Smart Spaces Approach to Development of Recommendation Services for Historical e-Tourism

Aleksey G. Varfolomeyev
Faculty of Mathematics
Petrozavodsk State University
Petrozavodsk, Russia
e-mail: avarf@petrsu.ru

Dmitry G. Korzun
Department of Computer Science
Petrozavodsk State University
Petrozavodsk, Russia
e-mail: dkorzun@cs.karelia.ru

Aleksandrs Ivanovs
Department of History
Daugavpils University
Daugavpils, Latvia
e-mail: aleksandrs.ivanovs@du.lv
Research Institute for Regional Studies (REGI)
Rezekne University
Rezekne, Latvia

Oksana B. Petrina
Faculty of Mathematics
Petrozavodsk State University
Petrozavodsk, Russia
e-mail: petrina@cs.karelia.ru

***Abstract*—Recommender systems support advanced services in many domains. In this paper, we study personalized recommendation services for historical e-Tourism. The considered recommendation-making is based on a corpus of historical data distributed over multiple sources and requires taking into account various semantic relations between historical objects. We adopt a multi-agent architecture to develop services using the smart spaces approach. In contrast to the existing web-based solutions and mobile standalone applications, we propose to provide a tourist with a smart space. It integrates and self-generates historical and other relevant information. Based on this information, personalized recommendations with quantitative and qualitative estimates are constructed and then visualized to assist the tourist in history-aware analysis of points of interests.**

Keywords–Historical e-Tourism; Recommender Systems; Point of Interest; Smart Spaces; Personalized Services.

I. Introduction

Currently, the role of e-Tourism recommender systems is growing. A lot of research has been done, especially in the direction of making services of such systems mobile and intelligent [1][2]. A topical subdomain is historical tourism [3][4], which we distinguish from a more general cultural heritage tourism. In particular, the historical tourism focuses on visiting historical Points of Interest (POI) and on studying their relation with other historical objects (POIs, events, persons, etc.).

For a historian tourist, a POI is recommended not only if it is nearby and within the user's interests. Such a tourist would like to see a spectrum of historically related POIs; some are closely located and some can be faraway. Clustering important POIs for recommendation needs semantic analysis of their relation with historical objects and can be performed by means of ontologies [5]. The content for reasoning about, however, must be extracted from some historical databases or archives. Moreover, some historical relations are subjective, e.g., depend on context or personal vision of historical facts.

The study represented in this paper is motivated by lack of "smart" assistants for historian tourists, although there is a lot of them for mobile e-Tourism in general [1]. Based on our previous work [6], we expect that practical development of recommendation services with built-in semantic analysis of historical data can be implemented using ontology-based technologies of Semantic Web. Furthermore, traditional web-based architectures and mobile standalone applications seem insufficient for this development. We focus on the emerging approach of smart spaces [7][8]. A ubiquitous computing environment is created where mobile users, multisource data, and various services constructed over these data are intelligently connected based on ontology-driven information sharing and self-generation. Services can be personalized by means of augmentation of personal data to the shared content and customization of required reasoning about the content.

We continue our research [6] on the historical POI recommendation problem. The scope of this paper is limited with such important parts of the service development as concept definition and design. We provide a reference scenario of recommendation services for historical e-Tourism. We present a smart space based architectural design solution for the studied class of recommender systems. The contribution consists of the concept definition and system design for creating a personalized smart space to assist the historian tourist by means of recommendations.

The rest of the paper is organized as follows. Section II discusses the related work motivating development of recommendation services for historical tourism. Section III introduces our reference scenario for historical e-Tourism services. Section IV describes our system design based on the smart spaces approach. Section V analyses our proposal contrasting it with the previous work. Section VI concludes the paper.

II. Motivation and Related Work

Historical tourism has distinctive features [3] compared with a more general application domain of cultural heritage tourism. The latter embraces both historical and present-day cultural phenomena. Its main focus is not on historical events and persons, but on artifacts (e.g., artworks, architectural monuments) and cultural traditions (e.g., festivals, cuisine). According to Nora [4], historical tourism addresses the so-called “sites of memory”. They present any material traces of historical events, which sometimes coincide with cultural heritage artifacts. For instance, an architectural monument is directly “involved” in historical developments related to its construction. The other example is any place or a spot associated with a historical event. Traces of historical facts are presented in the multitude of historical sources, including open sources in the Internet.

