Smart Service Efficiency: Evaluation of Cultural Trip Planning Service

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Abstract—**Nowadays the amount of "smart" services in e-Tourism grows rapidly. This is due to widespread using mobile devices with new input methods and large amount of digital data. Together with that, the smart services require complex methods and high cost of their creation. Thereby we have relevant problem of estimating smart service's efficiency. This paper presents evaluation of Cultural trip planning service based on defined smart attributes. For each of used attributes the execution scenario, ordinary service for comparison and used estimates are defined. Each estimate is calculated with taking into account the user experience. The evaluation results allow to compare Cultural trip planning service with some ordinary services.**

I. Introduction

E-Tourism covers a wide niche of the digital services market [1], [2], [3]. Its particular subarea—cultural heritage tourism—has become an essential part of it [4], [5]. By virtue of large amount of diverse information about the target region and various tools and required functions these services becoming smart.

This notion of a smart service is very wide. In particular, some criteria are needed to decide either a digital service is smart or non-smart (regular). A smart service can be considered as an extension of regular services, which are numerous in today's Internet. The distinctive characteristic of a smart service is its intentional aim to make everyday human activity more automated and digitally assisted [6], [7]. In the paper [8] we introduced the list of smart attributes which determines smart service in cultural heritage area.

The implementation of smart service requires complex methods, integration with third-party services and libraries, usage of new approaches and so on. It increases development costs and may lead to complication of its usage. On the other hand, smart service can be inefficient in terms of using. This is manifested in the form of a long work, requesting further information from the user or receiving of incorrect results.

In this paper we propose to carry out evaluation of smart service efficiency by comparing it with a regular service. One or more services with manual interaction can act as a regular service. The evaluation should answer to the following questions.

- How do a smart service become fast?
- How could manual work be decreased in a smart service?
- How good is the result obtained by a smart service?

The object of research is a Cultural trip planning service [9]. This service is based on software platform for creating smart spaces, called Smart-M3 [10], [11]. On this platform software part of a smart space includes "agents" and information "hub". Each agent is an autonomous knowledge processor (KP), which is a software module running on some device. Cultural trip planning service provides ability to process personalized search requests and make routes for selected points with a time plan.

The rest of paper is organized as follows. Section II contains analysis of related work. Section III introduces Cultural trip planning service. Section IV describes smart attribute presence. Section V presents service evaluation and results. Section VI summarizes and discusses the contribution of the paper.

II. Related work

Several measurement studies, including [12], [13], [14], [15], evaluated the performance of basic Smart-M3 read&write operations for agents to share information in the smart space.

Bhardwaj *et al.* [16] analyzed the end-to-end delay between interacting agents based on experiments on a power-managed smart lighting scenario. Authors investigated the delay performance of a semantic interoperability platform and showed the importance of delay performance in smart spaces. They made an analysis of the processing delay per device and the transmission delay per hop in a heterogeneous smart network.

Niezen *et al.* [17] evaluated the performance of query resolution and reasoning mechanisms for agents resided on embedded and consumer electronics devices in smart spaces. They presented the interoperability architecture implemented as a smart home pilot. This architecture was evaluated based on a performance analysis. Their results indicate acceptable response time for a network user interface.

Vanag and Korzun [18] analyzed the performance of resolving advanced search queries. For experimental evaluation, a special agent was implemented to generate knowledge patterns for different size parameters and search queries were made to the smart space. So nontrivial search was performed in the smart space and the search was controlled at the agent side. This search was possible from the performance point of view.

Galov and Korzun [19] evaluated the performance of a notification model used in Smart-M3 applications based on simulation experiments. The model extends the application ontology of smart spaces with possible requests and events that agents use in interaction. It allows to construct information flows between a publisher agent and its subscriber agents. The performance evaluation of notification model was measured on the case study of SmartScribo system for multi-blogging.

Korzun *et al.* [20] evaluated the efficiency of the notification delivery to the agents subscribed to information in a smart space, for the case when the delivery to a client is subject to losses. Several control strategies were introduced with initial analytical estimates. The performance comparison of the presented strategies was provided using simulation experiments.

Paramonov *et al.* [21] considered the mechanism when an agent is disconnected from the network may be substituted with another one in semantic information broker. The mechanism allows to transfer computational context from one agent to another safely and prevent long service downtime. This mechanism was represented on the case study of the medical telemonitoring service.

