Journal of Network and Computer Applications 42 (2014) 178–188

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

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

# Vitruvius: An expert system for vehicle sensor tracking and managing application generation

Guillermo Cueva-Fernandez *, Jordán Pascual Espada, Vicente García-Díaz, Cristian González García, Nestor Garcia-Fernandez

*Department of Computer Science, University of Oviedo, c/Calvo Sotelo s/n, 33007 Oviedo, Asturias, Spain*

ARTICLE INFO

*Article history:*
Received 16 October 2013
Received in revised form
18 January 2014
Accepted 24 February 2014
Available online 29 March 2014

*Keywords:*
Internet of Things
Vehicle sensor
Application generation
Web application
Tracking
Domain-specific language

ABSTRACT

Internet of Things promotes the use of physical intelligent connecting objects to automatize processes and tasks in multiple areas of society. There are numerous intelligent objects with different sensors and communication mechanisms. Today, road vehicles contain many advanced sensors that allow the collection of great amounts of parameters. With an appropriate communication mechanism, vehicles can be converted to intelligent objects capable of forming very useful systems such as road security, vehicle maintenance, urban mobility, traffic congestion, fleet management, $CO_2$ emissions, etc. The problem is that the implementation of a system is not quick or easy. Many subsystems and heterogeneous elements intervene. The lack of speed in the development can be a big inconvenient, especially when the environment is as dynamic as traffic, subject to many variables. Currently, there are several platforms that integrate intelligent objects and the generation of applications, but none of them are focused on road vehicles. In this paper we present Vitruvius, a platform where users with no programming knowledge can design and quickly implement rich web applications based on the data consumption in real time from interconnected vehicles and sensors.



## 1. Introduction

Internet of Things (IoT) is a paradigm that promotes the utilization of intelligent physical objects that communicate autonomously among them to realize certain tasks. Currently, the systems encompassed by IoT are applied to many society areas such as Smart homes, Smart cities, industry, medicine, food processing traceability, logistics (Kortuem et al., 2010; Miorandi et al., 2012), intelligent electric appliances, domotic elements, energy consumption, health parameter monitors (Turcu and Turcu, 2013), etc. Technological advances in sensors, embedded systems and communication networks are helping with the consolidation of these kinds of systems.

The intelligent objects that form part of the IoT systems are physical objects that are composed of a digital part that normally has an embedded system equipped with sensors and some kind of communication module, usually Wi-Fi (Tozlu et al., 2012), Bluetooth or IrDA.

Sensors play a very important role on intelligent objects since they are capable of obtaining information from the real world (Gungor et al., 2010). The information obtained can be very useful to optimize resources of processes and tasks. IoT systems based on sensors have gained popularity during recent years. Generally, these intelligent objects with sensors or sensor networks are installed in fixed locations to obtain data from the surrounding environment such as monitoring parking spaces, traffic conditions, weather, etc. (Noury et al., 2000).

However, not all the sensors are installed to satisfy the objectives of a specific system. Some sensors that have been included in complex objects such as vehicles where initially intended to monitor the behavior of the vehicle locally and to participate in IoT systems. Modern vehicles equip a large number of sensors that can be accessed through the On Board Diagnosis (OBD) port. The OBD port allows access to the values of multiple sensors in vehicles such as oxygen sensors, engine load, consumption, coolant temperature, etc. The OBD2[1] is a standard implemented in all the passenger road vehicles in the EU and the USA. Although OBD2 has a common standard interface with several sensors, manufacturers have been adding many more specific sensors to vehicles.

* Corresponding author.
*E-mail address:* cuevafdz@gmail.com (G. Cueva-Fernandez).

http://dx.doi.org/10.1016/j.jnca.2014.02.013
1084-8045/

[1] The first generation of OBD systems for vehicle diagnostics has emerged in 1981 and since each manufacturer developed its own system, there was a lack of standardization. Later, the Environmental Protection Agency (EPA) established a standard known as OBD2, a.k.a. OBD II, Global OBD II or Generic OBD II.

Today many computer systems use data obtained from road vehicles high quality sensors, converting vehicles into mobile intelligent objects, which can be useful to collaborate in vehicle-based systems (e.g., security, vehicle and road maintenance, urban mobility, traffic management, emission control etc.).

IoT systems usually combine several software applications to manage and process data obtained from intelligent objects (Kawsar and Nakajima, 2009; Baglietto et al., 2011). The information can be very valuable when analyzed and shared for a specific task such as detecting hazard scenarios, changing a route or make consumptions suggestions. However, the design of most IoT systems and the implementation of application and services is not a simple task, generally requiring the combination of several communicating technologies, protocols, programing languages and services (Castellani et al., 2010; Palattella et al., 2013). IoT systems are very heterogeneous and require integration between their components or objects to achieve their objective (Espada et al., 2011).

