Cyber-physical infomobility for tourism application

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Abstract: The paper proposes an approach, reference model, and case study for a cyber-physical infomobility for tourism application. The logistics system of the hub is considered as a cyber-physical system. The main idea behind the virtual tourist hub concept is to arrange a tourist trip based on the available schedules, capabilities and environment-friendliness of transportation and attraction providers, current and foreseen availability and occupancy of the available transportation means and attraction services. The approach assumes usage of a context-based group recommending system for generating recommendations for the tourists. A case study describes service-oriented architecture, implementation, and evaluation of mobile tourist guide application that is based on the presented in the paper approach and reference model.

Keywords: virtual tourist hub; cyber-physical system; infomobility; recommending system; tourist trip planning; scheduling; e-tourism; mobile application; tourist guide; logistic hub.


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1 Introduction

In accordance with ‘Global GHG Abatement Cost Curve v 2.0’ (https://solutions.mckinsey.com/), in the travelling sector the carbon emission can be significantly decreased (10.5% of road transport) via more efficient route planning, driving less, switching from car to rail, bus, cycle, etc. Additionally, in accordance with IEA Statistics (http://www.iea.org/) and the UK Industry Task Force for Peak Oil and Energy Security (http://peakoiltaskforce.net/) the fact that the transport sector is 95% oil dependent makes it vulnerable to the expected rise in oil price during this decade. As a result, evolving of flexible, ecological and energy efficient logistics systems can be considered as one of the significant steps towards the knowledge-based Green ICT applications in low carbon economy (see Smirnov et al., 2011; Martin, 1995).

Proposed approach is a step to ‘infomobility’ infrastructure, i.e., towards operation and service provision schemes whereby the use and distribution of dynamic and selected multi-modal information to the users, both pre-trip and, more importantly, on-trip, play a fundamental role in attaining higher traffic and transport efficiency as well as higher quality levels in travel experience by the users (Ambrosino et al., 2012). The approach is based on the concepts of cyber-physical system (CPS) and virtual logistic hub.

The term ‘cyber-physical systems’ is also often referred to as ‘the internet-of-things’ (Atzori et al., 2010) or similar. It is oriented to domain independent architectures and technologies for supporting cyber-physical artefacts and networks (Cohen, 1999). CPSs open the avenue towards new kinds of information services by exploiting the ability of physical systems to provide context information in a quality so far not available (Smirnov et al., 2013).
A good recent state-of-the-art review of different CPS approaches and supporting technologies can be found in Horvath and Gerritsen (2012). Horvath and Gerritsen conclude that “the next-generation of CPSs will not emerge by aggregating many uncoordinated ideas and technologies in an incremental fashion. Instead, they will require a more organised and coordinated attack on the synergy problem, driven by an overarching view of what the future outcome should be”.

The core of infomobility support is implemented as a virtual logistic hub. The concept of virtual logistic hub has already been mentioned in the literature, but it is still devoted very little attention in the research community. The major idea behind this concept is to arrange transportation based on the available schedules and capabilities of transportation and attraction providers, current and foreseen availabilities and occupancies of the available transportation means and attraction services. In this case, even though the schedules and actions of different members are not coordinated, the virtual hub will be able to find the most feasible schedule depending on the current situation and its likely future development. For the end-user, all this is hidden ‘under the hood’. The user only interacts with his/her computer or smart phone and sees the actual trip schedule ‘on the move’.

The proposed approach integrates models and methods enabling ad-hoc configuration of resources for multimodal logistics, which are based on dynamic optimisation of the route and transportation means as well as take into account user preferences together with unexpected and unexpressed needs (on the basis of the profiling technology).

The approach is illustrated via an e-tourism case study. The implementation of the ubiquitous environment is based on the ‘Smart-M3’ platform developed within smart objects for intelligent applications (SOFIA) ARTEMIS project. Implementation of the virtual logistic hub for e-tourism is a work in progress within project KA322 ‘development of cross-border e-tourism framework for the program region (smart e-tourism)’ of Karelia ENPI program co-funded by the European Union, the Russian Federation and the Republic of Finland.

The proposed general framework can also be a channel for collecting user’s feedbacks, preferences and demands for new services that users cannot find in the Region or quality of which shall be improved. What is important is that not only the problem is identified, but in most cases immediate hints/suggestions can be provided regarding what shall be done to better serve users’ needs.