In general, a point of interest (or attraction) is an actual spot with precise localization on the geographical map (e.g., geo-position coordinates or postal address). Nowadays, POI recommender systems form an important services class in e-Tourism [1]. In addition to POIs, historical tourism takes into consideration a lot of other historical-valued objects such as persons, events, and data sources (written records and narratives, alternative information sources, data and knowledge bases available on the Web). Relations between historical objects contain important semantics [9], localized in space and time. For instance, an event might be conditionally defined as a semantic relation between several historical objects [10].

Ontologies become of high application interest for knowledge representation and reasoning in historical research [5] and e-Tourism [2]. In historical tourism, we expect that the introduced semantic relations can be effectively represented and manipulated using technologies of the Semantic Web. To the best of our knowledge, no specialized knowledge base that comprise semantically enriched information about historical objects has been created yet, e.g., see [11]. To a certain extent, a corpus of historical information is represented in ontological form in such knowledge bases as DBpedia, Freebase, or YAGO. Additional information can be extracted from web publications of historical sources [6][12]. In these settings, the methods of web-based systems, mobile programming, and multi-agent systems provide means for implementation of data search, access, and reasoning [1][2].

There are mobile services for cultural heritage e-Tourism developed using semantic technologies, see survey [13]. For instance, an intelligent tourist guide [14] utilizes cultural heritage information. Nevertheless, the present-day developments do not take into account the principal peculiarity of historical tourism—semantic relations among historical data.

Methods of ubiquitous computing and, in particular, the recent progress in communication technologies of the Internet of Things make possible creating environments where diverse devices and computer systems cooperatively construct services surrounding the user [8][15]. New programming paradigms emerge, such as smart spaces [7]. A smart space supports cooperation by establishing a shared view of resources in the environment. The shared view is ontology-based, applying the technologies of Semantic Web. For e-Tourism services, a smart space is mobile and personalized, i.e., created around a traveling tourist, attracting appropriate web services and other data sources from the Internet [6][16][17].

The discussion above motivates our research focus on POI recommendation services for historical tourism. First, semantic relations between historical objects cannot be bypassed in recommendation making. Second, there is no single source of needed information. The latter is distributed within multiple sources, each represents the information either in ontological form or requires an extraction procedure. Third, a historian tourist needs personalized services, i.e., source information and the result are subject to her/his preferences and context. Last but not least, a recommendation service is “ubiquitous”, i.e., the service intelligently accompanies its mobile tourist.

III. Recommendation Scenario

Consider a historical POI recommender service that provides personal assistance for a tourist during her/his journey. Table I summarizes our formal symbol notation for the reference recommendation scenario.

Let P consist of POIs the service accesses from multiple sources. Typical examples of historical POIs are buildings, monuments, fountains, bridges, squares, etc. Spacious objects, such as streets or rivers, are not POIs. As a rule, a historical POI has a particular name. There may be several names associated with a given $p \in P$, e.g., due to historical developments or due to the use of different languages. Each POI has distinctive properties: coordinates and/or address, date, architect, etc. In the service, POIs and other historical objects form the set H.

Historical POI recommendation is essentially based on relations between the elements of H. First, “direct” links exist between historical objects. For instance, a person x is the architect of a building y. Second, links can appear between objects due to similarity. For instance, two buildings have been constructed by the same architect or they are located on the same street. Third, links are a result of involving diverse objects and POIs in a common historical event. Therefore, a semantic network G with nodes H can be constructed.

The historical relation semantics can be personified: some relations are treated differently by different historians or dependently on a context. For instance, there can be several visions of the role of a person for a certain POI. An important context correpsonds to an initial POI; a tourist selects $p \in P$ to consider semantic graph G_p. The first type of links mentioned above typically represents some stable and widely accepted historical relations. The last two types of links are the result of inference, and can be clear subject to context and personalization.

TABLE I. SYMBOL NOTATION

Symbol	Description
H	The set of all historical objects $H = H_1 \cup \ldots \cup H_n$ derived for the consideration from n data sources. Overlapping $H_i \cap H_j \neq \varnothing$ is possible.
$P \subset H$	The set of all POIs $P = P_1 \cup \ldots \cup P_n$, where $P_i \subset H_i$ for any data source i.
G, G_p	Semantic network G where nodes are from H and links are historical relations. In G_p, an initial POI $p \in P$ is fixed.
O	Ontology O describes the historical domain: possible classes and properties of historical objects as well as relations and restrictions for them.
R_p	Star graph R_p is a POI recommendation, where the internal node is the initial POI $p \in P$ and leaves are recommended POIs $q \in P$.
$r_q > 0$	Real-valued rank r_q shows the recommendation degree of $q \in P$ in respect to the initial POI p.
t_q	Annotation t_q summarizes (in a human-readable form) the reason of recommending q if the initial POI is p.

