# On Semantic Network Design for a Smart Museum of Everyday Life History

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***Abstract*—Technologies of the Internet of Things (IoT) and of smart spaces provide an effective base for creating smart museums based on digitized infrastructures and information systems already deployed in many modern museums. Cultural heritage knowledge in such a museum is used by interested visitors as well as by professionals. This work continues our research on the smart museum concept and its case study of everyday life history in the History Museum of Petrozavodsk State University. We provide an ontological model for the needs of studying the everyday life history. The ontology supports integrating available descriptions of museum exhibits (collected in the existed museum information system) into a semantic network, where the links reflect relations between exhibits and other historical objects. We apply the wiki technology within the smart spaces-based architecture of a smart museum. The wiki implements an ontology-enabled system that experts use to extract semantics from the existed museum information system. We discuss possible semantic algorithms for data mining in the museum semantic network.**

## I. INTRODUCTION

Technologies of the Internet of Things (IoT) and of smart spaces provide an effective base for creating smart museums based on digitized infrastructures and information systems already deployed in many modern museums. In particular, these technologies can be used for the following application problems, which appear in museum-based studies of everyday life history [1]. 1. Extension of the museum collection on everyday life history by adding semantic annotations about the exhibits by both museum personnel and visitors. 2. Discovery of historic-valued relations (semantics) between collected descriptions and facts about collected exhibits. 3. Construction of personalized recommendations for museum visitors based on the visitor profiles and other context information.

In this work, we consider the smart spaces-based architecture of a smart museum [2]. Our case study is the History Museum of Petrozavodsk State University (PetrSU). The studied information services operate with descriptions of museum exhibits and available information about other historical objects (persons, documents, events, etc.) [3]. These services assist collective semantic annotation, information linking, personalized access to the museum collection. Personnel and visitors of the museum can add descriptions, new facts and links to historical facts and other exhibits. The services support enrichment of the museum collection with additional semantics about everyday life history.

To develop such services within the given smart spaces-based architecture for the case study of the History Museum of PetrSU we focus on the following components of the smart museum environment. 1. Ontological model for structural description of collected objects of the everyday life history and their various history-valued relations. 2. The wiki technology to transform the semantics from the existed museum information system to the semantic network using experts and the ontological model. 3. Semantic algorithms for data mining in the semantic network to take into account existing relations between collected exhibits and other historical objects.

The rest of this paper is organized as follows. Section II overviews the existing approaches to development of cultural heritage services based on ontology modeling and the wiki technology. Section III describes the case study of the History Museum of PetrSU. Section IV presents our ontological model to structurally represent inforamtion in the everyday life history domain. Section V introduced the wiki technology into the smart spaces-based architecture of a smart museum. Section VI discusses possible semantic algorithms for data mining in the semantic network.

## II. RELATED WORK

The IoT-enabled development of advanced services for a smart museum is now a rapidly growing area [4]. On the one hand, material exhibits (real cultural objects) can be made smart things in a museum exposition room, similarly as it happens in IoT in general [5]. The IoT technology provides the opportunity for a cultural object to interact with people, environment, other objects, and transmitting the related information to visitors through multimedia facilities, e.g., see [6]. On the other hand, many information fragments become associated with material exhibits in the form of multimedia objects (e.g., descriptions, photos, audio-records). Such virtual objects create an augmented reality for the visitors to enhance their cultural and historical experience, e.g., see [7].

The need of semantic integration of the multitude of real and virtual cultural objects that the museum encompasses in its collection has been already understood [1]. The information amount grows quickly. Many virtual objects appear for one material exhibit. When considering relations between cultural objects, then the data become linked [8], and the number of links can grow in the quadratic law. The use of semantics in construction of valuable recommendation for museum visitors and appropriate visualization of the information are considered in [9], [10].

To structurally represent such amount of information the ontology modeling techniques are used. Ontology CIDOC CRM [11] is used for describing artifacts in a museum collection. In particular, a man-made thing can be described with its associated attributes, relations, and restrictions. The FDR historical ontology defines a range of linguistic phenomena and entities, including persons, titles, dates, locations, and organizations (military, government, civilian, etc.), as well as documents, treaties, policies, ships, and other military apparatus, raw materials, monetary references, etc. [12]

An effective mechanism for ontology modeling and collaborative data linking is semantic wiki. In particular, DBpedia [13] scrapes open cultural information from Wikipedia based on advanced queries. Semantic MediaWiki (SMW) adds database-like structuring and querying capabilities on top of an existing collaboratively managed online content, without requiring users to develop or adhere to a rigid database schema when authoring content [14]. For example, SMW-based publication of old Russian charters is studied in [15].

## III. Case Study

The smart museum concept was introduced in [1]. The concept can be realized using the smart spaces paradigm [16]. The system architecture and high-level design were proposed and discussed in [2]. We continue this smart spaces-based development for the case study of the History Museum of Petrozavodsk State University (PetrSU).