The paper is structured as follows. The next section describes related work in the area of tourist support. Then the virtual tourist hub concept based on the idea of virtual logistics hub is explained. After that, a description of the reference model is proposed. Then, the aspects of usage of group recommending system for the virtual tourist hub support are discussed. Thereafter the smart space-based case study that includes scenario, implementation, and evaluation is presented. The main results are summarised in the conclusions.

2 Related work in the area of tourist support

Table 1 shows a list of mobile e-tourism solutions that have been identified as most interested for providing the tourist services during the trip.
The carried out analysis of the mentioned above systems shows that they can be divided into two main groups for information extraction:

- applications that implement search for information around the tourist from internet sources
- applications that have own databases with information about attractions and provide this information to the tourist.

Applications from the first group require the internet connection while applications from the second group can provide the tourist information independently. The main disadvantage of the first group applications is a high price for mobile roaming and usual tourists cannot use internet connection during the trip. However, governments of different countries plan legislative regulations to reduce roaming prices (Ingraham, 2012). The main advantage of the first group applications is possibility get up-to-date information around the tourist independently on the tourist location. In addition, it is not needed to keep a big database with information about attractions in the tourist mobile device.

The following groups of applications have been identified based on travel phases (most of applications covers two or all travel phases):

- pre-travel phase, that provides range of services to facilitate travel-related information search, for instance attractions description, hotel and airplane booking, etc.
- travel phase, that provides the tourist real-time information about the destination, e.g., information about events, places of interest, advices and practical recommendations
- post-travel phase, try to get feedback from the tourist (variety of solutions to collect estimation information about attraction) and share his/her travel experience with others.

The first applications group provide the tourist possibility to plan his/her trip, get information about attractions for given destination, book hotels and flights. The applications from the second group provide the tourist personalised context-based information about attractions in the destination. The aim of the applications from the third group is to collect posts, photos, videos, and/or estimations about attractions attended by the tourist. This information can help other tourist to decide if they would like or not to attend these attractions. There are applications that incorporate two of three groups. For example, TripAdvisor allows to plan the tourist trip by browsing information in PC before.

During the trip, the tourist can use mobile application to see places of interests around. In addition, TripAdvisor allows making estimations about attended places of interests and posting some blogs about them.

The main difference of the proposed here approach from the existing services and solutions is that the considered systems use attraction information database or own information database, which has to be prepared beforehand. Besides, they have very limited infomobility support: these systems do not take into account information about the current situation in the museums and in the region, and they are oriented to assist user only in one museum, whereas the proposed approach allows monitoring the current
situation in whole city or region and provides context-driven update of the travel plan ‘on-the-fly’.

Table 1  List of mobile e-tourism solutions

<table>
<thead>
<tr>
<th>Name and link</th>
<th>Description</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GuidiGO <a href="https://www.guidigo.com/">https://www.guidigo.com/</a></td>
<td>Personal worldwide tour guide. It allows to get an experience about destination, by downloading guided tours created by local experts and passionate storytellers around the world. It is possible to choose a tour based on the tourist interests: history, architecture, art, fashion, etc.</td>
<td>iOS, Android OS</td>
</tr>
<tr>
<td>2 Viator Tours and Activities <a href="http://www.viator.com/">http://www.viator.com/</a></td>
<td>Mobile application that allows to find and book tours and activities in destinations worldwide. Viator’s local experts plus reviews and photos from travellers provides insider experience.</td>
<td>iOS, Android OS, Web application</td>
</tr>
<tr>
<td>3 COMPASS (Setten et al., 2004)</td>
<td>A mobile application for tourists COMPASS is an application that makes context-aware recommendation based on tourist’s interests and context. The application is built upon the WASP platform that provides generic supporting services combined with semantic web technology.</td>
<td>Research</td>
</tr>
<tr>
<td>4 Dynamic Tour Guide (Kramer et al., 2005)</td>
<td>Context-driven mobile tourist guide that has been developed for Windows Mobile operation system. The study presents methodology, implementation and evaluation of mobile tourist guide.</td>
<td>Windows mobile</td>
</tr>
<tr>
<td>6 World Around Me (Vdovenko et al., 2012) <a href="http://www.windowsphone.com/ru-ru/store/app/world-around-me/8fc95dcf-c50d-4123-82f9-1b00d8d61d5f">http://www.windowsphone.com/ru-ru/store/app/world-around-me/8fc95dcf-c50d-4123-82f9-1b00d8d61d5f</a></td>
<td>Windows Phone 7 application that shows the user photos around the user location. Photos are automatically downloaded from Flickr and Panoramio and presented to the user. URL for download: <a href="http://www.windowsphone.com/ru-ru/store/app/world-around-me/8fc95dcf-c50d-4123-82f9-1b00d8d61d5f">http://www.windowsphone.com/ru-ru/store/app/world-around-me/8fc95dcf-c50d-4123-82f9-1b00d8d61d5f</a></td>
<td>Windows Phone 7</td>
</tr>
<tr>
<td>7 ImogI (Luyten and Coninx, 2004) <a href="http://research.edm.uhasselt.be/~imogi/">http://research.edm.uhasselt.be/~imogi/</a></td>
<td>Context-aware mobile guide for outdoor as well as indoor locations. It uses GPS to identify user’s location in outdoor environments, communicates with other objects in the environment through Bluetooth. The information that is shown in the user interface can be obtained in two different ways: stored on the mobile guide, or queried from the artefacts that are in the direct surroundings of the mobile guide through wireless communication.</td>
<td>Windows Mobile</td>
</tr>
</tbody>
</table>
### Table 1  List of mobile e-tourism solutions (continued)

