Context-Oriented Knowledge Management for Intelligent Museum Visitors Support

Ontological approach

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***Abstract*—The paper presents an approach to context-oriented knowledge management for supporting visitors in museum smart environment. Museum smart environment is a private network consisting of museum rooms equipped with devices that allow identifying visitor location, his/her movement and providing information about exhibits. Visitor has a mobile device, which stores visitor's preferences and communicates with the museum smart environment. The mobile device calculates museum visiting plan for the visitor based on the visitor's preferences, amount of visitors in each museum room at the current time and other context information (closed exhibits, reconstructions, seasonal exhibitions and other) acquired from Internet and intranet services.**

Keywords-knowledge management; ontologies; Internet services; user profiles; smart environment.

I. INTRODUCTION

Recently, the tourist business has become more and more popular. People travel around the world and visit museums and other places of interests. This fact increases popularity of the museums. But overwhelming majority of museums has limited space for visitors causing accumulation of visitors and increasing waiting time for them.

In this regard an approach is needed, which allows assisting visitors (using their mobile device), planning their excursion plans depending of the context information about the current situation in the museum (amount of visitors around exhibits, closed exhibits, reconstructions and other) and visitor's preferences.

Smart environment is an aggregation of mobile and stationary devices, which can interact with each other and use pertinent services regardless of their physical location. Such technology allows seamless integration with other system, services, and program modules.

Research efforts in the area of the smart environment have become very popular recently. Such topics of research as smart home, smart car, etc. are widely discussed in the modern computer science. In such systems all elements have to interact and coordinate their behavior without any user intervention.

Modern tendencies of information and telecommunication technologies require development of stable and reliable infrastructures to extract and keep different kinds of information and knowledge from various members of the smart environment. The smart environment assumes more than one device that uses common resources and services. One of the most appropriate approaches to implement such infrastructure is applying knowledge management systems.

A museum can be considered as a smart environment (Figure 1) where each exhibit or a group of exhibits is represented by a stationary device of the smart environment. Each device can interact with other stationary devices representing exhibits and with visitors' mobile devices. Visitor's mobile device interacts with other smart environment devices and provides for the visitor an acceptable excursion plans inside the museum based on the museum context (amount of visitors around exhibits, closed exhibits, reconstructions and other) and visitor preferences.

Visitor's mobile device also can provide textual, graphical, video and audio information for the user in his/her language.

The following scenario can be considered. A tourist arrives in Paris. He/she is going to attend Louvre Museum and he/she has the intelligent museum visitors support system on his/her mobile device. The tourist adds his/her interests to his/her user profile within the intelligent museum visitors support system, for example it can be Leonardo da Vinci paintings. When the visitor enters the Louvre the mobile device guides him/her based on interests defined him/her earlier and museum context. For example, if at the moment there are no too much people in the room where the Mona Lisa painting is shown the mobile device proposes to start from this exposition because usually this room is overcrowded. After that he/she can see Madonna of the Rocks, Lady with an Ermine, Benois Madonna and other. When the tourist approaches the painting or another exhibition he/she gets audio, textual and video information about it from appropriate service through the Internet or intranet.

The rest of the paper is structured as follows. Section II presents an overview of mobile museum guides systems. Section III introduces developed approach to knowledge management in museum smart environment. The museum ontology is shown in Section IV. Information model of museum visitor profile is given in Section V. The case study can be found in Section VI. Main results and drawings are summarized in Conclusion.

 ISBN: 978-1-61208-148-9

II. Mobile Museum Guides Systems Overview

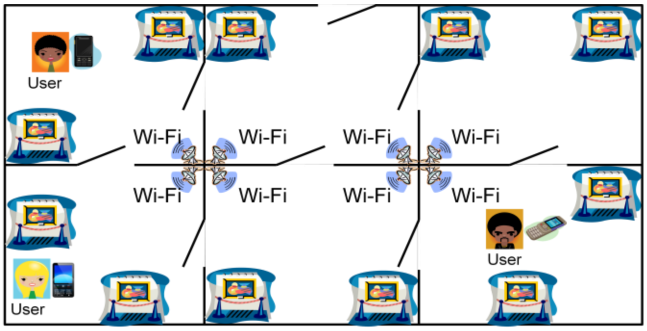

Figure 1. Museum smart environment infrastructure

spaces (i.e., museums, art exhibitions). The system is meant to provide the visitor with personalized information about the relevant artworks nearby. The information is mainly audio in order to let the user enjoy the artworks rather than interacting with the tool.

