Analysis of Service-Oriented Infomobility System and Architecture Model

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Abstract: This paper examines the development of a method and a model for building a service-oriented information mobility system that improves the quality of user service by using open data and services in travel planning, taking into account the formulated requirements, the semantic operability of the services and changes in their behavior depending on alterations in the system. In contrast to existing systems, a multimodal route planning method for local, regional, national and international trips with public and personal transport has been developed, which uses the methods of set theory, ontology management, context management, system analysis, privacy protection, geosearch and recommendation generation, with the ability to merge applications.

1 INTRODUCTION

In the course of analyzing the problems of road infrastructure development, scientists have derived the concept of comfortable living. One of the characteristics is the ability to move comfortably. It can be concluded that a developed transport network and the presence of convenient pedestrian infrastructure are essential components (Adomavicius et al., 2005). To improve the efficiency of urban transport planning management, a comprehensive analysis of the existing transport network is required, which includes all available modes of transport and the existing road infrastructure. The mix of modes of transport used in a city largely depends on its size and characteristics. For a small town, the choice of modes of transport is usually not a particular problem. Most of the needs of city dwellers can be met by individual transportation - on foot, by bicycle or by car. For cities with a low level of motorization or with a large number of inhabitants, public transport services must be developed. Thus, small cities with a high level of motorization are the only place where a unimodal car-road system supplemented by pedestrian infrastructure can be considered adequate and efficient. As the size of the city increases, so does the need for public transport, which has a significant load capacity. At the same time, a number of problems arise related to the use of cars within the city, excessive consumption of available territorial resources and negative externalities. Therefore, such cities should introduce a balanced transport system.

The goal of this work is to build a service-oriented infomobility system that provides users with access to multimodal, dynamic, personalized information, tailored to context services, to increase the mobility and ease of movement of users when planning a trip and during travel. To provide knowledge, based on a conceptualization that includes a description of a set of objects and concepts, knowledge and relationships between them, based on the use of services as sources of information and the way they are processed. The approach is based on the following principles arising from the requirements: openness of data and services, use of ontologies, distributed architecture, user orientation, use of contextual information, self-contextualization of services, real-time operation, multimodality of routes, information privacy for the user. Following these principles will satisfy the basic requirements and provide the user with quality services to ensure their mobility.

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2 RESEARCH AND PROJECTS IN THE FIELD OF INFOMOBILITY

Navitime is a mobile navigation service available in Japan (Arikawa et al., 2007). Navitime provides users with route calculation and guidance services by integrating several modes of transportation: walking routes, personal vehicles, trains, taxis and airplanes. Navitime combines mobility information provided by disparate data sources by converting it into four common formats. The publicly available documentation makes no direct reference to Navitime's adherence to existing mobility information storage and exchange standards.

The iTransit Integration Environment is the foundation for a multi-layered intelligent system architecture designed to integrate modern and traditional intelligent transportation vehicles (Brennan and Meier, 2007). It is based on a layered object data model. The model contains the spatial and temporal aspects of transport and traffic data and is a unified mechanism for querying and processing information from heterogeneous transport systems. It also includes global information layers containing the region's geography and transportation network. Data exchange between the systems making up the iTransit architecture is based on the use of CORBA technology and web services.

Xiang (Xiang et al., 2007a; Xiang et al., 2007b) describes the design principles adopted to implement the Information System for passengers on highways in China. The HTIS architecture is aimed at providing an environment that enables the interaction between distributed heterogeneous systems. The focus of contextual information collection is on highway monitoring and control information, while end-user-focused contextual elements (e.g., location, activity, etc.) are not considered. The emphasis is on the integration model of heterogeneous and distributed information systems based on multi-level architecture, common protocols and data formats.

Arktrans is the environment for multimodal intelligent transport systems in Norway (Natvig and Westerheim, 2007). Its aim is to create a common perspective on the transport problem area for all modes of transport (road, sea, rail and air) in terms of standard functions and interfaces for interaction between different transport systems. The operation of the system is aimed at assisting users in planning a trip, while the integration of the navigation service is not realized.

Lol@, the local assistant, is a prototype UMTS guide developed as part of a joint project at the Vienna Research Center for Telecommunications (Umlauft et al., 2002). Lol@ is a location-based travel service that implements SIP (Session Initiation Protocol) and the OCA/Parlay standards. It provides tourists with navigation services for predetermined routes. Lol@ uses different positioning methods: GPS, mobile network based and manual location input by users.

The main disadvantage of the described services is the incomplete geographical coverage. Although general maps are available worldwide, their details and the list of services provided vary greatly by region. For example, CIS and Asian users do not have access to many events on the map (only traffic is shown), not all cities have a traffic schedule, or not all available transport is covered. This situation is due to the fact that both services use third-party services to obtain additional information, and data processing for their own services is carried out in a semi-automatic mode (Verma et al., 2012).