<table>
<thead>
<tr>
<th>Name and link</th>
<th>Description</th>
<th>Platform</th>
</tr>
</thead>
</table>
| 8 Triposo  
http://www.triposo.com/         | The travel guide Triposo is a free mobile guide service available for Apple and Android devices. A user can download the application and appropriate database to the mobile device beforehand and use it during the trip without internet connection. The application supports logging of travelling. Each guide contains information on sightseeing, nightlife, restaurants and more. | iOS, Android OS,  
Nokia Ovi Store    |
| 9 TripAdvisor  
http://www.tripadvisor.ru       | Millions of traveller reviews, photos, and maps can be accessible in TripAdvisor. Tourists can plan their trips taking into account over 100 million reviews and opinions by travellers. TripAdvisor makes it easy to find the lowest airfare, best hotels, great restaurants, and fun things to do, wherever you go. The mobile application is free it supports all mobile platforms. | iOS, Android OS,  
Nokia Ovi Store,  
Windows Phone 7,  
Web application   |
| 10 Smart Travelling  
http://www.smart-travelling.net/en/ | Online travel guide that supports about 30 cities worldwide including the most interesting destinations in European countries and USA. The guide includes a database of restaurants, cafes, hotels, shopping-tips and other places of interests. The mobile application for iPhone is accessible in AppStore. Integration with Google Maps allows user to see the current location in the map and helps to navigate to each trip in destination cities. Application allows the user to download the content and use guide without internet connection. | iOS               |
| 11 ARTIZT  
(Garcia et al., 2011)                  | Innovative museum guide system, where a ZigBee protocol is used for determine user’s position information. Visitors use tablets to receive personalised information and interact with the rest of the elements in the environment. The system achieves a location precision of less than one meter. The context is used to provide needed at the moment personalised information to the user.                                                                                         | Prototype         |
| 12 Smart Space-Based Trip Planning Service  
(Kulakov and Shabaev, 2014) | The service is based on smart space technology that allows to create proactive services with context-based scenarios and multi-service usage. The presented approach includes high-level architecture, scenarios usage and possible data sources from existing third party services and used algorithms for data transformation.                                                                                               | Research          |
Table 1  List of mobile e-tourism solutions (continued)

<table>
<thead>
<tr>
<th>Name and link</th>
<th>Description</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 Smart personal assistant for historical tourism (Varfolomeyev et al., 2014)</td>
<td>Application system architecture is proposed. Solution constructs tourist’s smart space where multiple sources of historical data are integrated and user context is kept. Historical points of interests (POI) are augmented with historical facts and relations. This semantic information inputs the computation of POI ranks, and the most relevant POIs are then provided personally to the user.</td>
<td>Research</td>
</tr>
</tbody>
</table>

3  Virtual tourist hub

The idea of virtual logistics hub has already been mentioned in the literature (though it could have a different name, e.g., ‘e-Hub’ by Chang et al., 2003), but it is still devoted very little attention in the research community. For example, Working Group on Logistics (2002) and Sweeney (2002) consider the virtual logistic hub from organisational and political points of view.