Bohnert et al. [2] describes a system for providing a visitor with the challenge of selecting the interesting exhibits to view within the available time. It includes the recommendation and personalization process, i.e., the prediction of a visitor's interests and locations in a museum on the basis of observed behavior.

Kuflik et al. [3] describes an approach for supporting users in their ongoing museum experience, by modeling the visitors, "remembering" their history and recommending a plan for future visits. This approach identifies some of the technical challenges for such personalization, in terms of the user modeling, ontologies, infrastructure and generation of personalized content.

Project CRUMPET [4] has realized a personalized, location-aware tourism service, implemented as a multi-agent system with a concept of service mediation and interaction facilitation. It has had two main objectives: to implement and trial tourism-related value-added services for nomadic users across mobile and fixed networks, and to evaluate agent technology in terms of user-acceptability, performance and best-practice as a suitable approach for fast creation of robust, scalable, seamlessly accessible nomadic services.

The main research activities of HIPS project [1] are development of approach for navigating artistic physical

These systems don't take into account information about current situation. Proposed approach allows monitoring the current situation in the museum and uses it for visitor assistance.

III. Knowledge Management in Museum Smart Environment

The approach presented in the paper relies on the ontological knowledge representation. The conceptual model of the proposed ontology-based knowledge management is based on the earlier developed ideas of knowledge logistics [5]. In this work the ontology is used to describe knowledge in the smart environment.

The architecture of the approach is presented in Figure 3. Mobile and stationary devices interact through the smart environment. When the visitor registers in the system, his/her mobile device creates the visitor profile that allows specifying and complement visitor requirements in the smart environment and personifying the information and knowledge flow from the system to the user. Every time the visitor appears in the smart environment the mobile device shares information from the visitor profile with other devices.

The proposed ontological approach to context-oriented knowledge management in the museum smart environment is presented in Figure 2.

The following scenario for mobile and stationary device interaction support in the smart environment is considered.

A visitor enters a museum. His/her mobile device finds the museum smart environment using Wi-Fi connection.

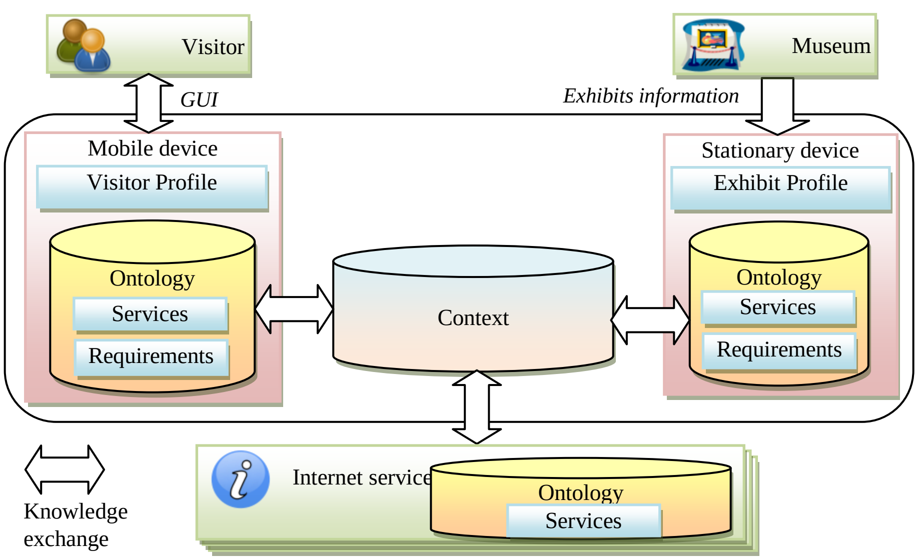

Figure 2. Ontological approach to context-oriented knowledge management in the museum smart environment

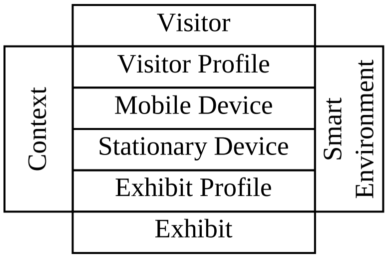

Figure 3. Architecture of the proposed approach

The mobile device informs the visitor that the smart environment has been found and based on the visitor's preferences and the current situation in the museum (the context) an acceptable path for visiting museum rooms is built. The context is formed based on the interaction process between the visitor's mobile device and other mobile and stationary devices through the smart environment. The context is the description of the visitor's task in terms of the ontology taking into consideration the current situation in the museum. The ontology in the knowledge management system describes the main terms used for the museum smart environment description and relationships between them.

