Infomobility for "Car-Driver" Systems: Reference Model and Case Study

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Abstract. The proposed approach to infomobility is based on the concepts of cyber physical system and context-aware decision support. The “car-driver” system is considered as a collaborative cyber-physical system. Its dynamic nature is addressed via the context management technology. The context is modeled as a “problem situation.” It specifies domain knowledge describing the situation and problems to be solved in this situation. An application of these ideas is illustrated by an example of decision support for tourists travelling by car. In this example, the proposed system generates ad hoc travel plans and assists tourists in planning their attraction attending times depending on the context information about the current situation in the region and its foreseen development.

Keywords: cyber-physical system, infomobility, context-aware decision support, tourist trip planning & scheduling.

1 Introduction

Infomobility infrastructure plays an important role in attaining higher traffic and transport efficiency as well as higher quality levels in travel experience by the users. It can be defined as operation and service provision scheme whereby dynamic multi-modal information is selected, used and distributed to the users both pre-trip and, more importantly, on-trip [1]. The proposed approach to infomobility is based on the concepts of cyber physical system and context-aware decision support.

The application of the concept of cyber-physical system (CPS) could enable higher flexibility and sustainability of transportation systems. CPS tightly integrate physical systems and cyber (IT) systems based on interaction between these systems in real time. This is a relatively new research field demanding for new approaches and techniques. CPS rely on communication, computation and control infrastructures commonly consisting of several levels for both the physical and the IT-part with sensors, actuators, computational resources, services or communication facilities.

CPS are oriented to domain independent architectures and technologies for supporting cyber-physical artefacts and networks [2]. 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 [3].

A good recent state-of-the-art review of different CPS approaches and supporting technologies can be found in [4]. Among the other conclusions, Horvath and Gerritsen conclude that "the next-generation of CPSs will not emerge by aggregating many un-coordinated ideas and technologies in an incremental fashion. Instead, they will require a more organized and coordinated attack on the synergy problem, driven by an overarching view of what the future outcome should be".

Sharing information and services between different devices independently of their physical location is achieved via usage of the ubiquitous environment technology.

Current developments of in-vehicle information systems (e.g., Ford's AppLink, Chrysler's UConnect, Honda's HomeLink, etc.) make it possible to benefit from integration of new decision support methodologies into cars to provide richer driving experience and seamless integration of information from various sources.

Context-aware decision support is required in situations happening in dynamic, rapidly changing, and often unpredictable distributed environments such as, for example, roads. Such situations can be characterized by highly decentralized, up-to-date data sets coming from various information sources. The goals of context-aware support to operational decision making are to timely provide the decisions maker with up-to-date information, to assess the relevance of information & knowledge to a decision, and to gain insight in seeking and evaluating possible decision alternatives.

Context is any information that can be used to characterize the situation of the considered entity where an entity is a person, place, or object that is considered relevant to the interaction between a user (driver) and a system (service network), including the user and system themselves (adapted from [5]). The context is purposed to represent only relevant information and knowledge from the large amount of those. Relevance of information and knowledge is evaluated on a basis how they are related to a modelling of an ad hoc problem.

The theoretical fundamentals of the approach are built around ontologies. The ontologies are a widely accepted tool for modeling context information. They provide efficient facilities to represent application knowledge, and to make objects of the dynamic environments context-aware and interoperable.

The proposed fundamentals are supported by advanced intelligent technologies with their application to Web. The developed context-aware CPS has a service-oriented architecture. Such architecture facilitates the interactions of collaborating service components and the integration of new ones [6, 7, 8].

The rest of the paper is structured as follows. Section 2 proposes the reference model of the proposed CPS. Section 3 illustrates the application of the reference model in the area of tourism. Main research results are summarized in the conclusion.

2 Reference Model

As it was mentioned, the developed reference model relies on the Web-service technology. In this framework, the resources of the CPS are represented by Web-services. Each resource is characterized by a profile describing its capabilities. Due to the representation used a service network comprises Web-services representing resources which provide informational and computational services for information support.