The History Museum of PetrSU is a typical domestic museum oriented to University life and activity in their wide connection with the whole Russian and World history. The museum exists since 1987 collecting artifacts and digitalized information on the university history for the period from 1931 to nowadays. The museum includes more than 10 thousand exhibits in material and digital forms: photos, documents, published and unpublished scientific papers, laboratory instruments, issues of University newspaper, audio and video interviews, movies to anniversaries of the University and its departments, personal things of lecturers and students (e.g., items of clothing, house ware).

The exposition room is small, targeting groups up to a few dozens of visitors. An exposition combines (i) traditional material exhibits allocated in the room and (ii) information show on surrounding wide-format screens. The latter are distributed in the physical room space. Such a screen can be either large (visible from any point in the room) or medium (located near the given exhibit to make its augmentation). In addition, personal mobile devices of visitors and personnel can be used for personalized information presentation.

Museum exhibition activity is primarily directed to University guests and historians, PetrSU students and lecturers, veterans and graduates, school pupils and teachers of the region. One of the priority themes is the University everyday

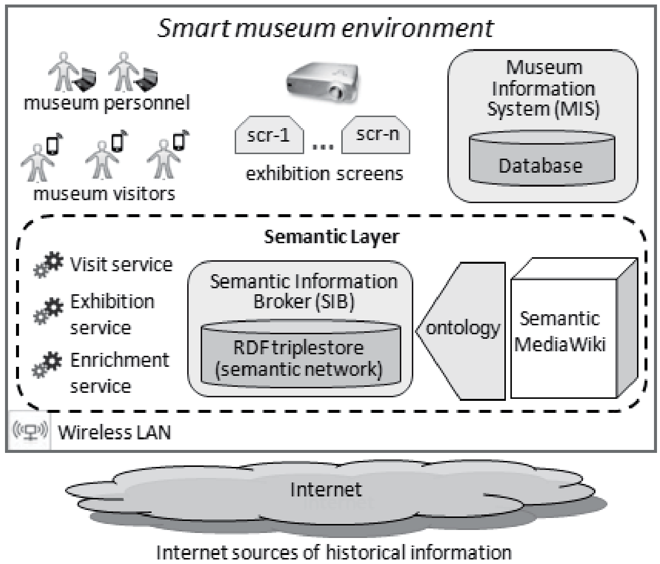


Fig. 1. The smart spaces-based architecture of smart museum environment

life history. Exposition topic (a presented suit of thematically related material exhibits) is regularly changed to cover various aspects of the University history.

The following tree particular services to assist museum personnel and visitors were defined in [1], [2].

*Visit service:* supports construction of a thematic exposition by finding exhibits recommended for the show subject to the given topic and its connection with expected visitors preferences and interest to study.

*Exhibition service:* supports provision of augmented information about a given exhibit based on analysis of the visitor profile and her/his situation to understand her/his personal interests in everyday life history.

*Enrichment service:* supports situational enhancement of the museum collection based on the knowledge provided by visitors during their study in the exposition room.

These services can be implemented within a service-oriented smart museum environment following the smart spaces-based architecture shown in Fig. 1. A smart space creates a semantic layer where the collected museum information is integrated and interrelated [1]. The smart space opens the information for shared operation by all involved participants, including human (personnel and visitors) and machines (information collection, processing, and visualization).

The shared information is represented in the form of a semantic network. In general, a semantic network is a directed graph consisting of nodes, which represent domain objects, and links, which represent semantic relations between them. In the museum case, nodes represent historical objects (exhibits, associated persons, etc.) and links represent relations between such objects. Objects and links have meaningful and interpretable value from history point of view. The rules of structuring the information are defined using a problem domain ontology.

For software system development of this type of smart spaces the Smart-M3 platform and appropriate Semantic Web technologies can be used [16]. In particular, the semantic network is represented and maintained using Resource Description Framework (RDF) in accordance with the predefined ontology. The semantic network is stored in an RDF triplestore, which is accessed and operated through a Semantic Information Broker (SIB). Semantic MediaWiki (SMW) is a mediator for a traditional Museum Information System (MIS). SMW supports RDF-aware construction of the semantic network by semantics that experts identify in records stored in MIS. This way, the implicit semantics are transformed to SMW representation (as a connected set of web-pages).

To realize the smart spaces-based architecture for the case study of the History Museum of PetrSU we focus on the following components of the smart museum environment.

1) Ontological model for structural description of collected objects of the everyday life history and their various history-valued relations.
2) The wiki technology to transform the semantics from MIS to the semantic network using experts (museum personnel and historians) and rules of the ontological model.
3) Semantic algorithms for data mining in the semantic network to take into account existing relations between collected exhibits and other objects.