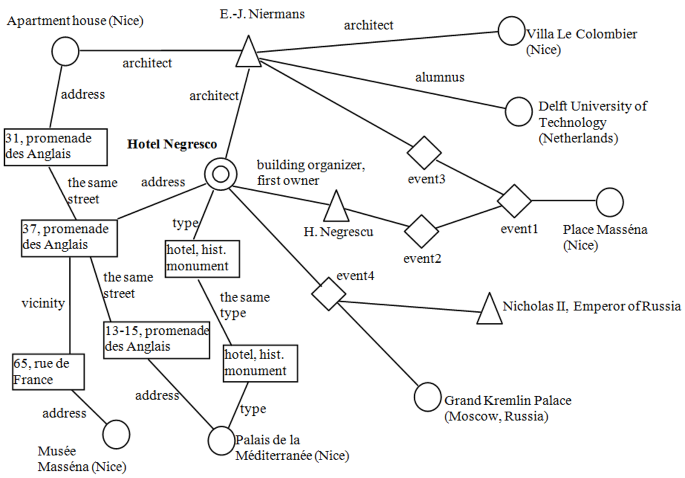

Figure 1. Sample semantic network: historical relations built around Hotel Negresco.

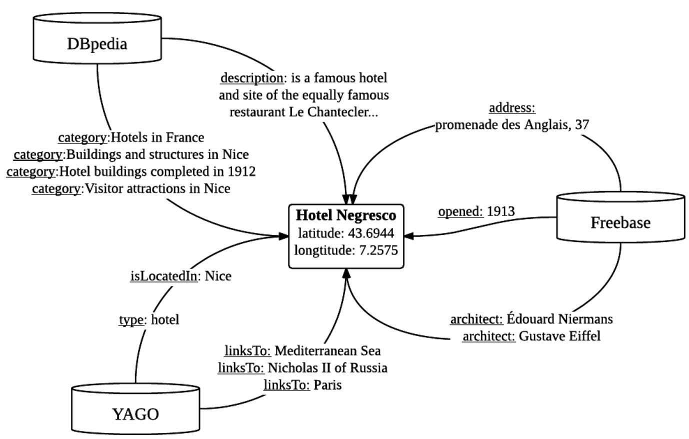

Figure 2. Hotel Negresco: information extraction from different sources

Figure 1 shows a sample semantic network that is built around Hotel Negresco, one of the most famous buildings of Nice. Small circles are POIs, triangles denote historical persons, text rectangles describe POI properties, and rhombuses represent historical events. The initial POI—Hotel Negresco—is linked with seven other POIs (five of them are located in Nice). The links are based on different properties: one and the same architect, close location, involvement in common historical events, etc.

Hotel information is extracted from different sources such as DBpedia, Freebase, or YAGO. Figure 2 shows an example of extracting facts from such sources. The search for POIs is usually performed by their coordinates. In DBpedia, historical description of each POI and categories the POI has can be found. Freebase provides formal attributes, such as POI address, the date of opening of the hotel, and architects. This information allows relating a POI with other entities.

Based on G_p, a tourist would like to understand which POIs are interesting for her/his personal consideration from historical perspective. An important context for this understanding is that she/he starts from p (e.g., being actually or virtually in this POI). The recommendation result can be represented as a

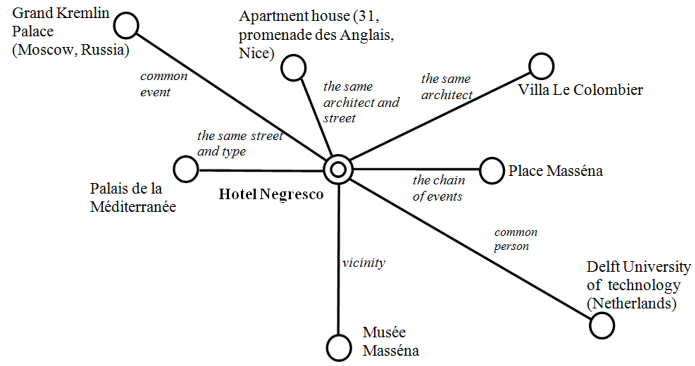

Figure 3. Star graph example: Hotel Negresco and recommendations on its historical surrounding.

star graph R_p. Its internal node is p and leaves represent all recommended POIs $q \in P$. Ranks $r_q > 0$ can be associated with the POIs to describe the recommendation degree of q (the higher rank the more recommendable). In a visual representation of G_p the length of edge (p, q) is proportional to the rank. Additional annotations t_q, which describe the reason of recommendation (in an aggregative form), can be also associated. Visual layout of R_p can also take into account the geographical position of q in respect to p (e.g., when q is on the North-East of p).