Interaction between services requires interoperability at different levels. The interoperability at technical and syntactic levels is achieved via usage of the common enterprise service bus (e.g. OpenESB, fig. 1). The interoperability at the level of semantics is addressed via an ontology-driven approach. It assumes usage of common semantics and terminology described via ontologies. It is proposed to have one common high-level application ontology. It generalises knowledge from internal ontologies of participating services. The context is also represented in terms of the application ontology. It is updated depending on the information from the environment and as a result of services' activities in the community.

The ontology slice that describes a service at a certain point of time is its abstract context. It is formed automatically (or reused) applying ontology slicing and merging techniques [9] and updated depending on the information from the environment and as a result of the service's activity in the community. The purpose of the abstract context formation is to collect and integrate knowledge relevant to the current task (situation). The information sources defined in the abstract context provide the information that instantiates the context and forms the operational context. The operational context updates defines the behaviour of the service. The ability of a system (service network) to describe, use and adapt its behaviour to its context is referred to as self-contextualization [10]. The presented approach exploits the idea of self-contextualization to autonomously adapt behaviours of multiple services to the context of the car-driver system in order to provide support according to this context and to propose context-based decisions.

A concrete description of the current situation is formed, and the problem at hand is augmented with additional data. On the knowledge representation level, the operational context is a set of RDF triples to be added to the smart space by an appropriate service. Therefore, other services can discover these RDF triples and understand the current problem.

In [11] service *i* queries up-to-date information from the operational context through smart space in accordance with the task specified in the service's ontology. Services *j* and *n* are involved in solving a particular task. They form the operational context related to this task and based on the abstract contexts of the services. This operational context is described by the smart space service ontology, which also corresponds to the current task and integrates abstract contexts of the involved services.

The embedded Web-services generate a set of feasible solutions (plans) for the current situation. The set of plans is generated using the constraint satisfaction technology. A plan is a scheduled set of actions for the driver and services of CPS. An efficient plan is selected from the set and proposed to the driver for approval. If the plan is approved by the driver, the corresponding service community is organized to support the plan. Otherwise, another plan is taken up. The process of re-planning is an iterative process repeated until a plan that suits the driver's needs and preferences is found. The approved plan is thought to be the guide to actions of the driver and services of CPS.

The option of rejection is provided for two reasons. Firstly, the situation on a road is a rapidly changing one – something may happen between the moment when a plan is selected and time when the driver is making the decision. Secondly, not all driver's preferences could be taken into account correctly. In this case, when the driver rejects the plan, his/her preferences are re-calculated accordingly.

