On-Board Dynamic Tour Support System: The Concept and Technological Infrastructure

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Abstract—**Modern technologies do not only enable new solutions improving humans life but also change the way of doing business. Together these two factors lead to the appearance of a new, previously unavailable, class of systems called product-service systems. The paper describes the concept and technological framework of a system aimed at context-dependent planning and dynamic adaptation of guided tourist rides in a car based on the usage of car connectivity technologies and cloud-based services. The system is based on the integration of the previously developed by the authors tourist support system TAIS with Ford SYNC Applink.**

I. INTRODUCTION

Modern technologies (e.g., Internet of Things, ubiquitous computing, connectivity) substantially change our lives. This can be seen not only in new products and services but also in new ways of business organization. Companies finding themselves in new conditions of globalized dynamic markets change business models to be able to maintain competitive advantage. An illustrative example is Uber, that not only provides taxi services, but it does this without actually owning any cars and acting just as a connecting link between the taxi drivers and passengers. Timely changed business model can provide for a significant competitive advantage (e.g., the capitalization of Uber in 2015 was about $68 billion, which was $20 billion higher than that of GM [1]).

Besides the mentioned above innovative taxi services (such as Uber, Gett, Yandex Taxi, Lyft, etc.) there could be mentioned some other interesting innovative mobility models. For example, there is a number of initiatives related to the car sharing concept (BMW's DriveNow, Zipcar, Anytime, enjoy, etc.). The key idea of such services is that the user has an app in his/her mobile phone that is used to locate the car, reserve and enter it (no need for keys) – everything is done in an automatic way "on the go".

Car manufacturers are not an exception. In-vehicle electronic systems are developing fast and continuously accumulating new and new features related to connectivity, information support and entertainment. Such systems have transformed from simple audio players to complex solutions, referred to as "infotainment systems". They are not only capable to connect with smartphones but also can share information from different vehicle sensors and present various information through in-vehicle screen (visual information) or stereo system (audio information) [2]. Such systems made it possible to treat a car not as a single product but as a product-service system [3]-[5], i.e. system that tightly integrates physical products and software services.

Infotainment systems can be used not only to improve driving experience, they provide new opportunities for developing various applications utilizing "connected car" technologies (e.g., [6]). "Connected car" (sometimes also referred to as "connected vehicle") originates from integration of the Internet-of-Things concept with vehicles. It stands for the connectivity of the vehicle with its surroundings in real time with the purpose higher safety and improved experience of the car driver and passengers [7].

The paper extends the previously presented work [8], [9] aimed at introduction of application of the concept of cyber-physical systems to support customized on-demand tours based on the "Connected car" technology.

The paper is structured as follows. Section II introduces e-tourism, main directions of its development and its connection to transportation services. The concept of the developed system is presented in section III. It is followed by the description of the technological infrastructure of the system, main tasks and the ways they were solved. Section IV concentrates on the mechanism of ad-hoc generation of the context-dependent audio guide. Main results are summarized in the conclusion.

II. E-TOURISM

Due to the growing amount of information and services available in the Internet, tourists are becoming more active and willing to explore new places on their own. The sights, in turn, e.g. museums, palaces, parks, etc. have been upgrading their offerings with interactive displays, audio tours, and other, e.g., [10], [11]. It is getting more interesting to spend time at the sights than just getting a quick view when passing by. The experiments show that usage of mobile applications allows tourists to discover more sights and stay at them longer than usage of conventional means (paper maps and books) [12]. The internet allows tourists to do their own research and planning before arriving, allowing them to use public transportation or other means to see the main sights.

One of promising tasks is integration of different mobile applications with cars' on-board infotainment systems with usage of the cloud computing concept for real time or quasi-real time processing of large amount of available information.

Such systems can be classified as infomobile driver support assuming distribution of dynamic and selected multi-modal information to the users, both pre-trip and, more importantly, on-trip [13]. It is a way of service organization capable to present user multimodal information at any time.

Transport service providers have been reacting to this shift introducing various services for individual tourists. For example, local commuter networks had introduced 2- and 3-day travel passes, directly targeting the tourists' transportation needs. Hop-on-hop-off bases are available in many tourist-oriented cities. They provide for multi-day ticket that allow customers unlimited use of the sightseeing buses, entering and exiting at convenient stops (sights, hotels and train stations), at their own schedule. This makes it possible to increase the utilization by each customer, spread the use over the whole day, and allow the operator to get more utilization out of each bus, instead of optimizing for peak periods.