Galov and Korzun [22] estimated the performance for an agent in case of restarting or reconnecting to the smart space. In the paper [23] authors presented results of several experiments for performance evaluation of a smart space based application.

III. CULTURAL TRIP PLANNING SERVICE DESCRIPTION

The goal of Cultural trip planning service is to create a trip plan based on tourist preferences [9]. The Cultural trip planning service provides an ability to search nearby attractions, view attractions on the map, organize new trip by selecting a set of attractions to be visited, calculate trip route as a result of solving traveling salesman problem and create trip plan based on time delays and time costs.

The service is based on Smart Space technology, which provides possibility to create common information space, proactive concept and flexible connections to external sources [6]. The service implementation uses Smart-M3 platform [10] and includes semantic information broker (SIB), which collects and distributes information, and a set of knowledge processors (KP), which represent external information sources or consumers and perform operations on the knowledge.

The service has tunable distributed architecture which can be changed by adding or removing KPs. In this paper we use the version of Cultural trip planning service with high-level architecture presented in Fig. 1.

The set of proposed KPs [24] is divided into service core and additional KPs. The service core includes the following KPs.

Client service performs delivery, visualization and personalization of information for the user. The main functions of the client service are publication of personal data and information about users preferences and subscription to recommendations related to attraction. The main software component of the client service is User KP. **User KP** is a mobile application for Android which is responsible for providing information about the user and users preferences and getting results from trip planning service. User KP presents users positions, personal data and information about users preferences, core attractions and planning restrictions. User KP gets GPS coordinates received from the users mobile device and determines the users location. User KP publishes personal data and information about the users preferences and subscribes to recommendations related to attractions. Also User KP provides the result of route planning algorithm to the tourist.

GeoInformation service interacts with external Internet services such as Dbpedia, GIS, Wikimapia, Booking and others. GeoInformation service gets information and publishes data (or references to the data) in the Smart Space (via the SIB) for shared use. Each KP of the geoInformation service interacts with special Internet-sources. **Geo-wm KP** is a KP for Wikimapia service and **Geo-db KP** is a KP for DBpedia service. Geo-wm KP and Geo-db KP provide the information about attractions (position, description, images, etc.) from the third-party services.

Recommendation service provides a personalization. It ranks POIs depending on the users preferences and the visiting history. The main software component of the recommendation service is a advice-KP. **Advice kp** publishes the ranked list of POIs drawn up for the user. Each candidate POI becomes assigned with a rank value. Then the client service can use these values to present the recommended POIs to the user. Client service gets notice of the user recommendations.

Combining service plans time and provides optimal route for attractions. It analyzes the found information from the geoInformation service and the result recommendations from the recommendation service. Combining service includes two KPs: Transport and TimePlan. **Transport KP** provides the optimal route for required set of points and options for each part (time, speed, distance). The KP is based on GraphHopper library and uses OpenStreetMap route graph. **TimePlan KP**

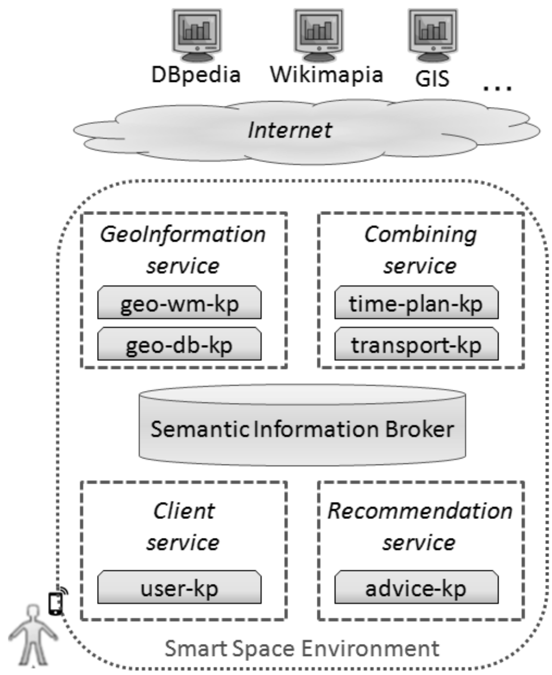

Fig. 1. High-level architecture of Cultural trip planning service

provides time plan based on selected route.

