Computer Standards & Interfaces 47 (2016) 108–119

Contents lists available at ScienceDirect

Computer Standards & Interfaces

journal homepage: www.elsevier.com/locate/csi

A methodology for structured ontology construction applied to intelligent transportation systems

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ARTICLE INFO

Article history:
Received 9 April 2015
Received in revised form 30 September 2015
Accepted 6 October 2015
Available online 17 October 2015

Keywords:
Intelligent transportation systems
Ontology
Collaboration
Distributed systems
Statistical data analysis

ABSTRACT

The number of computers installed in urban and transport networks has grown tremendously in recent years, also the local processing capabilities and digital networking currently available. However, the heterogeneity of existing equipment in the field of ITS (Intelligent Transportation Systems) and the large volume of information they handle, greatly hinder the interoperability of the equipment and the design of cooperative applications between devices currently installed in urban networks. While the dynamic discovery of information, composition and invocation of services through intelligent agents are a potential solution to these problems, all these technologies require intelligent management of information flows. In particular, it is necessary to wean these information flows of the technologies used, enabling universal interoperability between computers, regardless of the context in which they are located. The main objective of this paper is to propose a systematic methodology to create ontologies, using methods such as a semantic clustering algorithms for retrieval and representation of information. Using the proposed methodology, an ontology will be developed in the ITS domain. This ontology will serve as the basis of semantic information to a SS (Semantic Service) that allows the connection of new equipment to an urban network. The SS uses the CORBA standard as distributed communication architecture.

1. Introduction

The real-time estimation of traffic parameters and the control operations constitute a challenge for control of urban traffic systems [4]. Until now, the equipments installed in urban networks usually work in a centralized way, providing information to the traffic control center through the urban data network and performing actions according to the decisions of an operator at the control center. However, the enhancements of transport equipments due to the evolution of electronics and data networks allow them to share information and work cooperatively. The main challenge in the design and operation of ITS is information exchange, which is a difficult task in highly distributed systems. From a technical standpoint, there are difficulties in integrating information using compliant standards and connecting multiple systems, especially when considering the complexity and volume of information flows involved in the field of ITS, where both, the hardware as the data generated are highly heterogeneous [49]. Therefore it is necessary to optimize the interoperability, security and efficiency of processes and devices which are part of the ITS by developing new technologies. More specifically, it is necessary to analyze the needs of the transport and logistics from a multimodal perspective, and to design new systems and tools able to provide "higher intelligence" in the process of information exchange and interoperability between devices. Distributed systems are well known for their difficulty of interoperation among agents, which justifies the interest in unified software platforms [51]. SOA (Service-Oriented Architecture) is presented as an attractive alternative to enable interoperability of systems and the reuse of resources. But SOA applications face many security problems during design and development [37]. In SOA architectures, the WS (Web Services) are a commonly used technology. WS use SOAP (Simple Object Access Protocol) as the communication protocol between various services. SOAP is an XML-based protocol. However, processing large SOAP messages significantly reduces system performance, causing bottlenecks in comparison with other technologies like CORBA [46]. This represents a problem in wireless communication networks [35] and in the ITS field, where the number of connected devices is growing over time. In practice, SOA-based applications are not always successful as most of them are done on an ad-hoc basis, and primarily based on personal experiences [23]. Although companies are increasing their dependence towards SOA, these systems are still in an immature early stage with important security problems [25]. The common problem in all the mentioned technologies is the interoperability between services and devices that are part of ITS, due to the differences in the information representation and semantics. The use of ontologies in this field would be a solution to enable reuse of domain knowledge and to generate smart clients. Agents that

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http://dx.doi.org/10.1016/j.csi.2015.10.002
0920-5489/

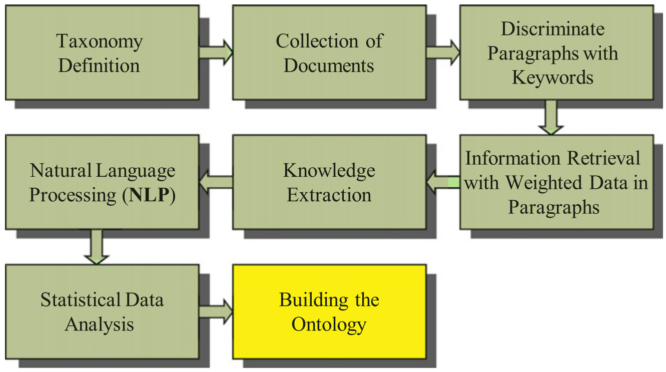

Fig. 1. Block diagram: proposed methodology.

share semantic information could use this ontological information to respond to requests DD (Device–Device), serve as input to other services, enable reuse of domain knowledge or work cooperatively with other existing ontologies.

A methodology to define an ontology in the field of ITS is proposed. The ontology will be used in a CORBA-compliant Semantic Service, which allows finding services in a distributed environment. The developed ontology will serve as initial DataBase to the intelligent system of semantic management, where the hardware devices can exchange information through a communication system and work cooperatively. Section 2 provides an overview of previous related work. In Section 3, the proposed methodology is introduced, using as a starting point Systematic Literature Review (SLR) techniques, and then applying semantic analysis techniques and statistical data analysis to build the ITS ontology. Section 4 details the obtained results with the proposed methodology, testing the resulting ontology in a CORBA distributed environment. Finally, Section 5 shows the conclusions and future work.