Uber has launched UberTour in some cities that integrates the concept of Uber (ad-hoc car reservation suing a mobile app) and hop-on-ho-off buses that drive the tourist through a number of pre-defined attractions.

Analysis of apps currently available in the market [14], [15] shows that there is a trend towards providing proactive tourist support based on his/her location, preferences, and current situation in the area (weather, traffic jams, and etc.) [16]. Development of such systems is still an actual task that attracts researchers from all over the world (e.g., [17-19]). Such systems are aimed to solve the following tasks:

- generate recommended attractions and their visiting schedule based on the tourist and region contexts and attraction estimations of other tourists. The tourist context characterizes the situation of the tourist, it includes his/her location, co-travelers, and preferences; the region context characterizes the current situation of tourist location area, it includes such information as weather, traffic jams, closed attraction, etc.
- collect information about attractions from different sources and recommend the tourist the best for him/her attraction images and descriptions;
- propose different transportation means for reaching the attraction;
- update the attraction visiting schedule based on the development of the current situation.

III. THE CONCEPT AND TECHNOLOGICAL INFRASTRUCTURE

The described system assumes ad-hoc generation of a tour route and support of the tour (guiding, narration, presentation of additional information) based on the personal schedule analysis, current situation monitoring and prediction, and integration of the on-board infotainment system with personal smartphone/tablet and external services via Ford's SYNC Applink API (fig. 1). It is based on the authors' previous work on personalized tourist assistance service (TAIS) [20].

The tour is generated based on the preferences stored in the tourist's profile, situation in the area and its possible development (e.g., regular traffic jams during rush hours can be easily predicted), and available information about attractions.

Based on the number of tourists a car of required type (standard, minivan, van, etc.) is selected automatically. The driver is notified about the tour order and, if he/she accepts the tour, picks up the tourist(s) at the time and location indicated in the on-board navigation system. Then, the driver just follows the tour route loaded into the car's navigation system.

Tourist(s) can use their smartphones/tablets during the tour for narration, imagery and video synchronized with the vehicle's location, speed and orientation. Guiding information is extracted from accessible in the smart city services and predefined libraries.

The user is also able to communicate in some extent through the SYNC system with the driver if he/she doesn't speak the person' language (e.g., ask for a stop near an attraction) and control some car elements as opening/closing windows or adjusting climate control.

The system takes into account the context information (fig. 2) including person's preferences described in his/her profile (preset and revealed via collaborative filtering techniques) and the current situation at the location (season, weather, traffic jams, etc.) to anticipate what the passenger would want and need. All this information constitutes the context of the current

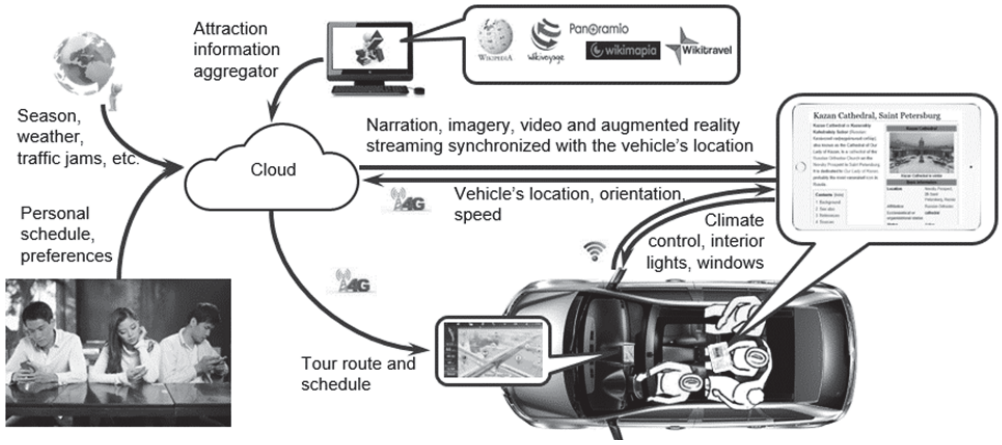

Fig. 1 The overall scheme of the on-board dynamic tour support system

situation that affects the tour flow and might cause changes in it. Here the context includes both the environmental information and tourist information. The tourist information is described in the tourist profile and is considered separately further in the paper, and the context assumes only the environmental information.

