EMAS (ISO 14001) legislation.

1 INTRODUCTION

The issues of knowledge management and mobility have often been explored separately. In a joint research project between decision science and software engineering researchers we devised a possible architecture for mobile knowledge management (Thiele et al., 2006). Our generalized approach towards mobile knowledge management aims at two main components in knowledge management architectures: knowledge sources (like knowledge database) and knowledge interaction modules (desktop applications). While most research focuses on certain aspects of the problem, we present a complete architecture, which builds upon previous work in the fields of knowledge management and mobility. A middleware component called the Contextualizer serves as the main building block of the architecture. The Contextualizer is complemented by components that reside on the mobile device and in the back-end. This reduces the resources needed to include a new mobile device or knowledge source into the system.

Inspired by practitioners in the field we built MobileAudit, an environmental audit prototype implementation, that takes advantage of our proposed architecture. Environmental audits are compulsory for many companies in Europe and the US. Other companies take the audit voluntarily due to public pressure. Typically, an external auditor is engaged to carry out the audit. Since on-site interviews, up-to-date pictures and personal inspection are part of every audit trail, auditors need to be mobile while still carrying all necessary material. Therefore, a mobile knowledge management software solution might aid in this situation.

In the next section, we present the mobile knowledge management domain and point out the technical prerequisites. In Section 3, we highlight our proposed architecture and explain its main components. Section 4 shows parts of our prototypical implementation while we draw the outline of other works in Section 5. Finally, we conclude with a resume and an outlook.

2 MOBILE KNOWLEDGE MANAGEMENT AND PROPERTIES

In this section, we highlight the main aspects of knowledge management and mobility relevant to our work.

2.1 Knowledge Management

Knowledge management is often described as a system of activities to permit the utilization of organizational knowledge by the members of that organization (Hannig, 2002). In this paper, we focus on four general knowledge management processes that are relevant to our more technical view. On the one hand, these are knowledge presentation and acquisition, which evolve around human interaction with the system. Knowledge presentation comprises both displaying data on the device as well as interacting with it. If this interaction leads to some sort of knowledge storage or if the user deliberately enters information through a form or just as plain text, we categorize these activities as belonging to knowledge acquisition. On the other hand, knowledge retrieval and storage are relevant to our work. We use these terms analogous to their technical counterparts.

2.2 Mobility Aspects

Classical knowledge management applications were programmed for desktop use. With the introduction of mobility, sophisticated adaptation to the mobile context becomes more important. In general, the unique properties of mobile devices are a major influencing factor in the proposed system. With a growing number of different device types, the heterogeneity grows enormously as most devices differ in their capabilities from PCs (e.g. screen size) and from other mobile device types (e.g. cell phones and PDAs). Critical factors include the display size and resolution, the memory size and accessibility, the processing power, connection protocols like GPRS, UMTS, or EDGE, interaction techniques like the stylus and supported standardized programming interfaces like Java or C (see (Lum and Lau, 2002) and more recently (Adipat and Zhang, 2005)). Key properties are the ubiquity and the ability to adapt to the user's context, given the current position and other preferences (e.g. user profiles). To sum up, benefits of joining the fields of knowledge management and mobility are ”anytime, anywhere information access” (Grimm et al., 2005), mobile-added values like ubiquity or context-sensitivity (Derballa and Pousttchi, 2004), and automatic context incorporation (e.g., knowledge is accessed in an adapted way and context variables such as location are stored automatically).

3 MOBILE KNOWLEDGE MANAGEMENT ARCHITECTURE

In this section, we introduce our mobile knowledge management architecture and its underlying components. Subsequently, we explain how the context

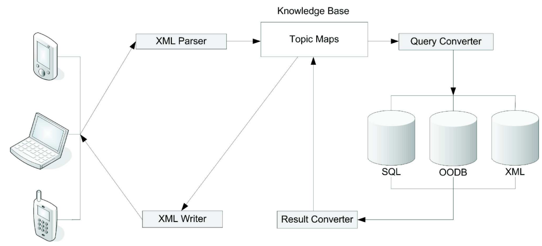

Figure 1: Mobile Knowledge Management Architecture.

mapping works and afterwards, we present the Contextualizer middleware in more detail in the MobileAudit Section 4.