2. Related work

One of the main challenges in the ITS is the cooperative traffic. The idea of cooperation within ITS was initiated by the concept of cooperative in automated highways where vehicles receive input signals from the road environment. The first ideas documented on automated highways were presented in 1960 by the research laboratory of the General Motors [19]. A cooperative traffic system makes use of data as soon as they are collected, automating decision making in situations that require the intelligent intervention of ITS environment. Soares et al. [44] present a strategy in data dissemination for cooperative systems, defending that diffusion policies plays a determining role in the spread of ITS for the efficient information propagation. Indeed, the main objective of the cooperative driving is to focus on prevention and early detection of risks. However, this study does not specify how to find or maintain information. Rockl and Robertson [41] argue that the success of cooperative ITS applications is mainly affected by the exchange of information between distributed nodes. According to authors, the transmission of large amount of information contrasts to the limited bandwidth of the channels that tend to be shared by all nodes participating in the ITS. But the extraction and interpretation of the information is out of the scope of the study. Therefore, it is necessary to develop efficient heterogeneous alternatives to increase the effective capacity of the ITS and to improve the efficiency of the transport systems. The solution lies mainly in the cooperative commitment to select relevant pieces of information for dissemination according to their value.

With the increasing development of electronics and the possibility of using embedded systems with increasing processing capabilities, the concept of cooperation has been extended from the original idea of cooperative driving to the current ITS distributed systems. The main idea of cooperation in ITS distributed systems is based on the collaboration of vehicle driving with available services in urban, suburban, metropolitan and rural areas, where vehicles interact with the environment, and the environment itself acts intelligently based on traffic events. Mitropoulos et al. [33] presented a system called WILLWARN (Wireless Local Danger Warning) based on recent and future trends in cooperative driving allowing electronic security to prevent risks through "Vehicle-Hazard" detection applications on-board, V2V (Vehicle to Vehicle) and V2I (Vehicle to Infrastructure) communications. One of the main causes of road accidents is the excessive and slow reaction of the driver in critical situations. However, the system proposed by Mitropoulos is exclusively focused on managing messages alerting the driver of the danger in ad-hoc basis, ignoring the quality and presentation of information.

Thomas and van Berkum [48] proposed a prediction scheme for recurring traffic events based on data collected at urban intersections. They argue that it is necessary the management of events on demand in case of possible incidents, but they do not validate the results of the analysis with real data of incident detection, and they do not define how the information is collected, shown or stored. The main challenges in current ITS distributed architectures, where information plays an important role, are the heterogeneity of software, hardware devices, and communication networks. In the case of hardware devices it is usual the incompatibility in the data representation, the problems of synchronization and the wide variety of controllers and processors. Software applications and services have problems caused by the existence of multiple programming languages, different versions of the same application or service, the competition between proprietary and free/open source software as well as problems of understanding and distributed DataBases complexity. Finally, heterogeneity in communication networks is mainly due to the wide variety of network protocols, and the deployment of distributed networks, in some cases incompatible with traditional networks.

To overcome these drawbacks, ontologies can be an important issue in the future of ITS. One of the main advantages of the integration of ontologies in ITS is the intelligent and secure semantic location of services with certain characteristics and properties. From the point of view of interoperability between devices from different vendors and platforms, the most striking advantage is the intelligent information retrieval. Services can be published in descriptive ontologies and devices can make use of data and metadata from different kinds of runtime traffic events. While more structured is the services information, more accurate, fast and smart they can be found. Metadata can provide some semantics to this problem since ontologies provide a conceptual framework to exploit through metadata exchange schemes. Numerous previous studies have made use of metadata to improve implementation of collaborative applications in different scenarios. García et al. [18] present a context model based on an ontology which takes a combined approach to model the context information used by transport services.

The modeled distributed information is related to a primary context about the location, time, identity and quality of services, but applied only to a service for location of parking spaces. Thanks to the proposed scenario, they demonstrate that context information generated from autonomous distributed sources can be represented using a common

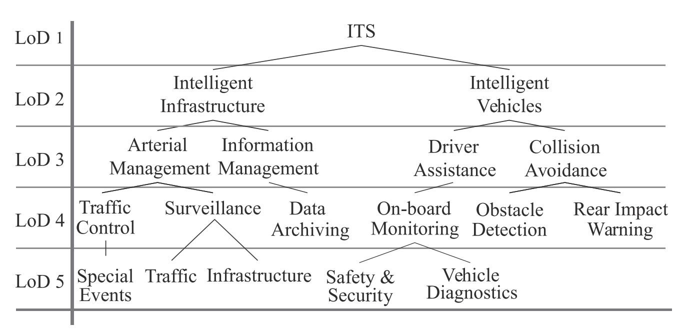

Fig. 2. Part of RITA U.S. DoT taxonomy (until LoD 5).