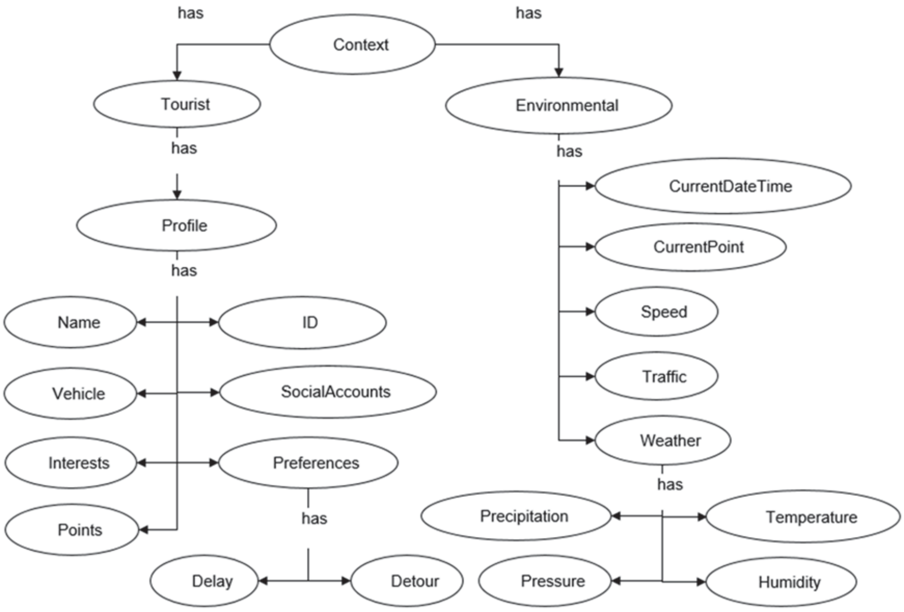

Fig. 2 Context structure including tourist’s profile

Fig. 3 illustrates the main technological infrastructure of the system (white rectangles) and related tasks that had to be solved (black rectangles). Information flows are shown with arrows. The environmental information collected by various car sensors is transmitted to the context located at the tourist’s personal device and pre-processed via context management techniques. Then, it is transferred to the cloud, integrated with preferences and submitted to the recommender block that is responsible for assembling the tour route and selecting appropriate media for guiding. The guiding can be done either through tourist’s device or on-board infotainment system (this is especially convenient when a minivan is used for a group of tourists). The feedback block analyses the preferences of the