3.1 Introduction

Our proposed architecture for mobile knowledge management, shown in figure 1 on the next page, is divided into four layers. The first layer contains the mobile users or mobile agents. This human agent interacts with the system to access knowledge. The human agent then utilizes this knowledge, transfers it to others or enters some new knowledge back into the system. The knowledge management activities, knowledge presentation and acquisition are the interface between layers one and two. The second layer consists of Java-enabled mobile devices like mobile phones, PDAs, or laptop computers. The implemented middleware serves as the connecting link between the adjoining layers - it is the main focus of our work. It translates the data flow coming from the mobile devices to a database query and the response is then adapted according to the mobile context and sent back to the device. The interfacing activities between the third and fourth layer are knowledge storage and retrieval. The fourth layer contains the knowledge source which is built up of different database types. We chose the three most popular types: relational (SQL), object-oriented (OODB), and XML databases. Due to the fact that most of the intelligence and complexity of our application reside on the third layer, we explain this component more detailed in the next subsection.

3.2 Outline of the Contextualizer

The Contextualizer is a middleware component, which serves as a mediator between the human agent and existing knowledge bases. It takes care of communication with the knowledge base (knowledge storage and retrieval) as well as linking the server and client side according to the context (knowledge presentation and acquisition). In general terms, if the

Contextualizer receives an XML query from a mobile device, it parses the request and analyzes the context according to the following four context elements: user dependency, technological environment, situation, and task. Subsequently, all relevant databases are queried, the results are transformed according to the four context elements, and, finally, the result is sent back to the client application. All four context elements are described thoroughly in the following subsections.

3.3 User Dependency

User dependent elements form the first type of context elements. They include technical preferences as well as the agent's role within the organization. Most technical preferences are represented through the user's profile. A typical user profile includes data on preferred color themes as well as favored font sizes. Profile information is stored on the client and is transferred to the Contextualizer in the initialization phase. In addition to the profile, the role of the user within the organization needs to be taken into account. On the one hand, not all members of an organization work with all available knowledge. The users' role determines what knowledge they are allowed to and need to access.

3.4 Technological Environment

The technical environment comprises elements of the device and the network. The device plays a major role for the Contextualizer. Variables like the screen size, processing power, available colors, or programming interfaces are key determinants for putting the knowledge into context. Two major types of applications need to be considered: text and graphical knowledge representations. Text can be displayed in many ways. Font size, text formatting and navigational elements within texts (e.g. hyperlinks) as well as ways for changing screens (e.g. scrolling) can be varied between mobile devices depending on their capabilities. As for graphical knowledge representation, display facilities vary a lot between devices. While some devices like laptops or PDAs offer powerful standardized programming interfaces, smaller devices like cell phones or smartphones usually have limited custom interfaces.

3.5 Situational Elements

Situational elements are those connected with time and location. The time variable includes the actual time as well as the corresponding time zone. Depending on the time of day, knowledge queries might return different results. Moreover, the time zone is important when retrieving time-critical information from databases in far away countries. The other important situational element is the location. The position of the user on the globe is one of the most prominent contextual elements and is used in many mobile applications. The location can be determined automatically (via GPS) or manually. The position of the user is especially interesting for graphical knowledge representation in maps or sketches. The dynamic nature of this element is also important in navigational tasks. Both the Contextualizer and client need to keep up with a driving vehicle to deliver timely knowledge.

3.6 Task-Specific Elements

All other context element implementations, as described above, are universal and can be used for most task types, but elements specific to the task need to be adjusted for each task type. To ease the programming effort needed for implementing new tasks, we developed a semantic XML description format (slightly enhanced Topic Maps), which can be used to semantically express where knowledge resides and how it should be handled. The semantic description is situated in a seperate Topic Maps repository. Apart from that, the Topic Maps include information on interrelated topics. The documentation of relations between topics is the great strength of Topic Maps and ideal for mobile contextual adaptation. Data about technical issues can easily be connected to a topic as well as other similar task related contents. See Seedorf et al. for more on the use of Topic Maps in mobile knowledge management (Seedorf et al., 2005).

4 MOBILEAUDIT IMPLEMENTATION

We implemented a protypical MobileAudit application to validate our mobile knowledge management architecture and to illustrate its features. First, a technical overview of the environmental audit implementation - MobileAudit - is given. Subsequently, we then present the basic idea of our use case and we introduce the implemented clients as well as the corresponding server side.