The mobile device of the visitor provides services for sharing information with other devices of the smart environment. For example, it shares the visitor's location, visitor's personal information, preferences and preferred exhibits to see.

For these purposes, the visitor profile has to contain personal information about the visitor, domain specific information (e.g., preferred exhibits to see), information that describes user preferences, feedback information and history that contains previous user activities in the system.

IV. MUSEUM ONTOLOGY

There are several different ontologies of intelligent museum visitors support systems has been analyzed [3][7][8]. The upper-level museum ontology based on these ontologies is presented in Figure 4.

It consists of Device entity divided into Infrastructure Device, Mobile Device, and Stationary Device entities. Infrastructure Devices provide infrastructure for the Smart Environment (e.g., Wi-Fi, hot spots).

Figure 4. Upper level of the museum ontology

Figure 5. Device entity of the museum ontology

Mobile Devices are used by museum visitors and allow visitors to connect to Smart Environment, to get assistance, and information about exhibits. Stationary Devices represent exhibits in Smart Environment (provide to Smart Environment all necessary information about exhibits).

A more detailed description of Device entity is presented in Figure 5. Every Device has location information (associative relationship to Location entity). Infrastructure devices have attribute Type (e.g., Wi-Fi or Bluetooth).

Mobile devices have attributes which characterize hardware and software information and rights in the museum smart environment. Every Mobile Device entity has associative relationship to Visitor entity, which means that this visitor uses that mobile device. Stationary device has associative relationship with Exhibition, which means that this exhibition is represented by this stationary device in smart environment.

A more detailed description of Excursion entity is presented in Figure 6. Every excursion is described by the following attributes: description, duration, name, and start time. Excursion entity has associative relationships to Exhibition, Visitor, and Museum entities.

 ISBN: 978-1-61208-148-9

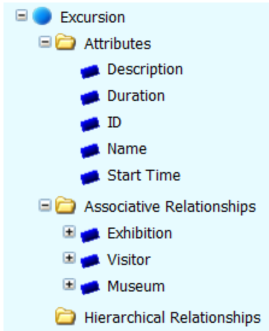

Figure 6. Excursion entity of the museum ontology

Description of Location entity is presented in Figure 7. It includes the following attributes: Accessibility for Disabled Visitors which means that this location is equipped to assist disabled visitors, and Description which describes the location. Class compatibility relation with Disabled Visitor entity determines if this Location is compatible or incompatible with the Disabled Visitor, based on Type of Disability (see Figure 12).

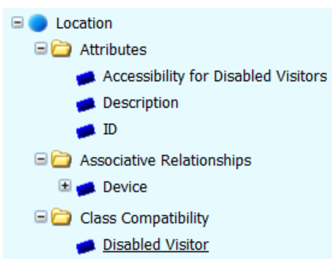

Figure 7. Location entity of the museum ontology

Figure 8 represents different roles for a museum visitor. Role entity has associative relation to Visitor entity. The following roles can be mentioned: researcher, school teacher, regular visitor, tourist, and other. Additional information for the every role can be used by the system. E.g., researcher will stay in museum for a long time, school teacher attend the museum with children, etc.

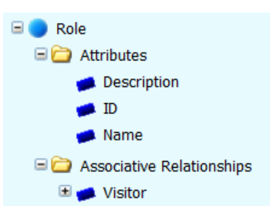

Figure 8. Role entity of the museum ontology

More detailed description of Museum entity is presented in Figure 9. This entity has attribute Name (the name of the museum), associative relations to Excursion and Smart Environment entities, and hierarchical (part-of) relations to Exhibition entity.

Description of Exhibition entity is presented in Figure 10. It is characterized by the following attributes: capacity, description, name, style, type.

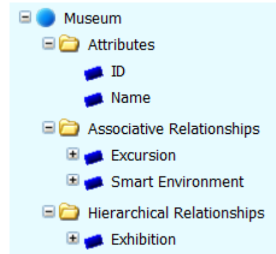

Figure 9. Museum entity of the museum ontology

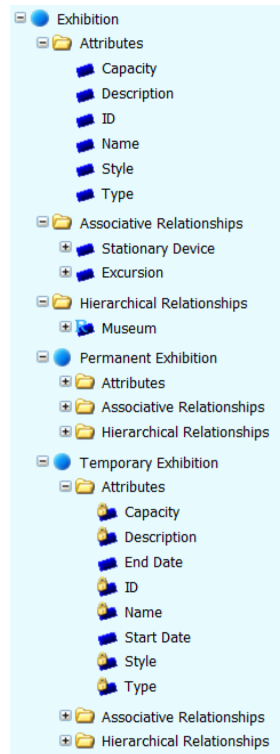

Figure 10. Exhibition entity of the museum ontology

Associative relation to Stationary Device entity means that this exhibition is represented by this stationary device in the smart space. Relation to the Excursion entity means that this exhibition is included into the excursion. Hierarchical relation to Museum entity means that this exhibition is part-of the Museum. Temporary exhibitions have additional attributes Start Date and End Date, which determine start and end date of exhibition.