IV. Smart service definition and attributes

In the paper [8] we introduced a list of smart service attributes for cultural heritage tourism which can identify smart services in a list of regular services. The use of these attributes can be extended to other services. The Table I contains description of smart service attribute presence in the declared Cultural trip planning service. According to analyze results the evaluation of cultural trip planning service includes the following areas: “multiple data sources”, “composed services” and “personalized services”.

TABLE I. Smart service attribute presence in Cultural trip planning service

Attribute	Presence description
Multiple data sources	The presented version of Cultural trip planning service uses Wikimapia and DBpedia services simultaneously. User KP shows combined result.
Composed services	The presented version of Cultural trip planning service provides attractions search action, route construction action and trip planning action. These actions can be used separately or coherently.
Personalized services	The presented version of Cultural trip planning service uses user data to personalize search requests and provide recommendations in semiautomatic mode.
Human–computer interaction	The User KP has regular user interface and does not provide ability to use natural input and output methods.
Self-learning	The presented version of Cultural trip planning service processes each request separately without any data accumulation.
Proactive Automation	The User KP requires user intervention in all actions. The presented version of Cultural trip planning service provides recommendations in semiautomatic mode which is not fully proactive.
Collaborative work	The presented version of Cultural trip planning service does not provide communication between users.

To evaluate smart service it is necessary to define corresponding regular service. The regular service for “multiple data sources” smart attribute is a set of small applications, where each small service grants access to a single data source. In this paper we use web interfaces of DBpedia (http://dbpedia.org/fct) and Wikimapia (http://wikimapia.org/) data sources. Each web interface provides access to source data, processes search requests and presents data in “ready to process” format (XML or JSON).

The regular service for “composed services” smart attribute is a set of small applications with manual data transformation of one application’s output to another application’s input. In this paper we use web interface of Wikimapia data source for processing of search request and GraphHopper service (https://graphhopper.com/) to create a route.

The regular service for “personalized services” attribute is a web interface of DBpedia data source. The web interface processes search requests without additional data from user.

V. Service evaluation and results

A. Common approach

In evaluation we use common work scenario for information service based on the following steps.

- “Service open”. This step includes preparation process like application load or database synchronization.
- “Input request”. This step includes input of various types of data which are used in target service to work with the third-party service.
- “Wait result”. During this step we are waiting for the response from connected knowledge storage. This step also includes subprocesses if they exist.
- “Result analyze”. This step depends on service goals and includes search process, data transformation and so on.

The main advantage of smart service is that it implements human work: service includes ability to make decisions by using information provided by human. The main results of this advantage is that service provides the increasing of speed, reducing of the human work and improvement of result quality. There are several estimates which can be used to compare smart and regular services.

- “Work time”. The value of “work time” estimate T calculates as the ratio
$$T = \frac{T_{\mathrm{s}}}{T_{\mathrm{ns}}},$$
where T_{s} is a “work time” for smart service and T_{ns} is a work time for regular service. For proposed common work scenario “work time” for services is calculated as follows:
$$\begin{aligned} T_{\mathrm{s}} &= T_{\mathrm{s}}^{\mathrm{open}} + T_{\mathrm{s}}^{\mathrm{input}} + T_{\mathrm{s}}^{\mathrm{wait}} + T_{\mathrm{s}}^{\mathrm{analyze}}, \\ T_{\mathrm{ns}} &= T_{\mathrm{ns}}^{\mathrm{open}} + T_{\mathrm{ns}}^{\mathrm{input}} + T_{\mathrm{ns}}^{\mathrm{wait}} + T_{\mathrm{ns}}^{\mathrm{analyze}}, \end{aligned} \quad (1)$$
where $T_{\mathrm{s}}^{\mathrm{open}}$ and $T_{\mathrm{ns}}^{\mathrm{open}}$ is a time to open a service, $T_{\mathrm{s}}^{\mathrm{input}}$ and $T_{\mathrm{ns}}^{\mathrm{input}}$ is a time to input data, $T_{\mathrm{s}}^{\mathrm{wait}}$ and $T_{\mathrm{ns}}^{\mathrm{wait}}$ is a time to wait result and $T_{\mathrm{s}}^{\mathrm{analyze}}$ and $T_{\mathrm{ns}}^{\mathrm{analyze}}$ is a time of results processing. This estimate shows common increasing of speed for smart service.
- “Handwork automation”. The value of “Handwork automation” estimate A calculates as the ratio
$$A = \frac{A_{\mathrm{s}}}{A_{\mathrm{ns}}},$$
where A_{s} is a “Handwork automation” for smart service and A_{ns} is a “Handwork automation” for regular service. Commonly “Service open” and “Wait result” steps does not required manual work. For proposed common work scenario “handwork automation” for services are calculated as follows:
$$A_s = T_{\mathrm{s}}^{\mathrm{input}} + T_{\mathrm{s}}^{\mathrm{analyze}}, \quad A_{\mathrm{ns}} = T_{\mathrm{ns}}^{\mathrm{input}} + T_{\mathrm{ns}}^{\mathrm{analyze}}. \quad (2)$$
This estimation shows reducing of human work in smart service.