3 A CONCEPTUAL MODEL OF A SERVICE-ORIENTED INFOMOBILITY SYSTEM

In order to develop an infomobility system, the following requirements can be defined that its architecture must meet: support of a heterogeneous environment of mobile devices; scalability; addition of new elements that provide new functions and are available to a wide range of users; free interaction; in the development of the system, ontology must be used, which provides the following advantages: it makes the system interoperable, reduces the development complexity associated with the variety of technologies used, and facilitates the interaction between people and computer systems; services must be accessible through various wireless technologies such as wireless LAN or Bluetooth.

The developed system should be focused on: the use of open data, an open information system including transport services, that provide information depending on the user's location (weather, attractions), information sharing mechanisms and mechanisms to ensure semantic interoperability. This requirement also defines the use of a distributed architecture to organize the cooperation of services. This approach makes it possible to support a wide variety of devices and information services. The addition of new functionality is carried out by starting a new service, without the need for a substantial redesign of the system. It is also necessary to support the planning of routes compatible with different vehicles and for individual modes of transport, as well as to ensure, if necessary, a change of modes of transport during the route (Xiang et al., 2007a; Yudenok and Krinkin, 2012).

User preferences can be set by creating a user profile that reflects the basic characteristics inherent to the user. Thanks to the use of smart spaces technology, it is possible to define a user profile in the form of an ontology.

The system must provide real-time information and support (traffic information, timely detection of traffic jams, search for objects on a map, up-to-date information on how objects work).

In the process of operation, the infomobility system must take into account the current situation in order to provide support options that are most suitable for the user at a given moment. For example: recommending objects on the map depending on the time (it is better to visit the park in sunny weather and wait out the rain in the nearest cafe, which has many positive reviews).

Unlike the centralized architecture, the distributed one introduces additional tasks related to ensuring the security of users' personal information. The advantage of a centralized infrastructure is that all information is processed in a single, self-contained environment. This allows to create a secure channel through which all processed information will be transmitted without leaving the environment. All users are isolated from each other, which prevents unauthorized access to their personal data. In the case of a distributed architecture, it is necessary to send and collect data for several services at once, some of which may be provided by a third party (for example, collecting photos of given coordinates). In this regard, it is necessary to further develop mechanisms to ensure the safety of the users personal.

4 MODEL OF SERVICE-ORIENTED INFOMOBILITY SYSTEM (SOIS)

As a result of the analysis of publications on infomobility systems, the main needs of potential users of the developed system were also identified. The performed analysis made it possible to formulate typical user situations for working with the system, united in a general model of SOIS (Figure 1). Individual situations can be grouped into three large groups:

1) Route planning. The system performs route planning, if necessary, combining several modes of transport while following the route, taking into account the schedule of public transport and providing the possibility of joint trips with private vehicles. This allows to reduce the waiting time at the transfer points and to plan the route in real time.

2) Search for objects. The system provides information support to the user when planning a route between objects on the ground. In addition to the route, the user is provided with context-sensitive recommendations for the nearest points of interest, ranked based on feedback from other users using collaborative filtering.

3) Visualization of the context. The user's device displays information about the current situation around him: the current time, the location of the means of transport on the routes of public transport, traffic jams and others.

Each work situation requires the use of several services, which allows the large task to be divided into component parts that are executed in parallel. Context visualization involves gathering information about the current situation from open data sources and displaying the gathered information on the user's device. It may include: temperature and weather conditions that provide weather information depending on the specified location, object list, context update notification, user service, object search service, recommendation generation service, search service for site information, route planning service, service interaction space, additional site information, routes to sites, site ratings, current road network status, road events, location of vehicles on public transport routes. In formalizing knowledge about the problem domain of the service described by the proposed ontology, the means of object-oriented constraint networks are used (Levashova et al., 2021). In accordance with this formalism, an ontology (A) is represented in the following form:

$$A = \langle O, Q, D, R \rangle, \quad (1)$$

where O is the set of classes representing objects; Q is a set of class attributes in which there are three subgroups that describe: parameters of the physical environment $P = p_1, ..., p_n$; results of information processing and other information components, $V = v_1, ..., v_m$; user social characteristics $S = s_1, ..., s_l, n, m, l \in \mathbb{N}$, where $Q = P, V, S; D$ is a set of domains, regions of valid attribute values; R is a set of relations by which classes are related. Relationships describe: class taxonomy, class hierarchy, inheritance, properties, etc. When forming the abstract context of the current situation, from the sets in the ontology, corresponding subsets are formed, which include only those elements of the original that are used to describe the current situation. At the same time, in an ontological model, many services are