For example, in a relatively simple IoT scenario, several vehicles constantly send their information to a centralized system that controls whether the vehicles are emitting a high concentration of $CO_2$ in a national park. The system would require applications executed in mobile devices inside vehicles that would use an Application Programming Interface (API) to obtain data through the OBD2 port and then send via Internet the location and $CO_2$ emissions of the vehicle (probably using a specific service). The system would probably also require a distributed application that should be hosted in a web server that acts as a centralized system receiving and analyzing information from vehicles. Finally, once the centralized system detects high $CO_2$ emissions in the park, the system would have to send some kind of notification to the park's control center so measures can be taken to detour the incoming traffic. This system would require robust technical requirements that may include generating two different applications with different programing languages, using specific APIs (OBD2 or Bluetooth), coordinating and managing the data sent through the Internet, managing an application in a web server and design services that allow constant communication in an efficient manner.

Designing and implementing a system capable of coordinating intelligent objects is not a simple task. In order to simplify this process, several platforms try to integrate intelligent objects and sensor network, encouraging the connection between intelligent objects or sensors in a common network (depending on the platform privileges and visibility). The main advantage of these platforms is that they offer normalized interfaces (web services) that are used to integrate objects in the platforms. Some of these platforms also integrate systems to develop distributed applications that interact with several objects or sensors using associated services to receive readings or to send notifications to objects.

Why is it important to implement IoT systems that can be implemented or modified in a rapid dynamic approach? New objects constantly appear or are installed, and including the functionalities or readings of these objects can result in radical changes in the efficiency of legacy systems, requiring slight changes in such systems (adding these new objects or changing them for several old ones). The intelligent objects and sensors are the parts that make IoT systems useful since they are capable of quickly and efficiently modifying their participating degree in the system. It results in a key aspect to guarantee the dynamism, adaption (in a specific moment, a necessity, etc.) and evolution of the system.

### 1.1. Goal

Several platforms allow the aggregation of intelligent objects and sensors to facilitate user development of software applications with limited functionalities. Applications are able to include interaction flows between sensors and objects using the information to create simple tasks. Thus, the objective of this paper is to design an integrated platform for the generation of road vehicles based applications. The platform allows registering vehicles (treated as intelligent objects in an IoT system) and facilitating the design and generation of rich software applications based on the information obtained from the interconnected vehicles.

The development of applications must be fast and dynamic and it should not require programming technical knowledge or a high language specification level. To facilitate the use of the language for everyone, we will use a Domain-Specific Language (DSL) (Bentley, 1986) based on Model-Driven Engineering (MDE) technologies (Kent, 2002). MDE raises the level of abstraction of the traditional languages (e.g., C++ and Java), allowing the use of concepts close to the domains of the problems. MDE is a paradigm that elevates models to first-class citizens in the field of Software Engineering (Kramer et al., 2012). It is based on the separation of the functionality of the system and the development of such a system for a specific platform, that is, it seeks to clearly separate the analysis and design of the programming. Models are used to achieve this goal (Seidewitz, 2003).

Since a road is a dynamic and unpredictable environment, platform users must be able to quickly specify their needs in an application that has to be ready to be used in a few minutes. Rapid application generation offers a quick response to situation that has been just detected, accidents between several vehicles, an area with work in progress, natural disasters, etc.

The platform is aimed for any of the public. Any user can register several vehicles in the platform and design with almost any non-specific computer knowledge applications with a specific purpose. For instance, a parent can control the use of the car of his son and receive notifications when he arrives to a final destination. However, the potential of the platform could be also valuable for expert personnel that require managing and monitor vehicles, such as public services, transport businesses, rental vehicles companies or any entity with a fleet of vehicles. The platform would simplify the process required by a software development team in the design and development of an IoT system in this area.

The structure of the paper is as follows: Section 2 presents some related work. Section 3 provides a description of the proposed platform. Section 4 shows the language and the development environment. Section 5 underlines different prototypes of web applications developed using our proposal. Section 6 presents and analyzes the results obtained comparing them to other well-known proposals. Section 7 introduces a usability analysis. Finally, Sections 8 and 9 respectively present the conclusions and future work to be done.

## 2. Background

The term of Internet of Things was proposed by Ashton (2009) and refers to uniquely identifiable objects and their virtual representations in a graph-like structure. The idea is that if all objects and even people in daily life are equipped with identifiers, they could be managed and treated by computers. Besides, using technologies such as Radio Frequency Identification (RFID), barcodes, Near Field Communication (NFC), or Quick Response (QR) codes, the task is made easier. Such objects are usually called smart objects (Atzori et al., 2010) and are physical elements that interact with the environment and other objects and can behave intelligently and autonomously under certain conditions. Some common examples of smart objects can be smartphones, tablets, smart TVs and vehicles, the case of application of this work.