Generally, virtual tourist hub represents a virtual collaboration space for three types of members:
1 transportation providers (who actually moves the passengers)
2 attraction service providers
3 other service providers (who provide additional services, e.g., seaport, border crossing authorities, etc.).

These providers can potentially collaborate in order to increase the efficiency of the logistic network (solid lines in Figure 1); however, it is not usually the case.

The major idea of the virtual tourist hub is to arrange transportation based on the available schedules and capabilities of transportation and attraction providers, current andforeseen availability and occupancy of the available transportation means and attraction services (‘dash-dot’ lines in Figure 1). The current occupancy of attraction services can be estimated via implementation of corresponding sensors and services, which would, for example, count the number of visitors in a room or in an area. Integration and usage of such systems is being developed in the CPS domain.

In this case, even though the schedules and actions of different members are not coordinated, the virtual tourist hub will be able to find the most feasible schedule depending on the current situation and its likely future development.

For the end-user (travellers), all this is hidden ‘under the hood’, and only the final trip schedule is seen (solid lines in Figure 1).

The region constituted by St. Petersburg, Russia and Helsinki, Finland together with nearby cities (Imatra, Lappeenranta, Kotka, Vyborg) can potentially provide the transportation infrastructure for such a hub for travelling all around the world (Figure 2). The distance between St. Petersburg and Helsinki is about 450 km and personal travel by cars, buses and trains is usually (and reasonably) done within the radius of
450–500 kilometres. Besides, Helsinki, Lappeenranta, and St. Petersburg have airports, and Helsinki, Kotka, and St. Petersburg have seaports.

In order for this hub to function, an efficient transportation system within the region has to be formed. However, today the travelling in the region is complicated due to a number of reasons, e.g., unpredictable situation at border crossing, unknown traffic condition on the roads, isolation of train, bus, and airplane schedules. The proposed approach is aimed at support of dynamic configuration of virtual multimodal logistics networks based on user requirements and preferences. The main idea is to develop models and methods that would enable ad-hoc configuration of resources for multimodal logistics. They are planned to be based on dynamic optimisation of the route and transportation means and should take into account user preferences together with unexpected and unexpressed needs (on the basis of the profiling technology).

The proposed approach assumes developing a system for ad hoc generation of travel plans for the region (the South of Finland and St. Petersburg city) taking into account the current situation on the roads and border crossings, fuel management aspects, travel time and distance. The increase of travelling will be a significant step towards development of the integrated economic zone in the region.

**Figure 1** Generic scheme of the virtual tourist hub

![Generic scheme of the virtual tourist hub](image1)

**Figure 2** The South of Finland and St. Petersburg City (see online version for colours)

![Map of the South of Finland and St. Petersburg City](image2)
4 Reference model

The reference model of the proposed approach is based on the above described components (Figure 3). The trip planning service is in the centre of the model. It collaborates with the transportation planning services to find appropriate transportation means and schedules, and attraction visit planning services to coordinate transportation and attraction attendance schedules. These services, in turn, use the transport information services and the attraction information services, correspondingly, to acquire information about schedules, availabilities, occupancies, and prices of the related resources. The latter services can also be used by the tourist to decide preferable means of the transportation and attractions.

The trip schedule is generated based on the context of the current situation provided by the context management service. It can provide such information as weather, special events, etc. The services constitute a so called ‘smart space’, which is accessed by the tourist through his/her computer (when at home) or smartphone (when in the trip). The tourist’s preferences are stored in his/her profile and also taken into account during trip planning.

Figure 3 Virtual tourist hub for infomobility: the reference model

5 Approach

The main idea of the approach (Figure 4) is to represent the logistics and attraction service providers by sets of services offered by them. This makes it possible to replace the configuration of the tourist logistics system with that of distributed services. For the purpose of semantic interoperability, the services are represented by web-services using the common notation described by ontology. The agreement between the resources and the ontology is expressed through alignment of the descriptions of the services modelling the resource functionalities and the ontology. As a result of the alignment operation, the services get provided with semantics. The operation of the alignment is supported by a tool that identifies semantically similar words in the web-service descriptions and the ontology. In the proposed approach the formalism of object-oriented constraint networks
(OOCN) is used (detailed description presented by Smirnov et al., 2010) for knowledge representation in the ontology.

