Context-aware Mobile Multimedia Services in the Cloud

Dejan Kovachev, Ralf Klamma

Chair for Computer Science 5 (Information Systems), RWTH Aachen University
Ahornstr. 55, D-52056, Aachen, Germany
{kovachev, klamma}@dbis.rwth-aachen.de

Abstract. Mobile devices become widely accepted computing paradigms; but the mobile services need to be aware of the dynamical user environment and adapt accordingly to the context. With the increasing amount of multimedia, ontologies can add value to the new semantic multimedia services, by considering the contextual information. Our goal is to provide new concepts for mobile multimedia computing in certain domains like cultural heritage data management. We propose to model the mobile, user and multimedia context with the use of ontologies. We take cloud computing as service infrastructure for supporting complex semantic multimedia tasks for the mobile clients.

1 Introduction

With the massive production of multimedia content nowadays, the usefulness of this content depends largely on the creation, sharing, reuse, discovery, access and delivery of the multimedia. Obviously, in many multimedia applications a semantic approach for knowledge representation and processing for the complete multimedia life cycle is needed. Using ontologies for domain knowledge representation can be identified as a promising tool that supports formal, explicit, machine-processable semantics definition and further knowledge discovery. Personalization brings benefits for the user by matching his stated and learned preferences, thus matching more the user's wishes and needs.

Most important concept of mobile computing is the "anytime, anywhere" computing by decoupling users from smart, intelligent device and viewing applications as entities that perform tasks instead of the user [10]. Using the contextual information in the multimedia value chain brings the possibility to provide value-added services or to execute more and complex tasks. Context-awareness takes an important role in the pervasive computing. Mobile phones that contain the basic building blocks for context awareness such as physical sensors, GPS, compass, accelerometers, light sensors and Internet access are seeing explosive adoption. On the other hand, the diversity of ways that the user context can be used by different services or context consumers is growing fast. This is due to the increasing number of service delivery or provider entities that can be accessed by the user [4]. Mobile phones enable new, rich user experiences, but their hardware is still very limited in terms of computation, memory, and energy reserves, thus limiting potential applications [6]. But their limitations can be exceeded by off-loading the execution of the hardware-intensive computations into the cloud. A recent study released by ABI Research [1] says that limited processing power, battery life, and data storage will limit mobile application growth in the mass market, even among smart phones like Apple's iPhone. But, applications that connect to cloud resources are much more likely to be successful than those that run only on the mobile device.

The problems are the following. New mobile phones provide a lot of contextual information, but this is not completly explotied for enriching the multimedia services on mobile platforms. The media context needs to be matched with the user's context. Other issues are exploiting the contextual information for adaptation for different devices and interoperability with the existing resources on the web.

In this paper we explore the possibilities for context-aware services for semantic multimedia targeted towards mobile devices in application domains like cultural heritage documentation. We consider also taking community context and other context information into consideration [5].

2 Background

Context is 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 the user and the application, including the user and the applications itself [7]. An application or 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. Examples of context information in mobile applications can be seen, e.g., spatial information - location, orientation, speed; and acceleration, temporal information - time of the day, date and season of the year; environmental information; social information - who you are with, and people that are nearby; resources that are nearby - accessible devices, and hosts; availability of resources - battery, display, network, and bandwidth; physiological measurements - blood pressure, hart rate, respiration rate, muscle activity, and tone of voice; activity - talking, reading, walking, and running; schedules and agendas. Many prototypes of context-aware applications are done [7, 15].

Context-aware systems use context models expressed as ontologies, in order to formalize and limit the notion of context and that relevant information differs from a domain to another and depends on the effective use of this information. The Web Ontology Language (OWL) is used to explicitly formalize the properties and structure of contextual information to guarantee common semantic understanding among different architectural components. OWL has well-defined syntax, formal semantics, reasoning support, and enhances information retrieval and interoperability. Ontologies also can well model the semantics of multimedia [8, 3].

A cloud-computing-based infrastructure for context-aware semantic multimedia services is promising [12]. One major benefit is to enhance interoperability between heterogeneous context-sources and applications. Other benefit are scalable resources on demand. There is also the need to manage massive amounts of diverse user-created data, synthesize it intelligently, and provide it as real-time services. Essential features of such visions are comprehensive context awareness, personalized user interfaces, and multimedia content adaptation. Ontology processing requires a lot of computing resources, especially for ontology reasoning that performs poorly according to the size of the ontology. Chun et al. [6] propose off-loading mobile applications in the cloud for resource demanding computations.

3 Application Areas of Context-aware Mobile Services

Possible applications areas of context-aware mobile applications are tourist guides, mobile advertisement, context-aware proactive news service, cultural heritage, technology enhanced learning and many others [15].

The *tourism* domain is widely considered to be one of the emerging industrial sectors where mobile services are highly demanded. In fact, in 2015 there will be more than 3 billion travelers around the globe and they will demand more ubiquitous services, specific to the situation of each individual, as well as to their personal preferences in specific circumstances. Surveys reveal that over 90% of travelers carry a mobile device with them. Time is a very scarce resource and connectivity to all kinds of services in mobility is highly demanded and required [4].