In the evaluation we use assessment of manual input rate [25] and divide persons into three groups:

- ”novice users” with rate 9 words per minute;
- ”regular users” with rate 15 words per minute;
- ”advanced users” with rate 30 words per minute.

The evaluation was carried out using Cultural trip planning service as a smart service with set of modules:

- user-kp — mobile application for input user data and output result;
- geo-db-kp — module for processing requests to DBpedia data source;
- geo-wm-kp — module for processing requests to Wikimapia data source;
- transport-kp — module for route creation, based on GraphHopper library;
- advice-kp — module for personalizing user requests.

All modules except user-kp and SIB (Cutesib version 0.1) were executed on laptop with the following characteristics: CPU Pentium(R) Dual-Core CPU E5300 2.60 GHz $\times$ 2, GPU Intel G41 x86/MMX/SSE2, 4 Gb RAM, 320 Gb SSD, 100 MB Wi-Fi network, Ubuntu 16.04. The user-kp was executed on Samsung Galaxy S4 which was connected to the Wi-Fi network (100 Mbps).

Each attribute was tested by 20 times per search request. The evaluation was presented by three estimations: minimum, average and maximum value per search request. For search requests we use keywords “sight”, “culture”, “historical”, “park”, “monument”, “fortress” and “city”.

B. Multiple data sources

Service with “‘Multiple data sources” smart attribute can operate with a huge amount of data, combine different types of information and verification of provided information. For this case we can define regular service as a set of small services and each service provides access to a single third-party data source. In this evaluation the regular service was presented as a web interfaces for DBpedia and Wikimapia data sources which was opened and used on the same mobile device.

The smart service with multiple data sources smart attribute uses common work scenario and “work time” estimation was calculated using formula (1). For regular service each data source uses common work scenario, but the results are combined at the end. Therefore the “work time” estimation for regular service is calculated as follows:

$$T_{\rm ns} = \sum_{i \in I} \left(T_i^{\rm open} + T_i^{\rm input} + T_i^{\rm wait} \right) + T^{\rm analyze},$$

where I is a set of data sources, $T_i^{\rm open}$ is a time to open a data source i, $T_i^{\rm input}$ is a time to input request into a data source i, $T_i^{\rm wait}$ is a time to wait from data source i, $T^{\rm analyze}$ is a time to combine results from multiple data sources into common set.

Commonly, the manual work time for data source is a time to fill search form and time to find expected result. Other actions are automated by default. Therefore the value of “handwork automation” estimation for smart service was calculated using formula (2). Regular service uses input multiple time and “handwork automation” estimation is calculated as following:

$$A_{\rm ns} = \sum_{i \in I} \left(T_i^{\rm input} \right).$$

The evaluation is based on work scenarios for smart and regular services. Each scenario starts from creating a time stamp A. After this step execution the time stamp in round brackets is created.

The evaluation scenario for smart service is following:

1) open mobile application, go to the search tab;
2) input search query (time stamp B);
3) wait results (time stamp C).

The evaluation scenario for regular service is following:

1) open web browser in mobile device;
2) for each data source service i:
    a) open data source service (time stamp D_i);
    b) input search query (time stamp E_i);
    c) wait results (time stamp F_i);
3) combine results into the single list (time stamp G);

The time stamps are used to calculate work time and handwork automation values: $T_{\rm s} = C - A$, $T_{\rm ns} = G - A$, $A_{\rm s} = (B - A)$, $A_{\rm ns} = \sum_i (E_i - D_i) + (G - \max_{i \in I} F_i)$.