Depending on the problem considered, the relevant part of the ontology is selected to form an abstract context. The abstract context is an ontology-based model embedding the specification of problems to be solved. It is created by the special services incorporated in the environment. When the abstract context is filled with values from the sources, an operational context is built. The operational context is an instantiated abstract context and the real-time picture of the current situation. Producing the operational context is one of the purposes of resource configuration. Since the resources are represented by sets of services, the configuration of the resources is replaced with the appropriate services.

Figure 4  Generic scheme of the approach

Besides the operational context producing, the services are purposed to solve problems specified in the abstract context and to get the resources to take part in the trip plan. Due to the usage of the OOCN formalism, the operational context represents the constraint satisfaction problem that is used during organisation of services for a particular task.

It can be guessed that for each particular situation there can be a large amount of feasible solutions for the users to choose from (e.g., the fastest transportation, the least amount of transfers, sightseeing routes, etc.). As a result, building such a system as a group recommending system is proposed, because it can learn user preferences and recommend solutions, which better meet those preferences (see Smirnov et al., 2012a).
6 Group recommending system

Generation of feasible trip plans taking into account explicit and tacit preferences requires strong IT-based support of decision making so that the preferences from multiple users (accumulated in the system and/or obtained from social networks) could be taken into account (McCarthy et al., 2006; Wang et al., 2012; Zhang et al., 2012). Group recommending systems are aimed to solve this problem. Recommendation/recommending/recommender systems have been widely used in the internet for suggesting products, activities, etc. for a single user considering his/her interests and tastes (Garcia et al., 2009), in various business applications (e.g., Hornung et al., 2012; Zhena et al., 2009) as well as in product development (e.g., Moon et al., 2009; Chen et al., 2010).

However, development of group recommending system requires solving a number of problems. Below, the main problems (highlighted with italic) are arising during the design and usage of recommending systems for virtual tourist hub.

- **Context information usage for generating recommendations.** Recommending systems have to be context-oriented. This requires application of the context management technology together with ontology-based domain description. Usage of context management methods enables not only selection of information and knowledge most relevant and actual for a particular task and particular circumstances, but also decreasing the amount of information to be processed, and as a result simplifies the task solving.

- Usage of the context information continuously changes the circumstances of recommendation generation; this requires developing mechanisms of the self-organisation of the user groups (Flake et al., 2002). Development of clustering algorithms capable of continuous group improvement based on the incoming information updates enables implementation of the above mechanisms.

- Since the recommendation generation circumstances continuously change, mechanisms are required that would enable most complete reuse of existing information. Two-level domain modelling makes it possible to separate structural and parametric constituents of the domain description. The abstract domain description contains only the structure of the problem to be solved and can be often reused. The parametric domain description contains the actual data describing a particular situation.

- **Complex domain representation:** domain description based on the complex of multidisciplinary intelligent models integrated via a common domain ontology enables separation of the domain into simpler subtasks, as well as application of existing models, ontologies and methods for different aspects of the considered problems.

- **Integration of multidisciplinary models:** ontological description of the virtual tourist hub via common formalism makes it possible to avoid multiple information translation from one formalism to another one, as well as excessive problem formalisation during structural synthesis of multidisciplinary models.
Knowledge representation: virtual tourist hub representation on the basis of object-oriented constraint networks enables integration of the object-oriented information and knowledge representation with the technology of constraint satisfaction. Usage of standard solutions for the dynamic virtual tourist hub configuration increases the constraint satisfaction technology efficiency due to application of schemes based on the knowledge of these standard solutions (known basic structures of the virtual tourist hub).

Integration of information obtained from various sources: usage of the idea of smart space together with web-service standards provides for standardised and easily implementable information and knowledge exchange between different elements of the complex recommending system. Besides, virtualisation of the tourist hub elements and members based on the services enables replacement of the configuration of the virtual tourist hub with that of the service network.

7 Case study

7.1 General description

Recently, the individual tourism has become more and more popular. People travel around the world and visit museums and other places of interests. They are usually restricted in time but wish to see as many attractions as possible.

The overall scenario of the tourist hub usage is shown in Figure 5. Before the trip, the tourist configures the preliminary plan consisting of the list of attractions he/she would prefer to visit, and gets information about specifics of the country/region of the trip.

Figure 5 Tourist hub usage scenario
During the trip the tourists get updates of the actual trip plan and movement directions. If there is no appropriate public transport available, the corresponding service can call for a taxi.