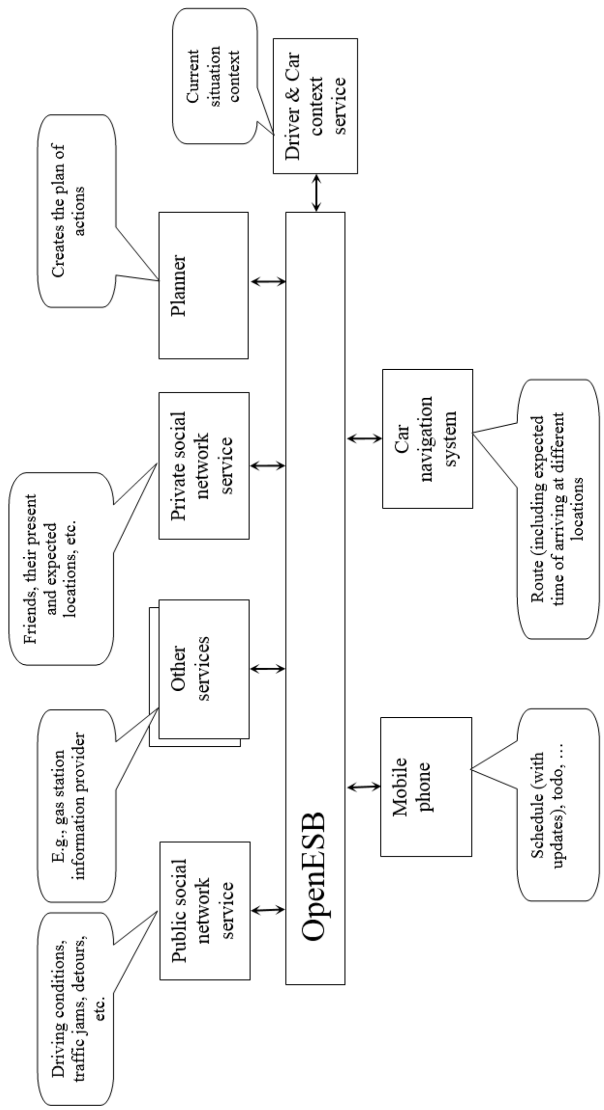

Fig. 1. Example services integrated via OpenESB

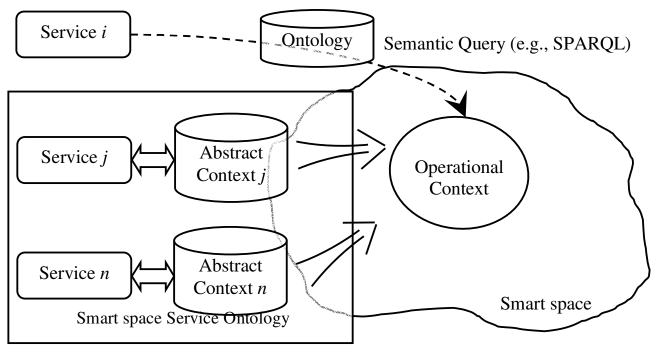

Fig. 2. Reference model of smart space-based service interaction for infomobility

In order for such system to operate efficiently, a number of issues are to be resolved. The proposed approach is aimed at coordinated design and run-time configuration of cyber physical human system integrating the car, driver and services, and incorporates some techniques and models in order to achieve this.

3 Case Study “Tourist Information Support”

Recently, the tourism business is getting more and more popular. People travel around the world and visit museums and other places of interests. They have a restricted amount of time and usually would like to see many museums. In this regard a system is needed, which would allow assisting visitors (using their mobile devices), in planning their museum attending time depending on the context information about the current situation in the museums (amount of visitors around exhibits, closed exhibits, reconstructions and other), traffic situation, and visitor’s preferences.

Mobile devices interact with each other through a smart space [11, 12] (a virtual space enabling devices to share information independntly of their locations) implemented via an open source software platform (Smart-M3) [13] that aims at providing a Semantic Web information sharing infrastructure between software entities and devices in the form of blackboard. In this platform, the ontology is represented via RDF triples (more than 1000 triples). Every visitor installs a smart space client to his/her mobile device. This client shares needed information with other mobile devices in the smart space. As a result, each mobile device can acquire only shared information from other mobile devices. When the visitor registers in the environment, his/her mobile device creates the visitor’s profile (which is stored in a cloud and contains long-term context information of the visitor such as his/her preferences). The information storage cloud (not computing, which is distributed among the services of the smart space) might belong to the system or be a public cloud. The only requirement is providing for the security of the stored personal data. The profile allows specifying visitor requirements in the smart space and personalizing the information and knowledge flow from the service to the visitor.

The tourist downloads software for getting intelligent tourist support. Installation of this software takes a few minutes depending on operating system of mobile device. When the tourist runs the system for the first time, the profile has to be completed. This procedure takes not more than 10 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.

The in-vehicle information system is also connected to the smart space (SS in Fig. 3) for a higher interaction level of decision support. For example, let us consider Ford's AppLink system. The AppLink provides the current user location and other car information to the operational context of the smart space automatically. Based on the operational context complemented with information from other sources, the attraction information service together with the recommendation service [14, 15] propose an attraction visiting plan and put it into the AppLink's in-car navigation system (Fig. 3).

Other services contributing to the creation of the operational context and involved in the scenario include: attraction information system (AIS) providing textual and multimedia information about the attractions, attraction recommendation service (RS) analysing appropriateness of attractions and points of interests to user preferences, croud sourcing service (CroudS) analysing feedback of other users with similar interests related to corresponding attractions and points of interests, motorway related information services (MSA), and car dealer service (CarS) monitoring the car condition, reminding about required servicing, etc. Any other services can also be connected to the smart space to enrich the decision support possibilities. For example, the car diagnostic system can perform firmware update while the user is visiting a museum if the expected museum vistitng time is longer than time required for the update.