4.1 Overall Implementation

Generally, all applications (client and server side) are programmed in Java. Technical context variables like processing power or disk size can either be typed be the user or - our preffered method - are detected automatically. This is especially useful for varying variables. While display sizes are invariable, available storage space changes permanantly. Situational context elements need some client programming as well. For PDA GPS reception, for example, we are using the Navilock BT-338 Bluetooth receiver. A Java client program on the PDA extracts the GPS position and sends the data directly via HTTP to the server. The server side and especially the Contextualizer were programmed using J2EE on JBoss. The Java 2 Enterprise Edition APIs offer the capabilities for handling multiple connections with clients as well as databases. The Contextualizer is therefore scalable and performant. We used Hibernate to access relational data and stored XML in the eXist XML database.

4.2 Environmental Audits

Environmental issues such as global warming dominate the news. Many companies, especially larger ones, show their ecological responsibility by taking environmental audits. Others, depending on local legislation, need to prove that they are following certain standards. While companies in the US show their EPA compliance (US-EPA, 2007), European companies follow the EMAS standard ISO 14001 (Eco-Management and Scheme, 2007). Some commercial applications are available to aid in the mobile auditing process. Most functionality is offered by CMO Easy Audit (for Environmental Audits ISO 14001 CMO-Global-Services, 2007). This Windows-based PDA application uses no context variables. It does not connect to a server application. While this may be an advantage in some situations, the interaction with larger data sources (like searching in existing reports) is impossible. Furthermore, all context variables need to be gathered manually. This takes up valuable time and some variables like the GPS position are best collected automatically.

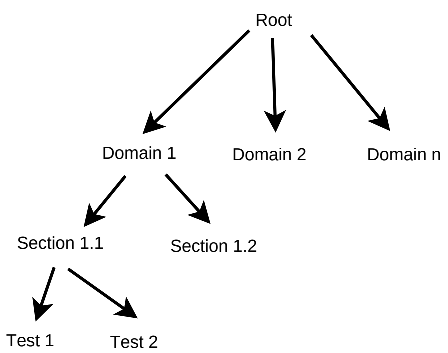

Figure 2: Sample Audit Trail.

Technically, an audit trail can be seen as a tree. To complete the whole trail, all subnodes need to be completed. Subnodes contain other subnodes and some are optional depending on previous answers in the trail. A simple model of the tree is depicted in Figure 2. The root nodes represents a complete audit trail for an area. Domains represents different audit areas like air pollution, noise, chemical waste or environmental impact. Typical sections for air pollution are furnace or chimney usage, use of liquid fuels or asbestos control. Tests are generally questions. These might range from yes/no answers to taking pictures or lengthy interviews on working habits. Depending on previous answers, tests can be skipped or lead to more elaborate tests.

4.3 Application Implementation

Generally, we implemented two different client applications. A J2ME-based application for cell phones and a JSP implementation for PDA‘s and laptops. Due to the HTML limitations of the JSP implementation, we programmed some Java programs and applets to gather context variables or ease interaction. The implemented use case adapts knowledge according to all four context elements. User dependent elements include a user profile and organizational role. The user is able to choose a certain skin and save favored top menu items. The skin features different font sizes as we found out that users vary in their preferences for reading on mobile devices. Some prefer colorful design whereas others want a clear, plain design. The organizational role determines, which parts of the system may be accessed by the user. In auditing the most important feature is sealing. Once a subsection has been marked as completed, it must no be changed. Therefore access rights are crucial for the auditing process.

Technical context elements in the use case include the color, interaction style, screen size, and bandwidth. The images sent to the device are adapted according to the given color table. Large images need to be scaled in order to be shown on an older cell phone. Modern cell phones can easliy handle even larger images. The graphics are sent in total if the device supports interaction types like zooming, stylus navigation or mouse movements. The screen size and bandwidth determine how much of maps or drawings are sent at a time. Devices with a slow network connection receive smaller pieces while broadband connection get sent everything. The bandwidth of a regular cell phone posed a problematic situation when moving fast while viewing high resolution images. Situational elements include the time and place. Some areas have a higher