The evaluation was executed near Saint-Petersburg, Russia. The average time distribution of the search time between sending request and obtaining response with using DBpedia geoinformation KP and Wikimapia geoinformation KP are shown in fig. 2. The average search time for DBpedia geoinformation KP is 1.59 seconds, for Wikimapia geoinformation KP — 4.63 seconds. In smart service these modules works in parallel, therefore we get a maximum of search times (4.63 seconds). In regular service these modules works in sequential, therefore we get a sum of search times (6.22 seconds).

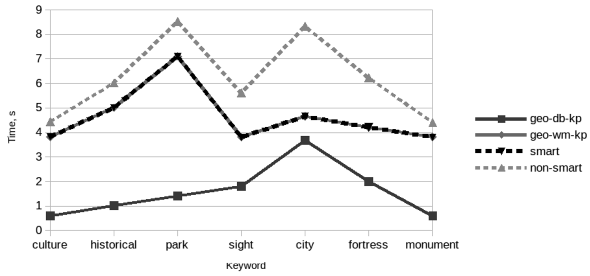

Fig. 2. Time distribution of search process

The time distribution has two peaks for keywords “park” and “city” because Wikimapia service found 750 items for “park” keyword and 8500 items for “city” keyword. Wikimapia geoinformation KP uses first 50 items in response. DBpedia geoinformation KP has small value of search time because it returns small number of found items.

The calculated estimations are shown in Table II. For regular service estimations include time to input service address and search keyword in mobile device.

TABLE II. THE CALCULATES ESTIMATIONS FOR MULTIPLE DATA SOURCES (SECONDS)

Service	Novice users	Regular users	Advanced users
Smart service	$T_{\rm s} = 11.30$, $A_{\rm s} = 6.67$	$T_{\rm s} = 8.63$, $A_{\rm s} = 4.00$	$T_{\rm s} = 6.63$, $A_{\rm s} = 2.00$
Regular service	$T_{\rm ns} = 66,22$, $A_{\rm ns} = 60.00$	$T_{\rm ns} = 42,22$, $A_{\rm ns} = 36.00$	$T_{\rm ns} = 24,22$, $A_{\rm ns} = 18.00$

The calculated estimations of Trip planning service with "Multiple data sources" smart attribute for regular user are following:

- "Work time" $T = 0.2044$ (increase speed more than 4 times);
- "Handwork automation" $A = 0.(1)$ (human work decreased 9 times).

Estimations show the effectiveness of parallel work on server side with a large amount of resources.

C. Composed services

Service with this smart attribute includes ability to transform output from one service to input for another service automatically. For this case we can define regular service as a set of external services with manual data transformation from output result of one service to input of another service.

For smart services with this attribute the value of work time T_s is calculated similarly by using (1). For regular service the work time is increased by data transformation and calculated as following:

$$T_{ns} = \sum_{i \in I} \left(T_i^{open} + T_i^{transform} + T_i^{input} + T_i^{wait} \right),$$

where $T_i^{transform}$ is a time of manual data transformation to input for service i which includes into $T^{analyze}$.

The value of "handwork automation" estimation for smart service is calculated by using (2). In regular service data transformation process includes into manual work and "handwork automation" estimation is calculated as following:

$$A_{ns} = \sum_{i \in I} \left(T_i^{input} + T_i^{transform} \right).$$

In evaluation we use Cultural trip planning service for search points and construct route between selected points. The regular service is presented as a mobile interface for service with points (Wikimapia) and mobile interface for routing service (Graphhopper). The evaluation is based on work scenarios for smart and regular services. Each scenario starts from creating a time stamp A. After this step execution the time stamp in round brackets is created.

The evaluation scenario for smart service will be following:

1) open mobile application, go to the search tab (time stamp B);
2) input search query (time stamp C);
3) wait results (time stamp D);
4) create route by selecting items in the list (time stamp E);
5) go to the map tab, wait route (time stamp F);

The evaluation scenario for non-smart service will be the following:

1) open web browser in mobile device, open Wikimapia service (time stamp G);
2) input search query (time stamp H);
3) wait results (time stamp I);
4) select expected items in the list (time stamp J);
5) open Google maps (time stamp K);
6) input selected items (time stamp L);
7) create route, wait result (time stamp M).

The time stamps are used to calculate work time and handwork automation values: $T_s = F - A$, $T_{ns} = M - A$, $A_s = (C-B)+(E-D)$, $A_{ns} = (H-G)+(J-I)+(L-K)$.

Let us consider, that items selection process is very fast and does not take any time. Therefore, $E-D = J-I = 0$ and we reduce formulas: $A_s = (C - B)$, $A_{ns} = (H - G) + (L - K)$.