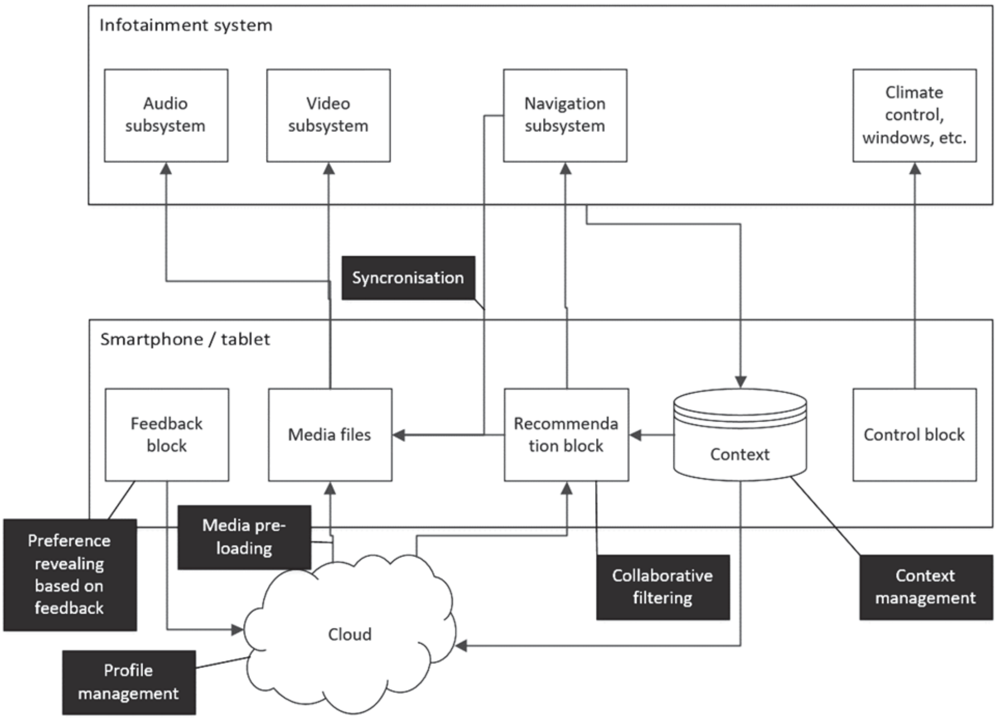

Fig. 3 Technological infrastructure

tourist and control block is responsible for communicating with car's controls (opening and closing windows, adjusting climate control, using passenger lights, etc.). Below, these components are described in detail.

A. Context management

Context (information about the current situation) can significantly improve the precision of preference revealing since in various situations the tourist might have different preferences. Being in a hurry, travelling with kids, weather conditions and time of the year, time of the day, etc. – all these aspects affect the impressions from each attraction and information that should be delivered to the tourist. Analyzed together with information from car sensors (GPS/GLONASS, compass, speedometer), tourist's device (GPS/GLONASS, compass), the route, and traffic situation from the navigation system this information improves the quality of the generated tours.

B. Profile management

Profile management assumes accumulation, storage and processing the tourist-related information (context-dependent preferences) for generating personalized and situation dependent tours.

C. Synchronization

Narration, imagery, and video has to be synchronized with the route, location, orientation and speed of the car. For this purpose the context information is analyzed in order to select appropriate imagery and to make a short-term (<10 minutes) prediction of the movement for selecting narration and videos of the corresponding duration.

D. Media caching

Media information (including narration, imagery, and video) has to be preloaded into the tourist's device in order for the guiding to be smooth. Based on the context information a mid-term (<1 hour) prediction of the movement is made for selecting and downloading media that will later be used for the guiding.

E. Preference revealing based on the tourist's feedback

Described in detail in sec. IV.A.

F. Collaborative filtering

Collaborative filtering refers to techniques used in collaborative recommender systems and assumes analysis of users with similar preferences. Usually, the developed service does not have enough information related to a particular user in his/her profile to create adequate tours for new places. However, this is the situation when such functionality is the most demanded. Usage of collaborative filtering techniques allows for analysis of profiles of multiple tourists and if they have similar preferences, the service thus is capable of building personalized tours with a higher degree of appropriateness for a particular tourist.

IV. ADAPTIVE GUIDANCE

In this work, an approach to creating a context-aware personalized narrative from fragments similar to an assembly line is proposed (Fig. 4). It assumes that there is a library of (relatively) short fragments (called "clips") each described with subject, running time, interests (keywords), and additional contextual parameters (appropriate weather, location, direction). Additionally, constraints are introduced that define alternative (mutually excluding) clips, clip restrictions (one clip cannot be played without another one), and clip sequences (one clip cannot be played after another one). The analysis carried out has shown that text to speech generation is not an appropriate solution for this task since long listening of monotonous narration is not comfortable. As a result, it was decided that clips had to be pre-recorder by human narrators.

The system analyses the current context and builds a sequence of clips of the given duration that is the most appropriate to the current situation and tourist's preferences. It can be seen in the figure that the narration for a given duration can be assembled from available fragments in a number of ways. As a result, there is a task of selecting those, which do not only fit the given duration but also match the context (both the tourist context and the region context) in the best way.

This task can be formalized as follows:

$o_i = (t_i, R_i, C_i, W_i)$, where

o_i – is a narrative fragment (clip) i, $i = 1 \dots n$,
t_i – duration of clip i,
R_i – is a set of constraints related to clip i,
C_i – is a set of contextual parameters of clip i,
W_i – is a set of associated weighted keywords.

The vector $X = (x_1, x_2, \dots, x_n)$ is a solution of the task, where x_i is a Boolean variable denoting that clip i is used in the solution ($x_i = 1$) or not ($x_i = 0$).