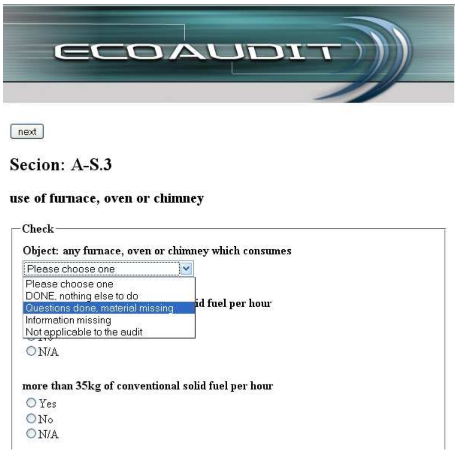

Figure 3: Screenshot Laptop.

chance of frost in winter time, which poses several environmental hazards. Other areas have reoccuring natural threats likes hurricanes or flooding.

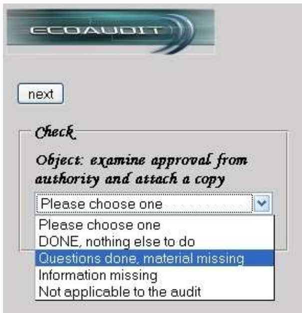

Figure 4: Screenshot PDA.

The clients contain only a minimal set of programming logic. The task specific logic of the application keeps track of the auditing status, while the Contextualizer organizes incoming and outgoing data according to the context variables. We implemented the feature in both clients that the number of questions presented on one page or screen can be set as a user context variable. Some participants liked it better to see many questions on one page by scrolling down and up again, others preferred only few questions per page without scrolling. This feature was rated higher that other features like the screenshot applet.

5 RELATED WORK

While knowledge management and mobility are well-established research fields, the combination of both raises questions and uncertainties. On the more technical side, for example, we face the problem that connections between mobile devices and databases are not dependable; a connection and session management has to be introduced to guarantee a complete and timely data exchange. Some (Holliday et al., 2002) attend to the question how a database query might be answered completely and discuss several disconnection modes while others (see for example (Chan and Roddick, 2003)) dwell on weak or partial connection modes. Zuma and Adigun combine these technical issues with some reference to knowledge management (Zuma and Adigun, 2006). In the field of user interfaces design, most are constructed especially for the targeted device (e.g. special PalmOS devices; also see (Bardram and Hansen, 2004)) or functionality is limited (e.g. WML; also see (Picco et al., 2000)).

Work similar to our approach was carried out by Fagrell et al. as early as 2000 (Fagrell et al., 2000). As mobile devices had much less processing power back then, context elements such as user dependency or automatic location detection were not considered. The work of Wei and Prehofer focuses more on distributed context repositories, which are queried for decision making (Wei and Prehofer, 2003). Derballa and Pousttchi present the idea of mobile-added values (Derballa and Pousttchi, 2004). Their approach is rather abstract and they do not offer a technical implementation roadmap. Focusing on similar issues are Grimm et al., who are working on the now finished MUMMY project (see (Grimm et al., 2005) or (Grimm et al., 2002)). They developed applications for several tasks (e.g. mobile facility management, trade fair information). Finally, Adipat and Zhang develop an adaptable framework for mobile knowledge management (Adipat and Zhang, 2005). Their main focus lies on web content adaptation according to user preferences. See their recent publication for an overview and update (Zhang, 2007). Further information on mobile web browsing from Pacheco et al. (Pacheco et al., 2006). Quite similar to our approach but more focussed on cell phones than PDAs and more on services rather than knowledge managment see Laako and Hiltunen (Laakko and Hiltunen, 2005).

6 CONCLUSION

Mobile knowledge management is a key application area for mobile computing in general and context-aware computing in particular. In this paper, we have presented a context-aware mobile knowledge management architecture. The key component of the architecture is the Contextualizer. This middleware implements the knowledge management activities (e.g., knowledge storage, retrieval, presentation, and acquisition) by taking into account the context elements, namely the user, the technical environment, the situation (i.e. time and place) and the specific task - here environmental audits - at hand.

In the last year we developed several use cases with the proposed architecture. While we continously improved the mobile knowledge management architecture, we noticed large variations in the quality and acceptance of the applications. Time and interest from practitioners in the field prove to be an important factor in the design of knowledge management applications. We are currently working on what specifications we need to implement a solid prototype implementation. Especially how our architecture can improve existing processes.