The evaluation was executed near Saint-Petersburg, Russia. The time distribution of route creation is shown in fig. 3. We use Wikimapia geoinformation KP to search points. Each point is presented as coordinates (two words) and the name of attraction. The route was constructed using first 15 items in search results.

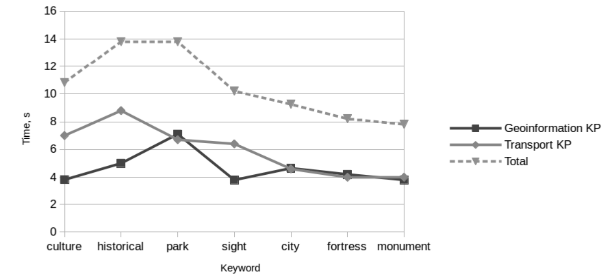

Fig. 3. Time distribution for composed services

The calculated estimations are shown in Table III. Regular service estimations include time to input service address, search keyword and coordinates of selected points in mobile device. Smart service estimations include time to input search keyword.

TABLE III. THE CALCULATES ESTIMATIONS FOR COMPOSED SERVICES (SECONDS)

Service	Novice users	Regular users	Advanced users
Smart service	$T_s = 17.23$, $A_s = 6.67$	$T_s = 14.56$, $A_s = 4.00$	$T_s = 12.57$, $A_s = 2.00$
Regular service	$T_{ns} = 243,90$, $A_{ns} = 233.00$	$T_{ns} = 150,56$, $A_{ns} = 140.00$	$T_{ns} = 80,57$, $A_{ns} = 70.00$

The calculated estimations of Trip planning service with "Composed services" smart attribute for regular user are following:

- "Work time" $T = 0.0967$;
- "Handwork automation" $A = 0.0286$.

The estimations show service acceleration by reducing manual work.

D. Personalized services

The features of service with "Personalized services" smart attribute includes the possibility to sort data by user preferences and filter unwanted data. For this case we can define regular service as a service which produce the same result for different users if they use the same request.

Smart service requires filled user profile and context. Let us consider, that user profile and context are created for each request. Therefore, the "work time" estimation for smart service is calculated as follows:

$$T_{\rm s} = T^{\rm open} + T^{\rm context} + T^{\rm query} + T^{\rm wait},$$

where $T^{\rm context}$ is a time to create and fill user context and $T^{\rm query}$ is a time to input query. $T^{\rm context}$ and $T^{\rm query}$ are the part of $T_{\rm s}^{\rm input}$. The smart service can process several requests to different external services for single user task, but it is included in to the "Wait result" step of base scenario. The "work time" estimation for regular service is calculated by using (1).

The value of "handwork automation" estimation for smart service includes time to create user context and is calculated as following:

$$A_{\rm s} = T^{\rm context} + T^{\rm query}.$$

The "handwork automation" estimation for regular service is calculated using (2).

The evaluation scenario for smart service will be the following:

1) open mobile application, go to the search tab (time stamp B);
2) input user context;
3) input search query (time stamp C);
4) wait the results (time stamp D);

The evaluation scenario for regular service is the same except for the context input:

1) open web browser in mobile device, open Wikimapia service (time stamp E);
2) input search query (time stamp F);
3) wait results (time stamp G);

The time stamps used for the calculation of work time and handwork automation values: $T_s = D - A$, $T_{ns} = G - A$, $A_s = C - B$, $A_{ns} = F - E$.

The evaluation was executed near Saint-Petersburg, Russia. The smart service was started with empty cache: build relations between Wikimapia results and user context were repeated for each request. The user context was defined as a location (latitude=59.938630, longitude=30.314130) and user preferences (keyword "heritage"). The time distribution of search request processing is shown on fig. 4.

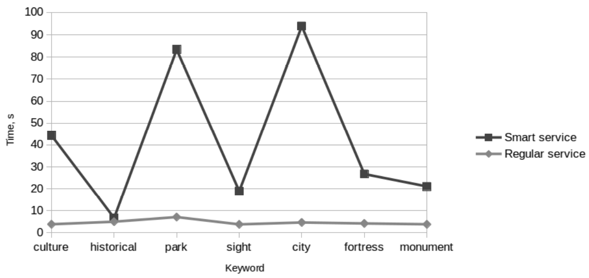

Fig. 4. Time distribution of smart and regular services

The calculated estimations are shown in Table IV. Regular service estimations include time to input service address and keyword search on mobile device. Smart service estimations include time to input search keyword.