In the subsequent sections of this work we study the selected components in detail.

## IV. Ontological Model

Let us introduce an ontological model that describes objects and relations from the everyday life history domain. The everyday life history is a new branch of historical research. The study subject is the human in multiple historical, cultural, political-event, ethnic, and religious contexts. The research focus is on a comprehensive study of the repetitive “normal” or ”common” way of life. For a historian a simple description of the daily practices is not enough, and fixation of the emotional component is essential.

The reconstruction and study of everyday life is a complicated problem due to the very broad and heterogeneous domain [17]. Information from multiple historical sources is diverse and often containing facts beyond the everyday life history. Although many works limit the everyday life history scope with the private life domain, we also consider the working life domain according with our university museum case. In particular, behavior patterns and relationships that arise in workplace and university activity are taken into the consideration.

Let us describe possible categories for the everyday life domain. On the one hand, we adopt the scientific tradition of studies in the university everyday life [18]. On the other hand, we are guided by the nature of the content. As a result, we identify the three major macro-areas.

1) The material life. Way of life in the broadest sense, including such subcategories as clothing, housing, food, working conditions, leisure, etc. A new approaches to the study of material cultural is presented in [19].

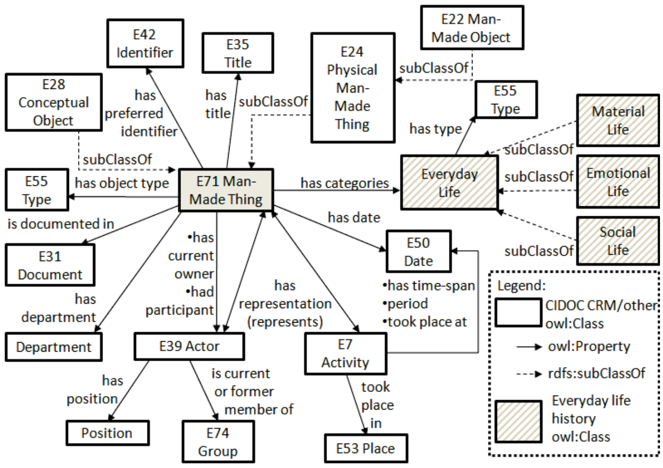


Fig. 2. Ontology model for the university everyday life

2) The social life. Event area of public daily life, including such subcategories as holidays, academic events, special rituals, etc.
3) The emotional life. The emotional side of events, the experience of everyday facts and domestic circumstances individuals and groups of people. There are two indicators: positive and negative evaluations of the respondents.

For the base we consider the well-known CIDOC conceptual reference model [11] for representation of historical information about exhibits. CIDOC CRM covers the major museum exhibition aspects: exhibits and other historical objects with their semantic relations between each other. Our particular focus in on the PetrSU everyday life, where PetrSU acts as an educational and research institution.

The proposed ontological model is based on CIDOC CRM. The basic ontology classes and properties are depicted in Fig. 2. We extent CIDOC CRM with a unique part for visit programs, exposition study, visitors, their interests, and recommendations.

To summarize, the model provides the following description opportunities for construction of the semantic network.

- Primary historical information about each particular exhibit (provided by experts from MIS).
- Supplementary information about collected exhibits (provided by museum personnel and visitors during the study).
- Particular relations between exhibits and other objects to link the nodes in the semantic network.
- General construction rules for the semantic network (classes of objects, their attributes and relations).

## V. Semantic Media Wiki

We apply the wiki technology to extract the semantics from MIS (a database with records of the fixed structure) and to transform the information to the semantic network. On the one hand, only an expert can identify valuable relations between different records. On the other hand, such traditional ontology editors as Protege are difficult for use by non-professionals (in ontology modeling). In this case, the ontology development tools should be lightweight. Among these tools, semantic wiki systems are of especial interest, and Semantic MediaWiki (SMW) [14] seems an effective candidate for use by museum personnel and historians.

SMW is an extension of the famous system MediaWiki, which is a technological foundation of Wikipedia. Each object (e.g., a description of an exhibit) is represented as a web-page. The main feature is support of typified links between pages. Such typified links enable construction of simple semantic networks, which can be further automatically translated into the RDF format. In our architecture, SMW plays the role of a mediator between MIS and the smart space. Since MIS does not store directly the semantics of museum exhibits, experts extract the semantics and represent in SMW.

In SMW, objects are represented as wiki-pages. Categories play the role of ontology classes that can be assigned to the pages, thus expressing an object belonging to the class. Categories can be nested into each other, forming a class hierarchy. To describe all other relationships typified links between pages are used. The role of the subjects and objects of semantic relations in SMW always represented as wiki-pages.