Having little to none client specific code is one of our key advantages. We are working with a large variety of devices, especially larger companies are not willing to exchange large quantities of existing hardware. Therefore, the client software needs to be adaptable. Furthermore, HTTP as the main transport protocol works well over company firewalls. One of the few drawbacks are rather bix XML-files. We are currently working on compressing them when transferring data from cell phones.

Finally, we have not addressed collaboration so far. Currently we are evaluating exisiting collaborative approaches and want to incorporate them into our architecture.

REFERENCES

Adipat, B. and Zhang, D. (2005). Developing adaptive and personalized mobile applications: A framework and design issues. In *Proceedings of the Eleventh Americas Conference on Information Systems (AMCIS 2005)*. Omaha, Nebraska.

Bardram, J. E. and Hansen, T. R. (2004). The aware architecture: supporting context-mediated social awareness in mobile cooperation. In *CSCW '04: Proceedings of the 2004 ACM conference on Computer supported cooperative work*, pages 192–201, New York, NY, USA. ACM Press.

Chan, D. and Roddick, J. (2003). Context-sensitive mobile database summarisation. In *ACSC 2003. Twenty-Sixth Australasian Computer Science Conference*.

Derballa, V. and Pousttchi, K. (2004). Extending knowledge management to mobile workplaces. In *ICEC 2004. Sixth International Conference on Electronic Commerce*, pages 583– 590.

Eco-Management and Scheme, A. (2007). Website: http://ec.europa.eu/environment/emas/.

Fagrell, H., Forsberg, K., and Sanneblad, J. (2000). Fieldwise: A mobile knowledge management architecture. In *CSCW 2000*, pages 211– 220.

for Environmental Audits ISO 14001 CMO-Global-Services, E. A. (2007). Website: http://www.cmohandheldsoftware.com.

Grimm, M., Tazari, M.-R., and Balfanz, D. (2002). *Lecture Notes in Computer Science 2569*, chapter Towards a Framework for Mobile Knowledge Management, pages 326–338. Springer.

Grimm, M., Tazari, M.-R., and Balfanz, D. (2005). A reference model for mobile knowledge management. In *Proceedings of I-KNOW 05*. Graz, Austria.

Hannig, U. (2002). *Knowledge Management and Business Intelligence*, chapter Zwei Welten wachsen zusammen. Springer, Berlin.

Holliday, J., Agrawal, D., and El Abbadi, A. (2002). Disconnection modes for mobile devices. In *Wireless Networks 8*, pages 391– 402.

Laakko, T. and Hiltunen, T. (2005). Adapting web content to mobile user agents. *IEEE Internet Computing*, 9(2):46–53.

Lum, W. Y. and Lau, F. C. M. (2002). A context-aware decision engine for content adaptation. *IEEE Pervasive Computing*, 1(3):41–49.

Pacheco, A., Serro, C., Costa, C., and Dias, F. (2006). Small screen rendering web-browser comparison - when web content is too large to fit the screen. In *ICE-B 2006 - International Conference on E-Business*, pages 145–150. August 7th-10th.

Picco, G. P., Murphy, A. L., and Roman, G.-C. (2000). Developing mobile computing applications with lime. In *ICSE '00: Proceedings of the 22nd international conference on Software engineering*, pages 766–769, New York, NY, USA. ACM Press.

Seedorf, S., Korthaus, A., and Aleksy, M. (2005). Creating a topic map query tool for mobile devices using j2me and xml. In *WISICT '05: Proceedings of the 4th international symposium on Information and communication technologies*, pages 111–116. Trinity College Dublin.

Thiele, O., Knapp, H., Schader, M., and Prat, N. (2006). A context-aware architecture for mobile knowledge management. In *Proceedings International Conference on Wireless Information Networks and Systems*. Winsys.

US-EPA, U. E. P. A. (2007). Website for auditing: http://www.epa.gov/compliance/incentives/auditing/.

Wei, Q. and Prehofer, C. (2003). Context management in mobile environments. In *Proceedings of ANwire Workshop, Paris*.

Zhang, D. (2007). Web content adaptation for mobile handheld devices. *Commun. ACM*, 50(2):75–79.

Zuma, S. M. and Adigun, M. O. (2006). Cacip: a pattern for interfacing components in a context-aware mobile environment. In *MS'06: Proceedings of the 17th IASTED international conference on Modelling and simulation*, pages 416–423, Anaheim, CA, USA. ACTA Press.