In the *cultural heritage* domain, a human expert relies on a number of properties to annotate artifacts at the capturing stage. The expert knowledge used in the process of archaeological investigation is then embedded in and integrated with the multimedia including the context information during the archaeological site documentation. This is an example of concurrent engineering where semantic multimedia can play an important role. Effective concurrent engineering systems should be based on knowledge management and sharing mechanisms and standards that are able to provide comprehensive formalization and reasoning infrastructure that supports the design and productions processes [13]. There are many attributes and properties of multimedia that scientists and professionals are using to exchange, process, and share content, and all these have to be classified and formalized thoroughly. Great value of the semantic multimedia is carried out also by the creation and annotation process, the intermediate steps that contributed to the definition of the final product and experts' knowledge used at the various stages of its development.

4 Analysis of Context-aware Mobile Multimedia Services

Conceptualization and realization of mobile context-aware multimedia systems face several design challenges that afford to cope with highly dynamic environments and changing user requirements.

Context-awareness can only be researched in relation to certain application domains or communities. A generic context management approach will not be manageable because of the inherent complexity of the context models as well as the sheer amount of context information. The problems here are related to gathering, modeling, storing, distributing and monitoring context.

We intent to create a set of web services that will allow devices to interface with applications anywhere in the cloud of accessible data sources, services and applications. A level of domain-specific and community-specific middleware glues all parts together, joining data from the sensors and applications with user input, storing contextual information, and allowing the mobile device to share that data across applications or even between different devices [16].

4.1 Architectural Design

The architecture should provide the foundations for the different entities to deal with context (how to discover it, how to store it, how to access it and how to take advantage of the information it provides) in a mobile environment.

Using the service-oriented computing paradigm will broaden the variety of accessible applications for mobile environments. Tim O'Reilly [11] believes that "the future belongs to services that respond in real time to information provided either by their users or by nonhuman sensors." Such services will be attracted to the cloud not only because they must be highly available, but also because these services generally rely on large data sets that are most conveniently hosted in large datacenters. This is especially the case for services that combine two or more data sources or other services, e.g., mashups. While not all mobile devices enjoy connectivity to the cloud 100% of the time, the challenge of disconnected operation has been addressed successfully in specific application domains, so this is not a significant obstacle to the appeal of mobile applications [2].

4.2 Data Management

An overview of the data organization for a cultural heritage documentation use case is given in Figure 1,. The system needs to cope with heterogeneous data from many sources, integrate contextual information from different sensors, cameras, 3D scanners and user input. The cloud of services provides interface to many applications and avoids cross-platform problems while easing the data sharing. The content delivery is performed using adaptation services while taking the context of the user and multimedia in consideration.

4.3 Context Modeling

For systems that provide context-aware mobile multimedia services we need to use context models in order to formalize and limit the notion of context and the relevant information from a domain. Ontology-based models propose a semantic modeling of context information, enhanced by appropriate reasoning mechanisms.

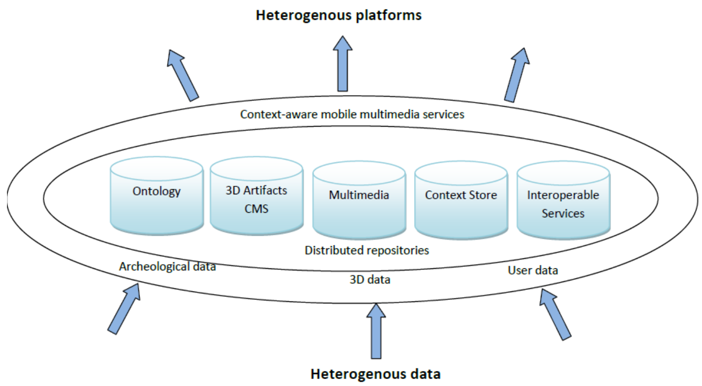

Fig. 1. Data organization in cultural heritage data management scenario

Ontologies are the basis and foundation for new intelligent multimedia applications, but we need further tools in order to make these applications a reality and to create commercially viable new businesses around these applications [9]. Reasoning enables formalization of the media interpretation process. The requirements that the model needs to fulfill are:

- **Appropriate multimedia and context ontology.** Higher-level context can be composed by low-level context. But dependencies of context items cause difficulties, which need to be resolved.
- **Exchange context information with other models.** Sharing conceptualized knowledge between different systems is the underlying idea of the Semantic Web.
- **Reuse existing related ontologies:** Ontonym, YAGO, DBpedia, CIDOC Conceptual Reference Model (CRM), aceMedia, Delivery Context Ontology, COMM and etc. Ontology-based models propose a semantic modeling of context information, enhanced by appropriate reasoning mechanisms [4].
- **Bridge the gap between social and Semantic Web.** Gather information about users from their Social Web identities and enrich with ontological knowledge.