An example of recommendation is shown in Figure 3. The star graph is derived from the semantic network of Figure 1. POI geographical positions are not reflected.

Our reference scenario of a recommendation service consists of the following steps.

Step 1: Initial POI selection. It can be made either manually (e.g., pointing out coordinates, a spot on the map, or POI's name) or automatically (e.g., within a definite area pointing out the nearest POI). The area can be either set by a tourist (for instance, on the map), or determined automatically taking into consideration the current tourist's location.

Step 2: Semantic network around the initial POI. The sets H and $P \subset H$ as well as semantic relations among them are searched and retrieved from available knowledge bases and other data sources. Since the network G_p is potentially infinite, the process is limited. For instance, if the construction reaches another POI q from p, then the search for additional historical objects interconnected with q is terminated. Note that the path from p to q is subject to analysis in order to derive the reason of recommending q (construction of an annotation t_q). This example of limiting the construction process straightforwardly leads to a star graph R_p.

Step 3: POI ranking. Differentiation of recommended POIs can be based on ranks r_q. They are computed based on tourist preferences. For instance, he/she wants to find a building constructed by the same architect, an edifice built in the same architectural style, or another historical building located on the same street. Such preferences can be defined in the user's profile. They can be manually defined for the initial POI (before the implementation of the second step of this scenario). A significant component of the user's profile is the history of the choices of previous initial POIs (e.g., history of visits). For instance, the previously chosen POIs acquire lower ranks, since these POIs should not be repeatedly recommended.

Step 4: Visualization. The recommendation results achieved on Steps 2 and 3 are visually presented in a user friendly way, i.e., by means of a star graph possibly augmented with a map and textual/visual descriptions. For instance, annotations t_q show the reasons of the provided POI recommendations.

Step 5: Feedback. The recommendation process is iterative. Based on the presented results (the star graph with ranks and annotations), the tourist supplements this information by expanding the semantic network G (additional data retrieved from historical sources). The process—supplementing and expanding network—is represented in G: new historical events appear in which both the user and the objects are involved. The user becomes a historical person—a network node in G.

IV. Smart Space based Design

The smart spaces paradigm considers computing networked environments equipped with a variety of devices and with access to the Internet [7][8][15]. Software agents—knowledge processors (KPs)—run on the devices and interact via information sharing. A semantic information broker (SIB) is a mediator for information collection and exchange. Each KP produces its share of information and makes it available to others via the SIB. Similarly via the SIB, a KP consumes information of its own interest. The information storage employs RDF (Resource Description Framework) [18]. Agents can apply such advanced Semantic Web technologies as SPARQL Protocol and RDF Query Language or Web Ontology Language (OWL) for shared information maintenance, search, and reasoning [19].

This programming paradigm suits well for the development of e-Tourism services, as recent works [6][16][17] indicated. Figure 4 shows a high-level architecture that we adopted from [6] for the case of historical recommendation services.

The recommendation service is constructed by cooperative work of multiple KPs on historical data and other information. Consider properties of the proposed architecture to analyze the advantages that the smart spaces approach provides to the development of recommendation services for historical tourism. Some advantages are valid for the more general e-Tourism case.

Popular architectural styles for e-Tourism recommender systems are web-based, agent-based, and mobile [1][2]. Smart

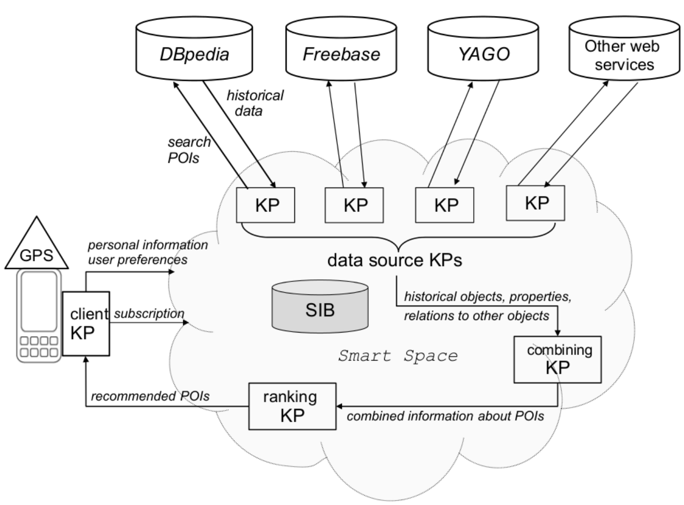

Figure 4. Multi-agent architecture: historical data from various sources and other information are semantically related and analyzed in the smart space.