After the trip, the tourist can leave his/her feedback and comments regarding the trip in social networks.

The Android-based mobile application has been developed based on Smart-M3 information sharing platform (Honkola et al., 2010) that makes possible to significantly simplify further development of the system, include new information sources and services, and make the system highly scalable. The key idea of this platform is that the formed smart space is device, domain, and vendor independent. Smart-M3 assumes that devices and software entities can publish their embedded information for other devices and software entities through simple, shared information brokers. Platform is open source and accessible for download at Sourceforge².

Implementation of the application has been developed using Java KPI library (http://sourceforge.net/projects/smartm3-javakpi/). Mobile clients are implemented using Android Java Development Kit (http://developer.android.com/sdk/index.html).

The application consists of a set of services (see Smirnov et al., 2014a) that interact with each other for providing the tourist recommendations about attraction to see around. There are client application, attraction information service, recommendation service (see Smirnov et al., 2014b), context service, ridesharing service (see Smirnov et al., 2012b), and public transport service (Figure 6).

Different entities of the system are interacting with each other through the smart space using the ontology. Each device has a part of this ontology and after connecting to smart space it shares a part of the own ontology with this space.

### 7.2 Recommendation service

To improve the quality of information presented to the tourist by the tourist recommendation system the list of attractions found by the attraction information service should be ordered with respect to a predicted degree of interestingness for the tourist as well as their reachability (taking into account the current situation in the area).

![Figure 6](image)

**Figure 6** General architecture of smart space-based tourist recommendation system (see online version for colours)
The attraction’s degree of interest is estimated by the recommendation service. The service takes tourist ratings associated with each attraction by all tourists as an input. According to the conventional classification (e.g., Balabanovic and Shoham, 1997), it performs a user-based collaborative filtering. One of the promising directions to improve the predictive quality of recommendation systems in general (and collaborative filtering systems among them) is context-awareness (Adomavicius et al., 2011). The context describes the conditions in which the tourist rates an object or asks for recommendations.

The main scheme of the recommendation process for tourist recommendation system in presented in Figure 7.

**Figure 7** The main scheme of recommendation process for tourist recommendation system

In the proposed tourist recommendation system the following context attributes are distinguished:

- **a** time
- **b** company in which the tourist visited the attraction (alone, with a friend or with the family)
- **c** weather (sunny, rainy, etc.).

Values are assigned to these attributes in mostly automated fashion. For example, the tourist opens the attraction evaluation screen being near to that particular attraction (according to the mobile device’s GPS sensor). In this case the time attribute is filled in with the current time and current weather is queried from the context service. However, there is also a possibility to set the values of context attributes manually in the evaluation screen of the mobile application. It is convenient, for example, if a tourist wants to rate the attractions seen during the day upon returning to the hotel in the evening. To facilitate deferred evaluation the proposed system tracks attractions the tourist visits and shows unrated visited attractions in a special screen. The tourist does not have to assign values to each context attribute. If a context attribute is not given a value, it is assumed to have value ‘any’.

There are three general approaches to take context into account in recommendation systems (Balabanovic and Shoham, 1997):

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**Ratings normalisation**

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**Definition group of tourists with similar interests**

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**Calculation attraction relevance based on other tourists ratings from the group**

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**Ranking attractions list based on the relevance and accessibility the attraction at the moment**

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**Preliminary stage**

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**Determination attraction relevance to the tourist**

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**Attractions ranking**

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a contextual pre-filtering
b contextual post-filtering
c contextual modelling.

The advantage of the contextual pre-filtering and post-filtering approaches is that they are compatible with classical (not context-aware) recommendation algorithms. The context awareness in these approaches comes true by transformation of either input or output of the classical recommendation algorithm. In the contextual pre-filtering approach, the rating data that is not related to the context is filtered out before applying the recommendation algorithm. On the other hand, in the contextual post-filtering approach the resulting list of recommendations is ordered or filtered taking into account the context values.

In the contextual pre-filtering approach all the ratings that are irrelevant to the context discarded from the rating matrix before the recommendation algorithm is applied. For example, if in some attraction recommendation service the context includes weather conditions, then making recommendations in a rainy day should not use ratings assigned in sunny days. This approach aggravates the important problem inherent to collaborative filtering systems – rating matrix sparsity. The main goal pursued by the contextual pre-filtering methods is to take into account the context, but not let rating matrix to become too sparse.