Ontologies offer new possibilities regarding knowledge management, retrieval effectiveness, and online collaboration compared to conventional technologies and techniques. Development of ontologies for multimedia applications are needed by taking care of defining a comprehensive schema for documenting and sharing the media repositories, to be linked and further specialized by experts in different domains. Context ontologies should be designed in a two-level hierarchy. We divide a pervasive computing domain into several sub-domains, and define individual low-level ontology in each domain. We also define a generalized ontology which describes the general concepts in upper level to link up all the low-level context ontologies. Domain-specific ontologies can be dynamically "bounded" or "rebounded" with the upper ontology when the domain is changed [14].

4.4 Other Challenges

The other aspects that need to be addressed in the construction of context-aware mobile multimedia services are:

- **Privacy.** Sending the current location information into the cloud could lead to difficulties in establishing trust. The system need to be capable of preserving the user's privacy.
- **Sensing.** A big challenge is to sense context changes and establishing relations between context entities.
- **Context processing and classification.** Deducing information form context can be done in several ways, where the most common are semantic reasoning, interpretation of context, and aggregation of context.

5 Conclusions and Future Work

In this paper, we presented an approach to context-aware mobile services with focus on semantic multimedia. The semantic multimedia can create beneficial opportunities for new mobile applications, since these add value to multimedia assets. Ontologies expressed in OWL can be used for modeling the user and media context. We point the expected benefits of the use of multimedia semantics and describe two applications areas, i.e. cultural heritage documentation or tourist guides. We identify several challenges in the system construction.

In the future, we aim to develop extendable service-oriented infrastructure following the cloud computing paradigm that will provide services for mobile semantic multimedia. The service architecture needs to cope with all the context-awareness issues required for the domain. Prototype will be implemented in cultural heritage domain that will prove the expectations of the described approach.

Acknowledgments. This research work has been supported by the Research School within Bonn-Aachen International Center for Information Technology (B-IT).

References

1. Abi Research. Mobile cloud computing. http://www.abiresearch.com/research/1003385, 2009. Last accessed on 21.09.2009.
2. M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. H. Katz, A. Konwinski, G. Lee, D. A. Patterson, A. Rabkin, I. Stoica, and M. Zaharia. Above the Clouds: A Berkeley View of Cloud Computing. Technical report, EECS Department, University of California, Berkeley, February 2009.
3. R. Arndt, R. Troncy, S. Staab, L. Hardman, and M. Vacura. *COMM: Designing a Well-Founded Multimedia Ontology for the Web*, volume 4825 of *Lecture Notes in Computer Science*, chapter 3, pages 30–43. Springer Berlin Heidelberg, Berlin, 2008.
4. A. Cadenas, C. Ruiz, I. Larizgoitia, R. García-Castro, C. Lamsfus, I. n. Vázquez, M. González, D. Martín, and M. Poveda. Context management in mobile environments: a semantic approach. In *Proceedings of the 1st Workshop on Context, Information and Ontologies*. ACM, 2009.
5. Y. Cao, R. Klamma, M. Hou, and M. Jarke. Follow Me, Follow You - Spatiotemporal Community Context Modeling and Adaptation for Mobile Information Systems. In *The Ninth International Conference on Mobile Data Management (MDM 2008)*, pages 108–115. IEEE, April 2008.
6. B. Chun and P. Maniatis. Augmented Smartphone Applications Through Clone Cloud Execution. In *12th Workshop on Hot Topics in Operating Systems*. USENIX, 2009.
7. A. K. Dey. Understanding and Using Context. *Personal and Ubiquitous Computing*, 5:4–7, 2001.
8. R. Garcia and O. Celma. Semantic Integration and Retrieval of Multimedia Metadata. *2nd European Workshop on the Integration of Knowledge, Semantic and Digital Media*, 2005.
9. Y. Kompatsiaris and P. Hobson. *Semantic Multimedia and Ontologies: Theory and Applications*. Springer London, London, 1 edition, 2008.
10. K. Kwang-Eun and S. Kwee-Bo. Development of context aware system based on Bayesian network driven context reasoning method and ontology context modeling. In *International Conference on Control, Automation and Systems*, pages 2309–2313. IEEE, 2008.
11. T. O'Reilly. What Is Web 2.0. http://oreilly.com/web2/archive/what-is-web-20.html, 2005. Last accessed on 26.10.2009.
12. S. Schenk, C. Saatho, and A. Scherp. SemaPlorer-Interactive Semantic Exploration of Data and Media based on a Federated Cloud Infrastructure. *Web Semantics: Science, Services and Agents on the World Wide Web*, 7, 2009.
13. M. Spagnuolo and B. Falcidieno. *Semantic Multimedia and Ontologies*, pages 185 – 205. Springer London, London, 2008.
14. G. Tao, P. Hung Keng, and Z. Da Qing. A middleware for building context-aware mobile services. In *59th Vehicular Technology Conference*, volume 5, pages 2656–2660. IEEE, 2004.
15. D. Weiss, M. Duchon, F. Fuchs, and C. L. Popien. Context-aware personalization for mobile multimedia services. In *6th International Conference on Advances in Mobile Computing and Multimedia*, pages 267–271. ACM, 2008.
16. A. Wright. Get smart. *Communications of the ACM*, 52:1, 2009.