spaces support them to be applied in a composition. SIB is deployed on a host machine in the Internet, similarly as it happens with web services now. Each user (tourist) is mobile, acts using her/his client KP (e.g., on smartphone or tablet), and consumes the service anywhere and anytime. Other KPs produce the information collecting it in the smart space for the use by the service. They can be hosted on the same machine with SIB (web-like solution) or on other computers (agent-based solution). The latter property leads to higher flexibility for system deployment. For instance, some KPs are provided by a travel agency and some KPs are from the user side in order to augment the system for personalized operation.

The recommendation service becomes not attached to a fixed source of historical information. A wide pool of available sources is used, where a data source KP is assigned per source (DBpedia, Freebase, YAGO, etc.). Configuration of the pool is flexible and subject to dynamic inclusion/exclusion. Some data source KPs are set up by system administrators. Some KPs can be attached by the users if the appropriate rights are delegated. Each data source KP has to implement its source-specific interface to access and search for information. Note that a client KP can also provide historical information to the smart space, in addition to her/his preferences, context, and control. The information is further used for personalization.

The function of data source KPs is to extract historical information from two key types of data sources. The first type is tourism-oriented or universal knowledge bases (e.g., DBpedia). They store many POIs and associated information. POI search is primarily based on coordinates, similar to popular location-based systems. The other type is historical publications (as a rule, in HTML—HyperText Markup Language or in PDF—Resource Description Framework) or archival databases records (e.g., in XML—eXtensible Markup Language). XML-files can be mapped into OWL [6]. HTML sources can be processed by means of NLP (Natural Language Processing) tools. In treating data sources of the second type, the main difficulty is that historical objects are usually identified by their names only (e.g., by means of record linking techniques).

As a result, the smart space contains a representation of the semantic network G, integrating the information extracted from multiple data sources. Their parallel activity is coordinated by combining KPs. The common ontology O is used to represent G in the smart space. The ontology provides a system of classes, relations, and restrictions that collected historical information must confirm. As a result, they constitute a historical semantic network for the reference recommendation scenario. A combining KP reasons over the extracted historical information and establishes semantic relations between historical objects. There can be several combining KPs, and the consistency of G is ensured by O. A combining KP may represent interests of a given tourist, act on behalf of a group of tourists, or perform generic context-aware construction.

Based on semantic network G in the smart space, a ranking KP constructs recommendations. Each recommendation is represented as star graph R_p for a given tourist, initial POI p, and context. Visualization on the client KP can utilize additional information such as ranks r_q and annotations t_q for all recommended POIs from R_p. Importantly that there can be many ranking KPs, each employs own computational method of POI selection for the recommendation. For instance, in POI selection method [6], values of r_q reflect the closeness of q's categories to the categories the initial POI p has. Then an

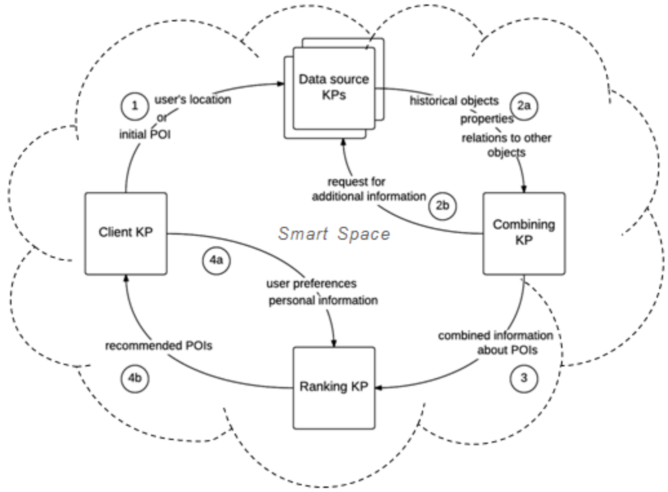

Figure 5. Many KPs interact in a smart space to construct a service.

annotation t_q can describe the common categories of p and q.