The duration constraint is formalized as $|\Delta t| \leq t_t k_t$, where k_t is an acceptable deviation from the target duration (e.g., 0.2), and t_t is the target duration.

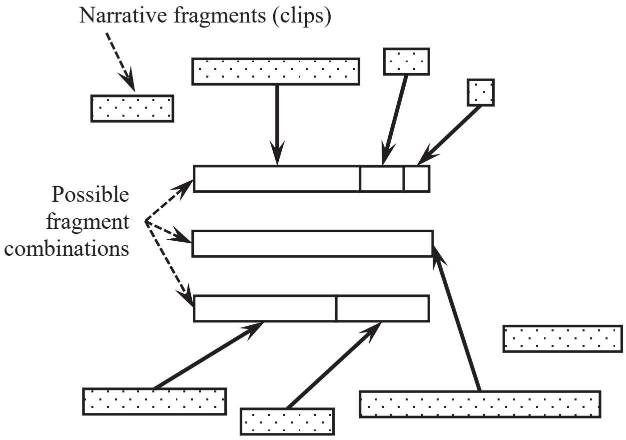

Fig. 4 Creating a narrative from available fragments

$\Delta t = t_t - t_{sum}$, where $t_{sum} = \sum_{i=1}^{n} x_i t_i$ is the actual duration of the built narrative.

The usefulness of the clip for the tourist is based on the matching of the weighted keywords associated with the clip (W_i) and weighted keywords associated with the tourist (W_j): $u_i = f(W_{i,}, W_j)$. This can be done, for example, based on the cosine function.

The contextual parameters are processed individually, and then they are aggregated into a weighted sum (c_i). For example, the value of the clip can be decreased if it is aimed at watching at something remoted and the weather is rainy or foggy.

The overall goal function is $u_{sum} = \sum_{i=1}^{n} u_i t_i c_i \to max$.

A. Adjustment of preferences and contextual parameters based on the tourist's feedback

Evaluation of the importance of contextual parameters is a difficult task. As a result, it is suggested to adjust their weights during the usage of the system based on the tourist's feedback. However, usually, the tourists do not leave any explicit feedback. The proposed approach is relying on the tacit (not annoying) feedback from the users such as skipping a fragment or requesting additional information on the currently narrated topic). Analysis of this feedback improves the weights of the contextual parameters as well as improves the tourist's profiles through adjusting weights of keywords. This is also useful since the tourist would unlikely explicitly identify all appropriate multiple preference options required for better "understanding" his/her preferred attractions and guiding information.

B. Semantic graph for keywords representation

One of the main problems of identifying common preferences is the absence of those for a relatively small number (3 to 10 people) of unrelated users due to the preference heterogeneity. The existence of interconnections of different nature allows the generalization of preferences and interests (e.g., the relation "is a": the interests of "architecture of the XVIII century" and "antique architecture" can be united by the interest of "architecture"), and the search for related interests or preferences (e.g., associative relations and relations "part of": the interests of "Carlo di Giovanni Rossi" and "St. Basil's Cathedral" can also be united by the interest of "architecture").

The solution to this is the application of ontological modeling methods that have proved to be an effective tool for structuring knowledge about the subject domain. Ontologies are a collection of concepts that presumably exist in a certain area of interest, as well as the interrelationships between them. In Fig. 5 (left) it is possible to easily "switch" from detailed preferences or interests (e.g. Architecture of XVIII century) to more general ones (e.g., Architecture). The nodes do not necessary have only one parent but could have several ones (the relationship is "many to many"). The preferences are generalized and in this case the match of preferences is higher. In Fig. 5 (right) the preferences are indicated as bold circles, and the resulting node as black circle.

The processing of such structured preferences is carried out on the basis of the graph theory methods (more precisely, semantic graphs). For this purpose the preferences on the weighted graph of ontology, whose vertices are the concepts of the subject domain, and the arcs are the relations between them, are "highlighted" and paths connecting them with supposedly common preferences are calculated. Based on the domain considered a system of weights for paths calculation on a weighted graph has to be identified.

C. Evaluation

With the purpose of proving the concept an experiment has been conducted aimed to estimate (i) the acceptance of the generated narrations by people as well as (2) the capability of the system implementing the approach to generate narrations similar to those prepared by people.