This model significantly limits the possibilities for information representation about the domain. That is, in SMW an expert can easily express the idea that an exhibit is addressed to a particular person Both exhibit and person are presented as pages. Nevertheless, SMW cannot describe a logical statement about individual words or other parts of the wiki-page.

Despite the limitations, SMW can be very convenient for the rapid creation of a simplified version of a semantic network around the museum exhibits. The simplified version reflects the expert knowledge about relationships of exhibits to each other and to other objects (such as a person).

In addition to expert-based work with the use of SMW, some other methods are needed for semantic network construction, including automated variants. In particular, knowledge extraction algorithms can be used for each information source (e.g., a text analyzer). In the smart spaces-based architecture, such algorithms are implemented in software agents associated with the sources.

## VI. Semantic algorithms

The considered assistance services need a semantic search operation when appropriate objects are found in the smart space. For example, Visit service needs to find a small group of tightly interrelated exhibits to form a given thematic exposition. This type of search is reduced to semantic algorithms for data mining in the semantic network of the museum. In this section, we briefly introduce possible classes of such algorithms.

The semantic network provides a peer-to-peer (P2P) virtualization of the museum problem domain, similarly as it happens in general smart spaces case [20]. As a result, graph-based algorithms over the semantic network can be applied.

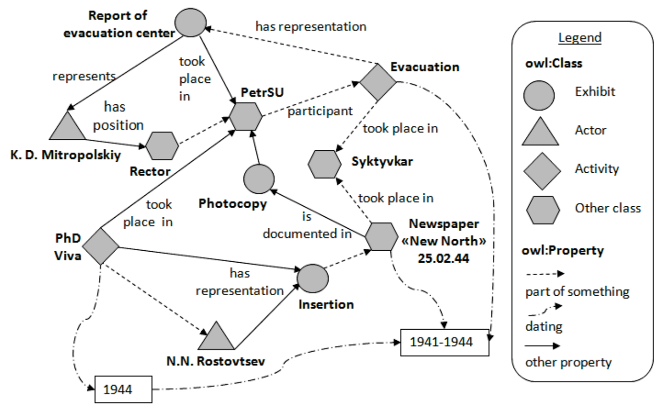


Fig. 3. Sample semantic network: some historical relations during the evacuation of the PetrSU

*Semantic ranking:* Numerical values (ranks) are assigned to nodes of the semantic network. In particular, exhibits are ranked based on their connectivity structure. The most ranked exhibits are clustered into a group of thematically tightly interrelated objects. This class of algorithms is based on the global knowledge approach when the entire network is analyzed. An advantageous candidate is the PageRank algorithm and its various modifications [21, ch. 10].

*Complex relations:* Identification of connected structures in the semantic network. In particular, a cyclic path means a closed form of relation for all objects on the path. Such an identified connected structure can be recommended to the visitor for study and interpretation. For example, it can be a starting point for Enrichment service when the visitor provides new knowledge by interpreting the studied connected structure. An advantageous candidate is algorithms for determination of the cyclic structures, which are used for advanced routing in P2P networks [21, ch. 8 and 9].

*Semantic neighborhood:* Context-aware selection of the most related objects for the given exhibit. In particular, personalized recommendation can be provided to the visitor on further exhibits to study in the relation with the current exhibit. For example, Exhibition service visualizes the recommended exhibits on the surrounding screens or on the personal mobile device. This class of algorithms is based on the local knowledge approach when a neighborhood is analyzed around the given node in the network. An advantageous candidate is algorithms for neighbor selection and local ranking from P2P networks [21, part II].

An example of the possible role of semantic algorithm for data mining in the museum semantic network is the activity of rector K. D. Mitropolsky. Since he headed the University in the period 1942–1944 he became connected with many articles about the University. The articles were published in newspaper “New North” during the evacuation of the PetrSU in Syktyvkar. Nevertheless the name of rector is not always explicitly mentioned in these articles. A fragment of the semantic network is shown in Fig. 3 with implicit relations between museum exhibits and the biography of K. D. Mitropolsky. Semantic algorithm aim at finding such implicit relations. The semantic network in Fig. 3 also shows the relation between K. D. Mitropolsky and N. N. Rostovtsev. Although such an important fact can be identified by a human expert only the initiation can be supported with a semantic algorithm that finds a fragment in the semantic network for the expert to study and interpret.

## VII. Conclusion

This work continued our study of the smart museum concept. We considered the case study of everyday life history in the History Museum of PetrSU. First, we developed an ontological model for the needs of semantic network construction in this case study. Second, we introduced the wiki technology into the smart spaces-based architecture of a smart museum. The SMW introduction support expert-driven extraction of historical knowledge from a traditional MIS. The extracted knowledge is then structurally represented in the semantic network. We discussed possible classes of semantic algorithms that implements problem-specific data mining on top of the constructed semantic network. The algorithms are inherited from the well-known area of P2P networks.

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