The proposed architecture reduces the service construction to interactions of KPs. It follows the principle that a smart space service is knowledge reasoning over the shared content and delivering the result to the users [20]. In our case of historical recommendation, the proposed model of KPs interaction is presented in Figure 5.

Smart space content is shared forming a subject to self-generation. That is, the steps in Figure 5 are performed simultaneously, with event-driven synchronization. An important event to activate data extraction is specifying the initial POI of tourist (step 1). Content self-generation also supports the service personalization. New historical objects can be found and new semantic relations can be associated with this given POI (the iteration in steps 2a and 2b). Request for additional information about historical objects (step 2b) occur until semantic network around tourist is being formed. The POI recommendation and ranking are further personalized (the iteration in steps 4a and 4b) when personal information is directly integrated into the rank computation, e.g., the POIs the tourist has already visited. Updating the user's personal information or preferences (step 4a) requires the rank conversion. This conversion may occur until the user likes the recommended POIs (step 4b).

Table II illustrates this content self-generation model showing the construction of the semantic network from Figure 1 and consequently the star graph from Figure 3. Note that in this paper we do not focus on particular ranking criteria. Intuitively, the closer and richer relations the higher rank. For instance, Apartment house receives the highest rank since the POI is a) located on the same street and b) designed by the same architect.

V. Comparison and Applicability Analysis

The proposed service scenario differs from other proposals. The most close to our work is [14]. The authors explore the use of location aware mobile devices for searching for and browsing a large number of general and cultural heritage information repositories. The application—Mobile Cultural Heritage Guide— searches for POIs in the current tourist's physical location and constructs a "mental map" of nearby POIs within a circular shape. Next semantic crawling is applied

TABLE II. EXAMPLE OF CONTENT GENERATION

Step	Interaction	Generated content
1	Initial POI	Hotel Negresco
2	Data source KPs retrieve facts about the initial POI from different data sources.	Hotel Negresco is located at Promenade des Anglais, 37. The architect of Hotel Negresco is E.-J. Niermans. The first owner of Hotel Negresco is H. Negrescu.
3	Combining KP advance the information description on POIs to create a semantic network.	POIs on the same street: Apartment house, Palais de la Méditerranée. POIs by the same architect: Place Masséna, Villa le Colombier, Apartment house. POIs related with H. Negrescu: Place Masséna.
4	Ranking KPs differentiate the POIs in the semantic network, selecting the most attracting for the user.	Rank-sorted list: Apartment house, Place Masséna, Palais de la Méditerranée, Villa le Colombier.

to resemble the process of a human using the Web to find other information relevant to these POIs. Finally, augmented reality is used in combination with facet selection to present this POI-related information to an active tourist on her/his mobile device. Similarly to our scenario, this application aims at dynamic provision of semantically-enriched information in favor of a classical travel guide. In contrast, our scenario introduces both nearby and faraway POIs, which are semantically related within a variety of historical objects, including common historical persons and events. Our scenario supports automation of semantic crawling with POI ranking; the ranks are then used for visual representation of POI recommendations to the user.

Paper [21] considers a prototype application with POI ranking. It supports content-based recommendations for generating personalized routes along cultural heritage assets in outdoor environments (e.g., city tours). The case of indoor environments, such as museums, is studied in recent work [22]. The mobile application helps the visitors to access information concerning exhibits that are of primary interest to them during pre-visit planning, to provide the visitors with relevant information during the visit, and to follow up with post visit memories and reflections. In contrast, our scenario resembles the process of a historian studying historical facts.

Based on recent studies of the Smart-M3 performance, we expect the proposed system design is applicable in real-life setting and has advantages over the other approaches to recommender system development. The applicability of the smart space based architecture, similar to the one shown in Figure 4, is discussed in [7]. A realistic case is a smart space [16][23] where the number of large data sources, such as web-based databases and repositories, is of the 10-order magnitude and the number of mobile users is of the 10^3-order magnitude.

In contrast to mobile standalone applications, the workload is delegated from a personal mobile device to smart space infrastructure deployed on powerful hosts. Experiments in [24] confirm that this design solution additionally improves reliability and fault tolerance, essentially in wireless network settings. In our scenario, the delegated workload includes the construction of semantic networks for many users and POI ranking over these networks. A personal mobile device visualizes aggregated fragments (e.g., a star graph) of the whole semantic network enriched with derived ranks.