The Evangelical Lutheran Church of St. Michael located in St.Petersburg, Russia, was chosen as an attraction since (i) it is not very well known and the information about it would be new for the participants, and (ii) it is located near the place where the experiment was conducted, so the participants would be interested to get to know something new about it. Eight narration fragments with duration from 10 to 60 seconds were created based on the Wikipedia description as well as other descriptions found in the Internet. Each fragment was annotated with keywords, importance and duration. The fragments were read by a human narrator and recorded.

The experiment was conducted in two stages. First, 13 participants selected their interests among the proposed seven keywords, and were given a task to create a tour out of available fragments (presented as text) of the approximately given duration. At the second stage, the system generated an audio tour out of recorded fragments with the same input parameters and the participants were listening to it. After that the participants were interviewed if they were satisfied with the generated tour, if the generated tour was better than one created by them and why.

It was observed that in most cases the system generated tours were the same as those created by human participants (precision 73%, recall 79%, F-Measure 76%). The interviews showed that deviations were mainly due to different understanding of the importance of the fragments by them and by the team preparing the experiment as well as different interpretation of the keywords. Besides, people tended to keep the tour duration below the given time frame, whereas the

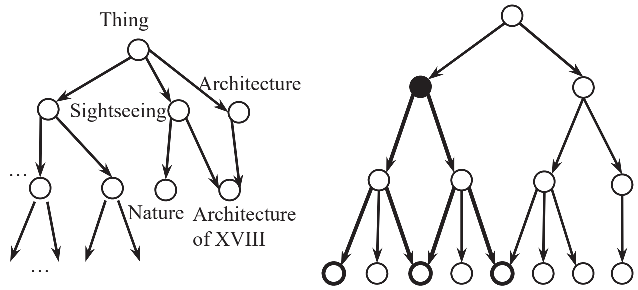

Fig. 5 Organization (left) and intersection (right) of preferences / interests

system generated tours both longer and shorter than the given time frame. However, all participants agreed that the tours generated by the system were fine and they would be satisfied when listening for such tours.

V. CONCLUSION

The paper describes the concept and technological framework of a system aimed at context-dependent planning and dynamic adaptation of guided tourist rides in a car based on the usage of car connectivity technologies and cloud-based services. The system is based on the integration of the previously developed by the authors tourist support system TAIS with Ford SYNC Applink.

The main technological tasks solved include context and profile management for adaptation of the tour to changing situation and better matching tourist's preferences; collaborative filtering for extending preferences to tourists with similar interests; preference revealing based on the tourist's feedback through behavior analysis for collecting information in an non-obtrusive way; guiding synchronization and media caching for smooth guiding, with audio guide assembly "on-the-fly". The audio guide assembly approach is based on the "assembly line" principle, when the tour is generated based on available fragments. The carried out experimentation confirmed that the clips generated are not significantly different from those created by people and are well accepted by the experiment participants.

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REFERENCES

[1] L. Chen, "At $68 Billion Valuation, Uber Will Be Bigger Than GM, Ford, And Honda", Forbes, 2015, Web: https://www.forbes.com/-sites/liyanchen/2015/12/04/at-68-billion-valuation-uber-will-be-bigger-than-gm-ford-and-honda.

[2] A. Taramov and N. Shilov, "A Systematic Review of Proactive Driver Support Systems and Underlying Technologies", *Proceedings of the 20th Conference of Open Innovations Association FRUCT*, St.Petersburg, Russia, 3-7 April 2017, pp. 448-459.

[3] C. Vezzoli, C. Kohtala, A. Srinivasan, L. Xin, M. Fusakul, D. Sateesh, and J.C. Diehl, *Product-Service System Design for Sustainability*. Routledge, 2017.

[4] A. Tukker and U. Tischner (eds), *New Business for Old Europe: Product-Service Development, Competitiveness and Sustainability*. Routledge, 2017.

[5] S. Cherubini, G. Iasevoli and L. Michelini, "Product-service systems in the electric car industry: critical success factors in marketing", *Journal of Cleaner Production*, vol.97, 2015, pp. 40-49.