Figure 11 represents Smart Environment entity. It has associative relation to Museum entity and hierarchical relation to Device entity.

Description of the Visitor entity is presented in Figure 12. The following attributes describe the visitor: name, gender, date of birth, e-mail, list of languages for communication, phone number, and position. Associative relation to Role entity means that the visitor has a role. Relation to Excursion entity determines that the visitor is connected to the excursion. Relation to Mobile Device entity determines that the visitor uses the mobile device to communicate with museum smart environment.

 ISBN: 978-1-61208-148-9

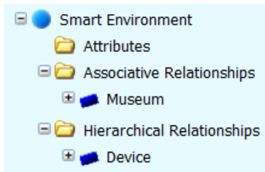

Figure 11. Smart Environment entity of the museum ontology

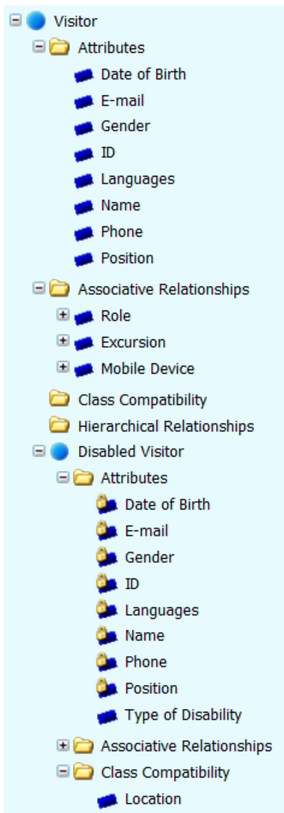

Figure 12. Visitor entity of the museum ontology

V. Visitor Profile

Most of user profile models include such information as: first name, last name, gender, date of birth, languages, and contact information and user position. This information is also important for intelligent museum visitor's support. It is stored in the "Personal Information" module (Figure 13).

Museums visitors can have different roles (e.g., individual visitor, family, group of schoolchildren and other). Intelligent museum visitor's support system can take into account this information for building the plan of the excursion. Some parts of the visitor profile can be hidden from other visitors (for example if the user would like to attend museum anonymously). For this purpose the visitor has to choose which information can be accessible to other devices. It is needed to provide the knowledge management system with information about visitor's hardware and software capabilities, because based on this information the system suggests the visitor which types of exhibit descriptions (audio, video, textual) he/she can use. This information is stored in the "System Information" module (Figure 13).

Since the knowledge management system is context-oriented, it is necessary to determine the location of the visitor in time. For this purpose the module "Context Information" is proposed.

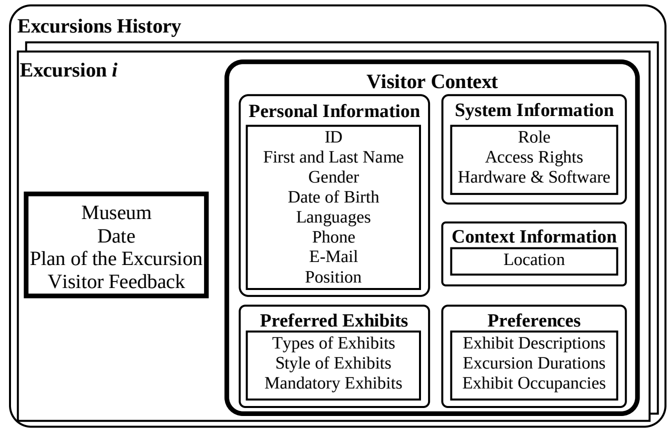

Figure 13. Model of museum visitor profile in intelligent museum visitor's support system

For building an acceptable plan of excursion the system needs information about exhibits preferred by the visitor: types of exhibits (paintings, ancient items and other), styles of exhibits (modern, impressionism and other), and mandatory exhibits which visitor have to see (e.g., Venus de Milo, Mona Lisa in the Louvre Museum). Also visitor profile has to keep the information about preferable types of exhibit description (audio, video or/and textual), excursion duration (how much time the visitor can spend at this museum), exhibit occupancies (in case of high occupancy of an exhibit the visitor might prefer to skip this exhibit or to try to see it later).