TABLE IV. THE CALCULATES ESTIMATIONS FOR COMPOSED SERVICES (SECONDS)

Service	Novice users	Regular users	Advanced users
Smart service	$T_{\rm s} = 48.86$, $A_{\rm s} = 6.67$	$T_{\rm s} = 46.14$, $A_{\rm s} = 4.00$	$T_{\rm s} = 44.14$, $A_{\rm s} = 2.00$
Regular service	$T_{\rm ns} = 37.97$, $A_{\rm ns} = 33.33$	$T_{\rm ns} = 24.63$, $A_{\rm ns} = 20.00$	$T_{\rm ns} = 14.63$, $A_{\rm ns} = 10.00$

The calculated estimations of Trip planning service with "Personalized services" smart attribute for regular user are the following:

- "Work time" $T = 1.8731$;
- "Handwork automation" $A = 0.2$.

The estimations show service slow down while reducing manual work. The work time for smart service can be reduced by using cache of relationships. These estimations do not take into account the quality of result.

VI. CONCLUSION

In this paper we presented results of several experiments for efficiency evaluation of a Cultural trip planning service which are based on Smart Space technology and usage of Smart-M3 platform. The evaluation was based on introduced list of smart attributes which includes "multiple data sources", "composed services" and "personalized services" smart attributes. During the evaluation a smart service was compared to the regular service. The regular service was presented as a base for extension to smart service. Evaluation was based on "work time" and "handwork automation" estimates which showed increasing of speed and reducing of manual work. Evaluation results depends on service implementation, but the speed of data input on mobile devices makes a significant contribution to it. The results of evaluation for "personalized services" smart attribute shows advantage of smart service for manual work but regular service works faster. This result requires further investigation.

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REFERENCES

[1] D. A. Guttentag, "Virtual reality: Applications and implications for tourism," *Tourism Management*, vol. 31, no. 5, pp. 637–651, 2010.

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

[3] A. Smirnov, A. Kashevnik, A. Ponomarev, M. Shchekotov, and K. Kulakov, "Application for e-tourism:intelligent mobile tourist guide," in *Proc. IIAI International Conference on Advanced Applied Informatics (IIAI AAI 2015)*, Jul. 2015, pp. 40–45.

[4] A. Wecker, "Personalized cultural heritage experience outside the museum: Connecting the museum experience to the outside world," in *User Modeling, Adaptation, and Personalization. LNCS 8538*, V. Dimitrova, T. Kuflik, D. Chin, F. Ricci, P. Dolog, and G.-J. Houben, Eds. Springer International Publishing, 2014, pp. 496–501.

[5] A. G. Varfolomeyev, A. Ivanovs, D. G. Korzun, and O. B. Petrina, "Smart spaces approach to development of recommendation services for historical e-tourism," in *Proc. 9th Int'l Conf. on Mobile Ubiquitous Computing, Systems, Services and Technologies (UBICOMM)*. IARIA XPS Press, Jul. 2015, pp. 56–61.

[6] S. Balandin and H. Waris, "Key properties in the development of smart spaces," in *Proc. 5th Int'l Conf. Universal Access in Human-Computer Interaction (UAHCI '09). Part II: Intelligent and Ubiquitous Interaction Environments, LNCS 5615*, C. Stephanidis, Ed. Springer-Verlag, Jul. 2009, pp. 3–12.

[7] J. Augusto, V. Callaghan, D. Cook, A. Kameas, and I. Satoh, "Intelligent environments: a manifesto," *Human-centric Computing and Information Sciences*, vol. 3, no. 1, pp. 1–18, 2013.

[8] K. Kulakov, O. Petrina, D. Korzun, and A. Varfolomeev, "Towards an understanding of smart service: The case study for cultural heritage e-tourism," in *Proc. 18th Conf. Open Innovations Framework Program FRUCT*. ITMO University, Apr. 2016, pp. 145–152.

[9] 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 University, Oct. 2014, pp. 38–44.

[10] J. Honkola, H. Laine, R. Brown, and O. Tyrkkö, "Smart-M3 information sharing platform," in *Proc. IEEE Symp. Computers and Communications (ISCC'10)*. IEEE Computer Society, Jun. 2010, pp. 1041–1046.