[6] N. Hashimoto, S. Kato, N. Minobe and S. Tsugawa, "Automated Vehicle Mobile Guidance System for Parking Assistance", *IEEE Intelligent Vehicles Symposium*, 2007, pp. 630-635.

[7] H. B. Shim, "The Technology of Connected Car", *Journal of the Korea Institute of Information and Communication Engineering*, vol.20, no.3, 2016, pp. 590-598.

[8] A. Smirnov, N. Shilov and O. Gusikhin, "Connected Car"-Based Customised On-Demand Tours: the Concept and Underlying Technologies", *Internet of Things, Smart Spaces, and Next Generation Networks and Systems, 16th International Conference NEW2AN 2016 and 9th Conference ruSMART 2016*, St.Petersburg, Russia, 26-28 September 2016, *Lecture Notes in Computer Science*, vol.9870, 2016, pp. 131-140.

[9] A. Smirnov, N. Shilov and O. Gusikhin, "Cyber-Physical-Human System for Connected Car-Based e-Tourism", *Proceedings of 2017 IEEE Conference on Cognitive and Computational Aspects of Situation Management*, Savannah, GA, USA, 27-31 March 2017, IEEEComSoc. 2017.

[10] G. Mincolelli, M. Biancardi, M. Fabbri, C. Feriotto, A. Massarente, S. Munerato and F. Raco, "QRCODE and RFID Integrated Technologies for the Enhancement of Museum Collections", *Proceedings of EuroMed 2014: Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection*, Limassol, Cyprus, November 3-8, 2014, *Lecture Notes in Computer Science*, vol.8740, 2014, pp. 759-766.

[11] R.Y.C. Li, and A.W.C. Liew, "An Interactive User Interface Prototype Design for Enhancing On-Site Museum and Art Gallery Experience Through Digital Technology", *Museum Management and Curatorship*, vol.30, no.3, 2015, pp. 208-229.

[12] M. Modsching, R. Kramer, K. Ten Hagen and U. Gretzel, "Effectiveness of Mobile Recommender Systems for Tourist Destinations: a User Evaluation", *Proceedings of 4th IEEE Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications*, Dortmund, Germany, September 6-8, 2007, IEEE, pp. 663-668.

[13] G. Ambrosino, M. Boero, J.D. Nelson and M. Romanazzo, *Infomobility systems and sustainable transport services*, ENEA Report, 2010.

[14] E. Price, "*Travel apps that can replace your tour guide*", 2015, Web: http://www.cntraveler.com/stories/2015-02-24/travel-apps-that-can-replace-your-tour-guide.

[15] B. Cowen, "*A personal tour guide – almost everywhere – for $9.99 or less!*", 2015, Web: http://www.johnnyjet.com/2015/01/a-personal-tour-guide-almost-everywhere-for-9-99-or-less/.

[16] A. Smirnov, A. Kashevnik, A. Ponomarev, N. Shilov and N. Teslya, "Proactive Recommendation System for m-Tourism Application", *Proceedings of the 13th International Conference on Business Informatics Research*, Lund, Sweden, September 22-24, 2014, *Lecture Notes in Business Information Processing*, vol.194, 2014, pp. 113-127.

[17] T. Gerhardt, "*3 Ways Multi-Modal Travel is Tricky for App Developers*", 2015. Web: http://mobilitylab.org/2015/03/10/3-ways-multi-modal-travel-is-tricky-for-app-developers/.

[18] S. Staab, H. Werthner, F. Ricci, A. Zipf, U. Gretzel, D.R. Fesenmaier, C. Paris and C. Knoblocket, "Intelligent Systems for Tourism", *IEEE Intelligent Systems*, vol.17, iss.6, 2002, pp. 53-64.

[19] T. Hasuike, H. Katagiri, H. Tsubaki and H. Tsuda, "Interactive Approaches for Sightseeing Route Planning Under Uncertain Traffic and Ambiguous Tourist's Satisfaction", *New Business Opportunities in the Growing E-Tourism Industry*, Hershey, PA: Business Science Reference, 2015, pp. 75-96.

[20] A. Smirnov, A. Kashevnik and A. Ponomarev, "Context-based infomobility system for cultural heritage recommendation: Tourist Assistant—TAIS", *Personal and Ubiquitous Computing*, vol.21, no.2, 2017, 297-311.