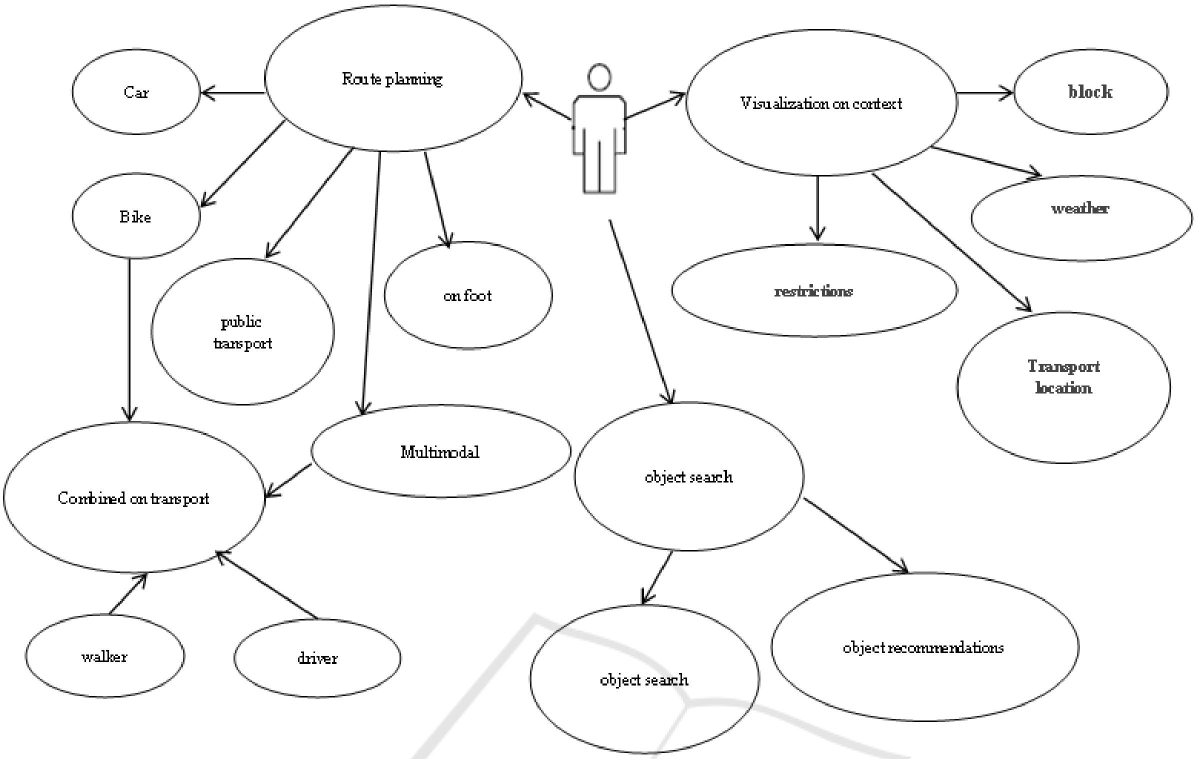

Figure 1: Situation model diagram.

added that can provide knowledge and information to form the context and services capable of performing certain actions with the existing knowledge and information. Thus, an abstract context can be expressed as:

$$Context_{abs}(C, T_{abs}) = \langle O_{abs}, Q_{abs}, D_{abs}, R_{abs}, WS_{abs}, T_{abs} \rangle, \quad (2)$$

where C is the simulated situation; $O_{abs} \subseteq O$ is the set of classes needed in the first case to simulate situation S; $Q_{abs} \subseteq Q$ is the set of attributes of class O_{abs}; $D_{abs} \subseteq D$ is a set of domains Q_{abs}; $R_{abs} \subseteq R$ is the set of constraints involved in an abstract context; WS_{abs} is a set of web services that model information resource functions that assign values to attributes Q_{abs} and can perform processing of available information, $W_aS_{bs} \subseteq WS$, where WS is the set of registered web services; T_{abs} is the predicted model adequacy time. In order to be able to obtain information about the current situation involved in the system, relationships are established between ontologies and sources indicating from where the corresponding property values of an object can be obtained. As information is received from other services, values and attributes are assigned to the classes of the abstract context and the formation of the operational context. The operational context $Context_{top}$ is a model of the current situation described by an abstract context $Context_{abs}$, with attribute values Q_{abs}. This model can be interpreted as a problem for the constraint satisfactio. The application context model is represented as:

$$Context_{top}(C, t) = \langle O_{op}, Q_{op}, D_{op}, R_{op}, WS_{op}, T_{op}, \delta T \rangle, \quad (3)$$

where t is the current time.