The overall scenario of the case study is shown in Fig. 4. Though the scenario is shown as linear, in fact, it can be interactive and iterative if the user wishes to adjust generated solution via adding additional constraints or preferences.

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. During the trip the tourists gets updates of the actual trip plan and driving directions (including re-fueling, eating, etc.). The current situation information includes current attraction occupancies, traffic, car gas level, etc. After the trip, the tourist can leave his/her feedback and comments regarding the trip in social networks.

An example of the attraction visiting plan is presented in Fig. 5. The tourist starts from the Astoria hotel at 11:52, visits the State Hermitage, the Museum of History of Karl May Gymnasium (with a guided tour starting at 17:00), and finally returns back to the Astoria hotel. The expected travel time from Astoria to the State Hermitage based on the current traffic (provided by Yandex.Traffic service of Yandex.ru, the biggest Russian Internet company) is about 5 minutes. Since the guided tour at the Museum of History of Karl May Gymnasium starts at 17:00, and the expected travel time from the State Hermitage to the Museum of History of Karl May Gymnasium based on accumulated traffic statistics is 15 minutes, the driver is suggested to leave the State Hermitage at 16:35.

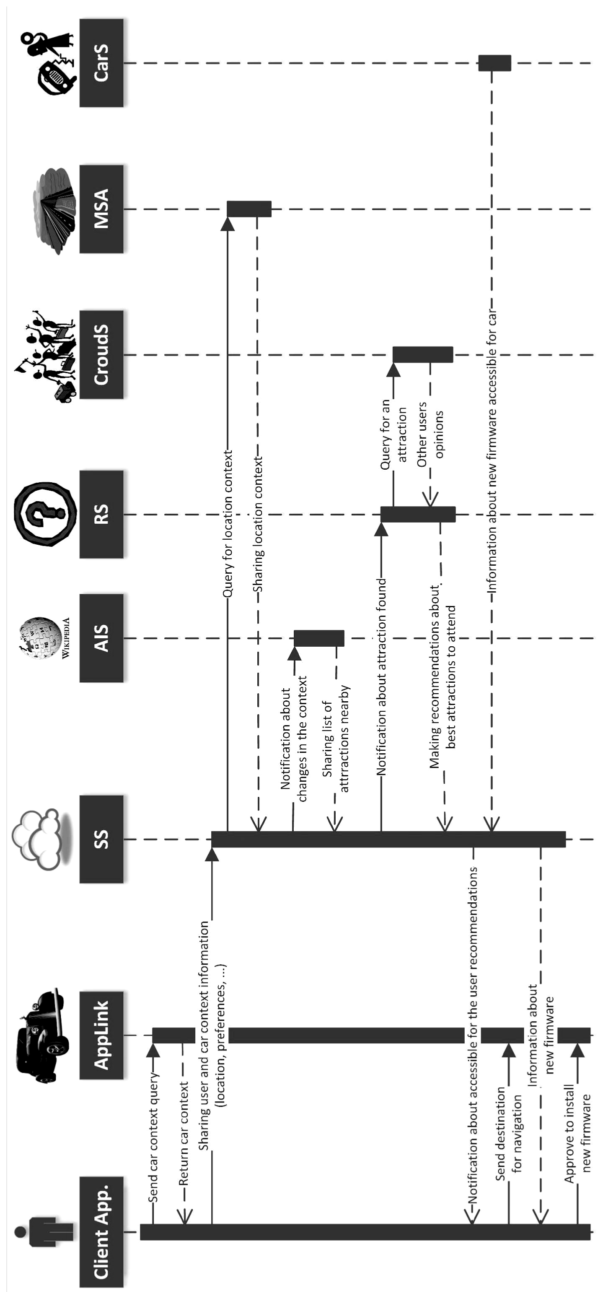

Fig. 3. Service interaction

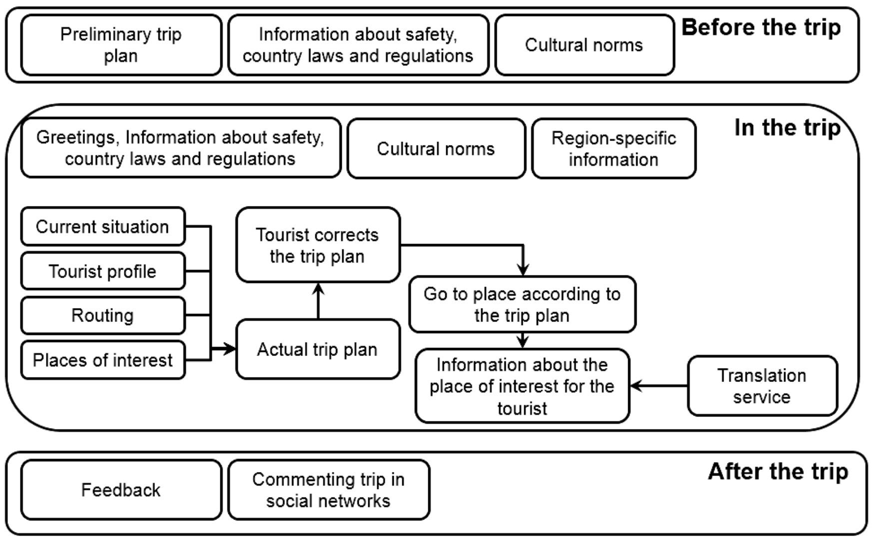

Fig. 4. Overall case study scenario

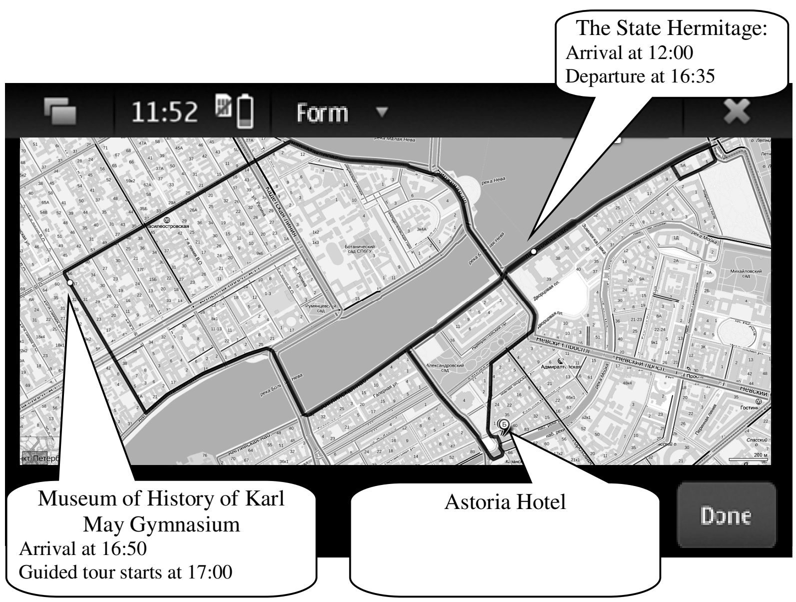

Fig. 5. A sample of attraction visiting plan at the center of St. Petersburg

4 Conclusion

The paper presents the concept, main supporting technologies and an illustrative case study for CPS enabling infomobility. Unlike existing navigation or trip planning applications the developed system implements usage of context information from different sources (Internet resources, car information, user mobile device), integrates with car on-board information system, doesn’t transfer private information into a public cloud. The key idea is to implement context-aware service-based CPS, which could provide a new, previously unavailable level of personalized on-board information support via finding decisions taking into account the context of the current situation and driver’s preferences. The users of the system will have up-to-date personalized support of their trip based on the current situation and taking into account its various aspects from traffic jams and attraction occupancies to gas level in the car and required car servicing.

For illustrative purposes, the methodology is implemented in a decision support system for tourists visiting attractions by car. The system helps tourists to plan their attraction attending time depending on the context information about the current situation in the region, its foreseen development and tourists’ preferences, using their mobile devices and in-car information systems.

At the moment, if the user wishes to adjust generated solutions via adding additional constraints or preferences the solutions will have to be generated from scratch (only the context is reused). Future work will address incremental solution adaptation via iterative interaction with the user based on planning models (e.g., opportunistic planning [16]).

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