[11] D. Korzun, A. Kashevnik, S. Balandin, and A. Smirnov, "The Smart-M3 platform: Experience of smart space application development for Internet of Things," in *Internet of Things, Smart Spaces, and Next Generation Networks and Systems. Proc. 15th Int'l Conf. Next Generation Wired/Wireless Networking and 8th Conf. on Internet of Things and Smart Spaces (NEW2AN/ruSMART 2015), LNCS 9247*, S. Balandin, S. Andreev, and Y. Koucheryavy, Eds. Springer, Aug. 2015, pp. 56–67.

[12] M. Etelapera, J. Kiljander, and K. Keinanen, "Feasibility evaluation of M3 smart space broker implementations," in *Proc. 2011 IEEE/IPSJ 11th Int'l Symp. on Applications and the Internet (SAINT)*. IEEE, Jul. 2011, pp. 292–296.

[13] F. Morandi, L. Roffia, A. D'Elia, F. Vergari, and T. S. Cinotti, "RedSib: a Smart-M3 semantic information broker implementation," in *Proc. 12th Conf. of Open Innovations Association FRUCT and Seminar on e-Tourism*, S. Balandin and A. Ovchinnikov, Eds. SUAI, Nov. 2012, pp. 86–98.

[14] A. D'Elia, D. Manzaroli, J. Honkola, and T. S. Cinotti, "Access control at triple level: Specification and enforcement of a simple RDF model to support concurrent applications in smart environments," in *Proc. 11th Int'l Conf. Next Generation Wired/Wireless Networking (NEW2AN'11) and 4th Conf. Smart Spaces (ruSMART'11)*. Springer-Verlag, 2011, pp. 63–74.

[15] 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, pp. 856–874, Aug. 2014.

[16] S. Bhardwaj, T. Ozcelebi, R. Verhoeven, and J. Lukkien, "Delay performance in a semantic interoperability architecture," in *Proc. 2011 IEEE/IPSJ 11th Int'l Symp. on Applications and the Internet (SAINT)*, Jul. 2011, pp. 280–285.

[17] G. Niezen, B. J. J. van der Vlist, S. Bhardwaj, and T. Ozcelebi, "Performance evaluation of a semantic smart space deployment," in *Proc. 2012 IEEE Int'l Conf. on Pervasive Computing and Communications Workshops (PERCOM Workshops)*. IEEE, Mar. 2012, pp. 835–841.

[18] 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.

[19] I. Galov and D. Korzun, "A notification model for Smart-M3 applications," 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-Verlag, Aug. 2014, pp. 121–132.

[20] D. Korzun, M. Pagano, and A. Vdovenko, "Control strategies of subscription notification delivery in smart spaces," in *Distributed computer and communication networks. CCIS 601*, V. Vishnevsky and D. Kozyrev, Eds. Springer International Publishing, 2016, pp. 40–51.

[21] I. Paramonov, A. Vasilev, D. Laure, and I. Timofeev, "Agent substitution mechanism for dataflow networks: Case study and implementation in Smart-M3," in *Proc. 13th Int'l Conf. Next Generation Wired/Wireless Networking and 6th Conf. on Internet of Things and Smart Spaces (NEW2AN/ruSMART 2013)*, ser. LNCS 8121, S. Balandin, S. Andreev, and Y. Koucheryavy, Eds. Springer-Verlag, Aug. 2013, pp. 60–71.

[22] 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 University, Oct. 2014, pp. 16–23.

[23] D. Korzun, S. Marchenkov, A. Vdovenko, A. Borodulin, and S. Balandin, "Performance evaluation of Smart-M3 applications: A SmartRoom case study," in *Proc. 18th Conf. of Open Innovations Association FRUCT*, S. Balandin, T. Tyutina, and A. Levina, Eds. ITMO University, Apr. 2016, pp. 138–144.

[24] K. Kulakov and O. Petrina, "Ontological model for storage historical and trip planning information in smart space," in *Proc. 17th Conf. Open Innovations Framework Program FRUCT*. ITMO University, Apr. 2015, pp. 96–103.

[25] R. W. Soukoreff and I. S. Mackenzie, "Theoretical upper and lower bounds on typing speed using a stylus and a soft keyboard," in *Behaviour & Information Technology*, 1995, pp. 370–379. [Online]. Available: http://www.tandfonline.com/loi/tbit20