For the purpose of keeping the history of interaction between the visitor's device and the museum smart environment, and its further analysis all excursions of this visitor, including the museum name, date, plan of the excursion, visitor's feedback about the excursion, and user context at the moment of excursion are stored in visitor profile. Based on this information, the visitor's preferences and preferred exhibits can be semi-automatically identified using ontology-based clustering mechanisms described in [6].

VI. Case Study

The intelligent museum visitor's support system has been implemented based on proposed approach and ontology. Maemo 5 OS – based device (Nokia N900) and Python language are used for implementation.

An open source software platform [9] that aims to provide a "Semantic Web" information sharing infrastructure between software entities and devices is used for system implementation. In this platform the ontology is represented via RDF triples. Communication between software entities is developed via Smart Space Access Protocol (SSAP) [9].

Different entities of the system are interacting with each other through the smart environment using proposed in Section IV ontology. Every device has a part of this ontology and after connecting to smart environment it shares own ontology part to the smart environment.

The system has been partly implemented in Gymnasium of Karl May History Museum [10] which located in the same building with St. Petersburg Institute for Informatics and Automation RAS.

When the visitor enters the museum he/she can connect to the museum intranet network and download appropriate software for getting intelligent museum visitors support. Installation of this software takes few minutes depending on operating system of mobile device (at the moment only Maemo 5 OS is supported). When the visitor runs the system first time the profile has to be completed. This procedure takes not more than 10 minutes. The visitor can fill the profile or can use a default profile. In case of default profile the system can not propose preferred exhibitions to the visitor.

Response time of the Internet services depends on the Internet connection speed in the museum, number of people connected to the network, and workload of the services. Average response time should not exceed a one second.

On the three top screenshots (Figure 14) the visitor profile is presented. According to the model of museum visitor profile in intelligent museum visitor's support system it consists of personal information, system information, visitor preferences (preferred exhibits and other preferences). The fourth screenshot shows an exhibit description acquired from an external Internet service (e.g., Wikipedia).

VII. Conclusion

The paper presents an innovative approach to context-oriented knowledge management for supporting visitors in museum smart environment. This approach allows different devices in the museum smart environment to interact with each other for the purpose of guide visitor in the area of museum. User profiles allow keeping important information about the user and using it in the smart environment.

Since there is no the centralized server in the proposed system, the performance is affected by the number of visitors indirectly. If there are many visitors using the system, the bottleneck of the system performance will be network capacity and Internet services.

Acknowledgment

The paper is a part of the research carried out within the project funded by grants # 09-07-00436-a, 11-07-00045-a, and 10-07-00368-a of the Russian Foundation for Basic Research; project # 213 of the research program "Intelligent information technologies, mathematical modeling, system analysis and automation" of the Russian Academy of Sciences; and contract # 14.740.11.0357 of the Russian program "Research and Research-Human Resources for Innovating Russia in 2009-2013".

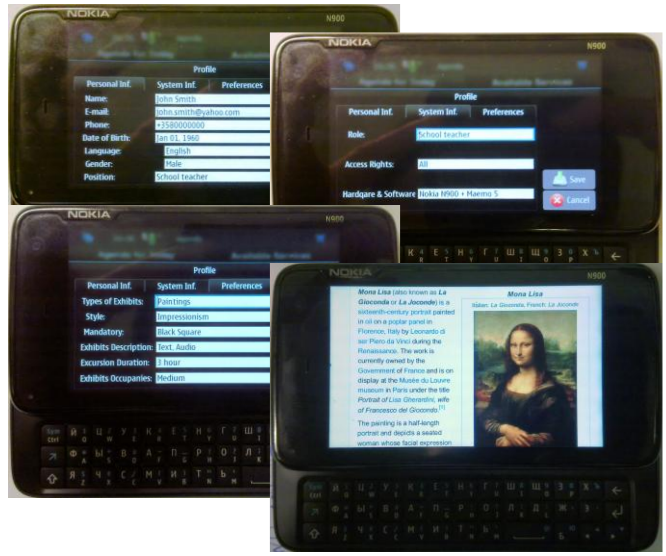

Figure 14. demonstrates some screenshots of the prototype.

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 ISBN: 978-1-61208-148-9