In the proposed system, the context generalisation method (one of the contextual pre-filtering methods) is used for taking context into account (Smirnov et al., 2014b).

A tourist rates attractions on a five-point scale (1 – bad, 5 – excellent). The rating obtained from the tourist (raw rating) is normalised to reduce individual bias in assessment: some tourists tend to put relatively high ratings to all attractions, others in contrary tend to put relatively low ratings. Normalised rating $\tilde{r}_{uj}$ given by tourist $u$ to attraction $j$ is defined by the formula:

$$\tilde{r}_{uj} = r_{uj} - \frac{1}{|K_u|+1}(3 + \sum_{i \in K_u} r_{ui})$$

here $r_{uj}$ is raw rating of the attraction $j$ given by tourist $u$, and $K_u$ is a set of all attractions rated by tourist $u$. The idea of normalisation is to shift from user-oriented five-point scale to calculations-oriented zero-centred scale. The sign of the normalised rating corresponds to general attitude of the tourist (whether it is positive or negative) and the absolute value of the rating corresponds to the strength of that attitude. The straightforward way to normalise ratings is to subtract scale average (i.e., ‘3’) from each rating. It would work nice if tourists normally used all the range of five-point scale. However, most tourists in fact rate items using some subset of the scale, e.g., only ‘3’, ‘4’ and ‘5’. In this case subtracting scale average would result in non-negative normalised ratings missing the fact that the tourist definitely likes items he/her rated ‘5’ and probably does not like items rated ‘3’. Hence, the normalisation procedure should capture not only the scale characteristics but also the observed usage of this scale. Therefore, a popular method of normalisation is subtracting average tourist rating from all his/her ratings. This method works well in most cases but have some subtle drawback, which turns out when there are only a few ratings. For example, when the tourist rated only two items – both with ‘5’ – then normalisation over the average tourist rating would turn these ratings into zeroes,
i.e., a priori notion of five-point scale with ‘5’ as the best mark is lost in favour of adaptation to the observed usage of this scale. To alleviate this drawback in the proposed system we use slightly modified version of the normalisation over the average tourist rating. During the normalisation we add one fake rating of ‘3’ (scale average) to the set of tourist ratings having a purpose to stick other ratings to the original notion of the scale. This modification is significant when there are a few ratings (in the example above two ‘5’ ratings become positive) but its contribution to the normalised ratings vanishes as the number of tourists’ ratings grows.

Attraction rating estimation for a given tourist is performed in two steps:
1 a group of tourists with ratings similar to the given tourist’s is determined
2 rating of attraction is estimated based on ratings of this attraction assigned by tourists of the group.

While building the list of recommendations, several possible generalisations of the context are used. For each context generalisation ratings received in the contexts incompatible with this generalisation are not taken into account.

Tourist group is determined by k-nearest neighbour method (kNN). The similarity between tourists \( u \) and \( v \) is calculated as a cosine measure between normalised ratings vectors of tourists according to the following formula:

\[
\tilde{r}_{uv} = r_{uv} - \frac{1}{|K_u| + 1} \left( 3 + \sum_{i \in K_u} r_{ik} \right).
\]

Here \( O \) is a set of attractions rated by both tourists \( u \) and \( v \).

Attraction rating estimation for the tourist is based on ratings of that attraction assigned by other tourists of the group with respect to their similarity to the tourist. It is calculated as a weighted average of normalised ratings among group members:

\[
r_{uv} = \frac{\sum_{w \in G} \tilde{r}_{uw} s_{uw}}{\sum_{w \in G} |K_w|},
\]

here \( G \) is the group of the tourist. The resulting list of attractions \( L \) presented to the tourist \( u \) is sorted in descending order of:

\[
s_j = k s_j + (1 - k) \left( 1 - \frac{d_j^w}{\max_{i \in L} d_i^w} \right),
\]

here \( k \in [0, 1] \) is a model parameter correlated to the importance of the attraction rating estimation in favour of its reachability; \( d_j^w \) is the estimated reaching time of the attraction \( j \).

7.3 Implementation

The tourist downloads software for getting intelligent tourist support. Installation of this software takes few minutes depending on operating system of the mobile device. When the tourist runs the system for the first time, his/her profile has to be completed. This
procedure takes not more than few minutes. The visitor can fill the profile or can use a default profile. In case of default profile, the system cannot propose preferred exhibitions to the visitor.

