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Dynamic road lane management study ☆ A Smart City application

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ABSTRACT

Our Smart City contribution is transportation-oriented in that it proposes a dynamic road lane management system in order to share appropriately the space devoted to traffic. After a historical view of a series of solutions from physical to ICT supported, we present our proposal extensively supported by up-to-date ICT. Following a main presentation, we describe the system architecture and its working conditions. Then, we present the proposed simulator designed to study operating and driver's conditions with respect to the new traffic signs proposed. We also describe a Mock-up technology validation and give preliminary information on in-the-field deployment.

1. Introduction

In recent years, the "Smart City" concept has emerged to describe how investments in human and social capital and modern Information and Communication Technologies (ICT) infrastructure and e-services fuel sustainable growth and quality of life for its inhabitants and workers.

In Smart City systems, two opposite approaches can be used: (1) Elaboration of an opportunistic system allowing access to collected information and its "vitalization" by integration–interaction–aggregation in a non-predetermined way; (2) Well-defined systems able to solve identified problems, working in a specific clearly-defined and modeled situation.

In the first case, according to Xiong (2012), the "Smart City" principle in opportunistic perception is based on the concept of "Data Vitalization". The idea is to give data life, to combine separated data by avoiding information islands, to build a combination between each type of data, and to increase utilization of data. The main issue concerns sharing and integration of data that were initially separated due to their types and different collection methods. New contextual access and use of these data are fundamental in relation with emerging non-expected situations.

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While in our international China–France academic research project we study these two approaches, in this paper we focus on explaining the second approach oriented to a precise Smart City system, the goal of which is to solve a particular problem related to traffic management in confined circulation infrastructure, avoiding congestion by better allocation of traffic lanes. In this case "data vitalization" is not the main goal. In our case, we have chosen to study the design and implementation of a system, allowing appropriate use by private and professional vehicles and their drivers of a limited circulation infrastructure by extensive use of ICT (Information and Communication Technologies).

Consequently, our main contributions to this paper are: (1) Identification of main characteristics and design of an intelligent road lane management system as a Smart City application; (2) Integration of ICT and appropriate user interfaces in the system, allowing effective communication and collaboration among actors; (3) Development of a simulator validating system function designed to study drivers' acceptability and security of proposed User Interfaces, mainly oriented toward new traffic sign understanding and interpretation in dynamic driving conditions; (4) Technology validation of main ICT principles used in the mock-up, namely: Location-Based Services (LBS) and Internet of Things (IoT).

The next sections of this paper are structured as follows. After a state-of-the-art in dynamic management of road lines from historical, concrete and bibliographical points of view, we present the main characteristics of our extensive ICT-based dynamic road lane management system. Then, we describe its architecture from physical and digital point of views with the ICT technologies used. The following section is devoted to presenting the simulator with its organization, functionalities and main utilizations. A technology validation mock-up is explained in the next section, while the last section is devoted to presenting the results and the in-the-field deployment process. This paper ends with some conclusions and expected prospective actions.

2. State-of-the-art in dynamic management of road lanes

Our study concerns dynamic management of road traffic, which is regularly increasing both in towns and outside built-up urban areas. The first approach designed to allow increase in traffic leads to solutions such as increasing the number of lanes, while the second approach aims at segmenting traffic according to categories (private vehicles, heavy vehicles, public transportation, priority vehicles) by proposing specific development and traffic rules, with, in particular, the creation of specialized lanes (bus, tram, trolley). This second choice can lead to satisfactory solutions provided that there is sufficient space.

When space is lacking and the frequency of this type of specialized traffic is not sufficient, there is a sense of waste and poor management. A third solution then emerges, i.e. dynamic allocation of lanes to different types of transportation. A significant study consisting of data gathering, analysis and classification was carried out by Nouvier from the CERTU (Center for studies on networks, transportation, urbanism and public construction) (Nouvier, 2007), (Fig. 1).

Nouvier (2007) collected and presented a large number of varied solutions, from the more physical (ad hoc movement of low walls with trucks) to the more informational (signposts with variable displays), enabling lesser or greater speed of dynamicity. For dynamic bus lane allocation it is important to mention Lisbon experiment (Viegas and Lu, 2004; Viegas et al., 2007). We were also inspired by two works (Dept. of Transportation, 2009; Guler and Menendez, 2013).

3. Our ICT-based dynamic road lane management system

It is an established fact today that telematics or embedded and/or mobile ICTs can provide solutions leading to a very high dynamicity (clear a lane for a bus or an ambulance in real time), provided that users are sufficiently informed and that regulations are complied with in terms of transportation (or suggestions to modify it) and, in particular, of user safety. Hereafter, we give a brief description of the ICT vision, in a system-perspective.

"Dynamic circulation lane allocation" aims at providing a system designed to share circulation lanes dynamically between public transportation (buses) or rescue services (fire-fighters and ambulances) and personal vehicle transportation in order to share traffic lanes appropriately in the context of low frequency of specialized traffic or lack of space (impossibility or inadequacy of static allocation of circulation lanes). When there are no buses, all lanes are allocated to general traffic. When a bus approaches and on the bus driver's request, the right-hand lane is reserved for it. Once the bus has passed, the reserved lane is returned to general traffic (Fig. 2). However, if all lanes are already jammed, the system switches to "static mode", i.e. the right-hand lane is allocated to buses permanently. More sophisticated situations are also possible (Fig. 3). In (Fig. 3a and b) a one-way sharing line in the narrow part is alternatively used by opposite running buses. When two opposite running buses are present at the same time, two lanes are allocated to them and only one lane is devoted to personal vehicles (Fig. 3c). In (Fig. 3a and b) the change in orientation of the central lane is proposed. Dynamicity is less in this case because, for security reasons, long periods of time are needed to be sure that no buses are still engaged in this lane at the time of change.

3.1. Overall view

The global view of our approach is shown in Fig. 4. The infrastructure is based on a multi-lane road with sensors allocated under and near it, vertical and horizontal signs with associated actuators, and a management system connecting them. On