For the context of the user and the multimodal travel planning service, which are part of the infomobility system, an ontology that most fully meets the specifics of the relevant problem area has been developed. In this way, the general ontology of the system for each situation, if necessary, can be composed of private ontologies of services formed taking into account the current situation. In addition, a description of the ontology used on user devices to provide information to system services is given.

5 USER CONTEXT ONTOLOGY AND MULTIMODAL TRAVEL PLANNING SERVICE

With the help of the user context in the infomobility system, its main characteristics and the state of the environment are described. This information is used by system services to provide personalized support based on the current situation (Figure 2).

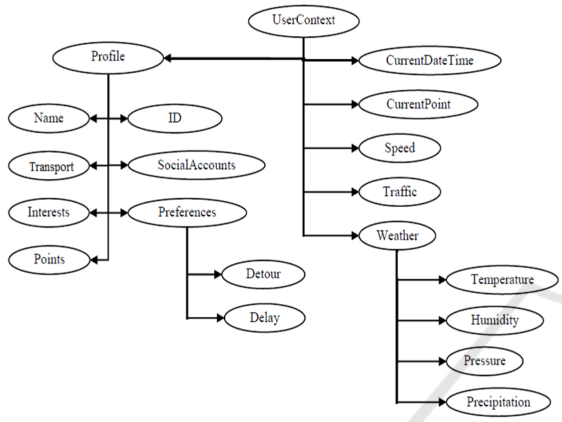

Figure 2: User Context Ontology.

It consists of two parts: information provided by the user himself, his profile (name, preferences, car ownership, key locations on the map, etc.) and automatically collected information about the environment (current location, traffic speed, weather, etc..).

User context includes attributes obtained from the sensors of the user's devices and from the information provider's services.

The problem area of the route planning service covers tasks related to the use of map, time and personal information for route planning with different modes of transport. In this regard, the ontology of this service should consider objects related to the representation of map information, vehicle schedule information, vehicle characteristics, and user characteristics figure 3.

6 INFOMOBILITY SYSTEM ARCHITECTURE

The architecture of the infomobility system is shown in Figure 4. According to the developed model, a service-oriented approach was used to build the architecture. The sources and processors of information and knowledge are the services installed on the user's devices and on the servers that ensure the operation of

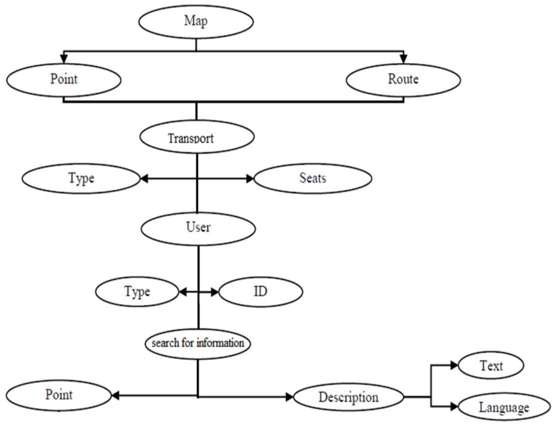

Figure 3: Map Context Ontology.

the infomobility system. The interaction of services is carried out through the "blackboard" architectural model, implemented based on intelligent space technology (Hu et al., 2005; Hu et al., 2008).

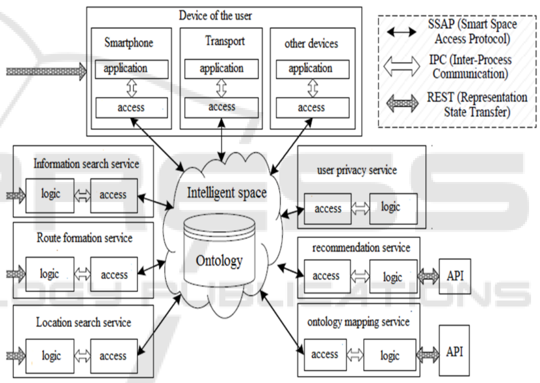

Figure 4: Service Oriented Architecture

7 CONCLUSIONS

In this work, the authors have proposed an approach to building an infomobility system based on the use of services as sources of information and knowledge. The approach is based on the following requirements: openness of data and services, use of ontologies, distributed architecture, user orientation, use of contextual information, self-contextualization of services, real-time operation, multimodality of routes, user information privacy. Following these principles will satisfy the basic requirements and provide the user with quality services to ensure their mobility. One of the main advantages of an ontology is its reusability. Self-contextualization of services is based on this, i.e., the ability to self-describe and change the context, which can be changed by expanding the ontology by including new concepts in it or narrowed by excluding unnecessary ones. For each service, an ontology is defined that most fully describes the relevant subject area. Services can change the knowledge description model to better fit the current situation, allowing them to respond adequately to its change. The method used to build the core services of the infomobility system is to be presented in the future.

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