Figure 8 (left screenshot) shows the main application screen, where the tourist can see images extracted from the accessible internet sources around, clickable map with his/her location, context situation (weather), and the best attractions around ranked by the recommendation service. When the tourist clicks to an attraction the following context menu is opened (right screenshot). The tourist can see detailed information about the chosen attraction (Figure 8, left screenshot), browse attraction reaching path (Figure 8, right screenshot), and/or estimate it (Figure 8, left screenshot).

Figure 8  Tourist assistant screenshots: main screen, context menu with actions (see online version for colours)

Figure 9  Tourist assistant screenshots: attraction details and route to the attraction (see online version for colours)

Detailed information about attraction contains a list of images associated with this attraction and its description (see Figure 9, left screenshot). This information is extracted by the attraction information service from different internet sources (e.g., Wikipedia,
Wikivoyage and Panoramio are used at the moment). The tourist can browse the attraction reaching path by choosing ‘Show on the map’ item in context menu (see Figure 9, right screenshot). The routing service that is responsible for calculating attractions reaching path is based on developed OpenStreetMap-based web mapping service (Teslya, 2014). Routing service provides the tourist possibility to build pedestrian path, find fellow travellers who go to the same direction, and find public transport to reach the chosen attraction.

The tourist can browse information about the best attractions around presented by the mobile tourist guide in the main screen and click button ‘More’ to see more attractions (see left screenshot in Figure 10). The tourist can estimate an attraction as is interested or not by looking through its name and image. If he/she would like more information, it is possible to open the description window (Figure 10, left screenshot).

The tourist can estimate the attraction if he/she likes or dislikes it (see Figure 10, right screenshot). For this purposes he/she specifies the context (company and weather) and makes the estimation using five scale rating.

**Figure 10** Tourist assistant application screenshots: all attractions around and estimation attraction (see online version for colours)

By pressing ‘menu’ button guide application allows to search information for worldwide attractions by choosing another area (country, region and city) and access the settings page of the mobile tourist guide application. In the status bar, the tourist can search for attractions worldwide.

### 7.4 Evaluation

Response time of the internet services depends on the internet connection speed in the museum, number of people connected to the network, and workload of the services. Average response time should not exceed one second. The evaluated tourist assistant response time is not more that few seconds for every operation. For example, for the centre of St. Petersburg (Vasilyevsky Island area) recommendation of attractions use case takes about three seconds for the acquiring (2.9 sec), ranking (0.1 sec) and providing to the tourist up to 50 nearest attractions. The most of this time is spent on acquiring a list of
attractions nearby the tourist. In the considered example, the online Wikipedia is used as an information source. In case of using Wikipedia dump the time can be decreased.

The analysis of dependency of tourist assistant execution time based on number of tourists is shown in Figure 11. For the experiments, a test application has been developed that generates triples that describe tourists in smart space and calculates application response time.

**Figure 11** Application execution time dependency on number of tourists (see online version for colours)

8 Conclusions

The paper presents an approach, reference model, and case study for cyber-physical infomobility for tourism application for performing ad-hoc transportation scheduling based on the available schedules, current and foreseen availability and occupancy of the transportation means and services even though they do not cooperate with each other. The reference model is based on the services represented by web-services using the common notation described by an ontology. The agreement between the resources and the ontology is expressed through alignment of the descriptions of the services modelling the resource functionalities and the ontology. The developed application helps tourists to plan their attraction attending time and excursions depending on the contextual information about the current situation in the museums and tourists’ preferences, using their mobile devices. User profiles allow keeping important information about the visitor and using it in the smart space. Unlike existing systems, developed application allows monitoring the current situation in whole city or region and provides context-driven update of the travel plan ‘on-the-fly’.

For the future work a model for identifying a text block described attractions the tourist is interested in will be developed. This model has to be based on the text analysis methods and collaborative filtering techniques. The model will allow to provide the tourist the most interesting for him/her information related to the chosen attraction at the moment.
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References


Cyber-physical infomobility for tourism application


Notes
1 by 0.5 GtCO₂e (gigaton of carbon dioxide equivalent); combined with results of IEA Statistics in 10.4% of road transport or 7.5% of all transport.
2 Smart-M3 at Sourceforge, URL: http://sourceforge.net/projects/smart-m3.