In comparison with web-based recommender system, the proposed smart space based system design provides flexibility in selection of 1) data sources, 2) semantic network construction, 3) POI ranking, and 4) personalization. Although the cost is performance, Semantic Web technologies are now capable to create and maintain relatively large RDF triple stores [18], where the number of RDF triples is of the 10^5-order magnitude and more. In particular, Smart-M3 SIB employs the Redland library for RDF triple store and SPARQL support [8][15].

VI. CONCLUSION

This paper addressed recommendation services development for historical e-Tourism. We studied the problem of historical POI recommendation, the necessity of using semantic relations between historical objects, and the personalized (subjective, contextual) aspect of services. We proposed the smart space based system design for implementing such a recommender system. The proposal provides a concept definition and design solutions for creating a smart space to accompany a historian tourist. Multiple external sources of historical data can be attached to the smart space and used for provision of information relevant to the situation and user's interests. The information is integrated using Semantic Web technologies and analyzed to produce personalized recommendations. The result is visually presented with quantitative (POI ranks) and qualitative (reason annotations) estimates.

Our study makes a step towards concept development for historical e-Tourism. Feasibility study of the proposed concept, including ontology engineering for integrated representation of historical objects, analysis of POI ranking methods over a semantic network of historical objects, and experimental evaluation, is subject to our further research.

ACKNOWLEDGMENT

This work is financially supported by the Ministry of Education and Science of the Russian Federation within project # 2.2336.2014/K from the project part of state research assignment and project # 14.574.21.0060 (RFMEFI57414X0060) of Federal Target Program "Research and development on priority directions of scientific-technological complex of Russia for 2014–2020". The presented results are part of the research carried out within project # 14-07-00252 of the Russian Foundation for Basic Research.

REFERENCES

[1] D. Gavalas, C. Konstantopoulos, K. Mastakas, and G. Pantziou, "Mobile recommender systems in tourism," J. Netw. Comput. Appl., vol. 39, Mar. 2014, pp. 319–333.

[2] J. Borrás, A. Moreno, and A. Valls, "Intelligent tourism recommender systems: A survey," Expert Syst. Appl., vol. 41, no. 16, Nov. 2014, pp. 7370–7389.

[3] V. L. Smith, Hosts and Guests: The Anthropology of Tourism. University of Pennsylvania Press, 1989.

[4] P. Nora, "Between memory and history: Les lieux de mémoire," Representations, no. 26, 1989, pp. 7–24, Special Issue: Memory and Counter-Memory.

[5] N. Ide and D. Woolner, "Historical ontologies," in Words and Intelligence II: Essays in Honor of Yorick Wilks, ser. Text, Speech and Language Technology, K. Ahmad, C. Brewster, and M. Stevenson, Eds. Springer, 2007, vol. 36, pp. 137–152.

[6] A. Varfolomeyev, D. Korzun, A. Ivanovs, and O. Petrina, "Smart personal assistant for historical tourism," in Recent Advances in Environmental Sciences and Financial Development. Proc. 2nd Int'l Conf. on Environment, Energy, Ecosystems and Development (EEEAD 2014), C. Arapatsakos, M. Razeghi, and V. Gekas, Eds., Nov. 2014, pp. 9–15.

[7] D. Korzun, S. Balandin, and A. Gurtov, "Deployment of Smart Spaces in Internet of Things: Overview of the design challenges," in Proc. 13th Int'l Conf. Next Generation Wired/Wireless Networking and 6th Conf. on Internet of Things and Smart Spaces (NEW2AN/ruSMART 2013), LNCS 8121, S. Balandin, S. Andreev, and Y. Koucheryavy, Eds. Springer, Aug. 2013, pp. 48–59.

[8] J. Kiljander, A. D'Elia, F. Morandi, P. Hyttinen, J. Takalo-Mattila, A. Ylisaukko-oja, J.-P. Soininen, and T. S. Cinotti, "Semantic interoperability architecture for pervasive computing and Internet of Things," IEEE Access, vol. 2, Aug. 2014, pp. 856–874.

[9] M. Kalus, "Semantic networks and historical knowledge management: Introducing new methods of computer-based research," The Journal of the Association for History and Computing, vol. 10, Dec. 2007, Retrieved: May, 2015. [Online]. Available: http://hdl.handle.net/2027/spo.3310410.0010.301

[10] A. Ivanovs and A. Varfolomeyev, "Computer technologies in local history studies: Towards a new model of region research," Acta Humanitarica Universitatis Saulensis, vol. 19, 2014, pp. 97–107.

[11] A. Meroño-Peñuela, A. Ashkpour, M. van Erp, K. Mandemakers, L. Breure, A. Scharnhorst, S. Schlobach, and F. van Harmelen, "Semantic technologies for historical research: A survey," Semantic Web journal, 2015, to appear.

[12] E. Ahonen and E. Hyvonen, "Publishing historical texts on the semantic web - a case study," in Proc. 2009 IEEE Int'l Conf. on Semantic Computing (ICSC '09). IEEE Computer Society, 2009, pp. 167–173.

[13] L. Ardissono, T. Kuflik, and D. Petrelli, "Personalization in cultural heritage: The road travelled and the one ahead," User Modeling and User-Adapted Interaction, vol. 22, no. 1-2, Apr. 2012, pp. 73–99.

[14] C. van Aart, B. Wielinga, and W. R. van Hage, "Mobile cultural heritage guide: Location-aware semantic search," in Proc. 17th Int'l Conf. on Knowledge Engineering and Management by the Masses (EKAW'10), LNCS 6317, P. Cimiano and H. S. Pinto, Eds. Berlin, Heidelberg: Springer, 2010, pp. 257–271.

[15] I. Galov and D. Korzun, "Design of semantic information broker for localized computing environments in the Internet of Things," in Proc. 17th Conf. of Open Innovations Association FRUCT. ITMO Univeristy, Apr. 2015, pp. 36–43.

[16] A. Smirnov, A. Kashevnik, A. Ponomarev, N. Teslya, M. Shchekotov, and S. Balandin, "Smart space-based tourist recommendation system," in Proc. 14th Int'l Conf. Next Generation Wired/Wireless Networking and 7th Conf. on Internet of Things and Smart Spaces (NEW2AN/ruSMART 2014), LNCS 8638, S. Balandin, S. Andreev, and Y. Koucheryavy, Eds. Springer, Aug. 2014, pp. 40–51.

[17] K. Kulakov and A. Shabaev, "An approach to creation of smart space-based trip planning service," in Proc. 16th Conf. of Open Innovations Association FRUCT. ITMO Univeristy, Oct. 2014, pp. 38–44.

[18] C. Gutierrez, C. A. Hurtado, A. O. Mendelzon, and J. Pérez, "Foundations of semantic web databases," J. Comput. Syst. Sci., vol. 77, no. 3, May 2011, pp. 520–541.

[19] D. G. Korzun, A. A. Lomov, P. I. Vanag, J. Honkola, and S. I. Balandin, "Multilingual ontology library generator for Smart-M3 information sharing platform," International Journal on Advances in Intelligent Systems, vol. 4, no. 3&4, 2011, pp. 68–81.

[20] D. Korzun and S. Balandin, "A peer-to-peer model for virtualization and knowledge sharing in smart spaces," in Proc. 8th Int'l Conf. on Mobile Ubiquitous Computing, Systems, Services and Technologies (UBICOMM 2014). IARIA XPS Press, Aug. 2014, pp. 87–92.

[21] N. Stash, L. Veldpaus, P. D. Bra, and A. P. Rodeirs, "Creating personalized city tours using the CHIP prototype," in Late-Breaking Results, Project Papers and Workshop Proceedings of the 21st Conf. on User Modeling, Adaptation, and Personalization (UMAP 2013): Proc. Workshop on Personal Access to Cultural Heritage (PATCH 2013), ser. CEUR Workshop Proceedings, S. Berkovsky, E. Herder, P. Lops, and O. C. Santos, Eds., vol. 997, Jun. 2013, pp. 68–79.

[22] T. Kuflik, A. Wecker, J. Lanir, and O. Stock, "An integrative framework for extending the boundaries of the museum visit experience: linking the pre, during and post visit phases," Information Technology & Tourism, vol. 15, no. 1, 2015, pp. 17–47.

[23] P. Vanag and D. Korzun, "SmartSlog knowledge patterns: Initial experimental performance evaluation," in Proc. 11th Conf. of Open Innovations Association FRUCT and Seminar on e-Tourism, S. Balandin and A. Ovchinnikov, Eds. SUAI, Apr. 2012, pp. 176–180.

[24] I. Galov and D. Korzun, "Fault tolerance support of Smart-M3 application on the software infrastructure level," in Proc. 16th Conf. of Open Innovations Association FRUCT. ITMO Univeristy, Oct. 2014, pp. 16–23.