Real–Time Smart Navigation and the Genetic Approach to Vehicle Routing

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INTRODUCTION

In 2050, nearly 70% of the global population will be living in large cities (UN, 2014). Among the grave problems that institutions, companies and researchers are summoned to face, pollution and traffic management are particularly challenging.

This huge aggregation of people and vehicles, in fact, is already causing serious trouble to sustainable lifestyle, health and environment, so that mobility management becomes a crucial application field (EC, JRC, IPTS, 2014).

Besides the economic impact, in fact, urban mobility accounts for 30% of energy consumption and 70% of transport pollution, and the increasing urban concentration in large cities is making the problem more and more difficult.

In this scenario, smart mobility is bound to play an increasingly focal role: private travelers, commercial users and the public sector are continually searching faster route planning services.

In line with the Smart Navigation paradigm, in addition, the best path can vary as traffic conditions vary and updates should be indicated in real-time. Since traffic conditions are strongly time-variant, this feature can be achieved through the constant monitoring of road conditions, so as to provide the user with possible updates of routes previously suggested.

Several factors contribute to smart navigators efficiency; three issues are here considered. Firstly, a communication infrastructure for managing traffic and vehicular mobility. Secondly, enabling communication technologies and strategies. Lastly, route planning algorithms suitable for the real-time case.

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BACKGROUND

The infrastructure must provide for communication among vehicles, service centers and sensors, and is one of the main requirements identified by international institutions, service providers and car manufacturers (Papadimitratos et al., 2009).

New standards are necessary, so as to exploit Information and Communication Technologies (ICT) potentialities and develop integrated architectures for communication among vehicles, roadside units and wireless infrastructures. Advanced projects and outstanding standardization bodies are active (ERTICO, 2014).

Concerning communication technologies, several on-board services for drivers and passengers can be provided, as well as different communication facilities among vehicles. To this purpose, wireless access technologies are being exploited, i.e. short-range ad-hoc systems and cellular systems in Metropolitan Area Networks (MANs).

Among short-range ad-hoc systems, IEEE 802.11p is the current evolution of ad-hoc vehicular communication and standardization entities are working on latency reduction and real-time communication quality. As for

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MANs, mobile Worldwide interoperability for Microwave Access (mobile-WiMAX) is being deployed, a key technology for rapid backhauling connection of roadside devices and control centers. Cellular systems represent the promptest solution for data collection and retransmission from vehicles. In fact, they guarantee high market penetration, worldwide users' coverage, and service continuity at vehicular speeds, especially thinking to the Long Term Evolution (LTE) revolution.

Finally, traditional best route search is born for static environments, whereas real-time routing algorithms must fit environments evolving over time. Performing approaches can be found in advanced algorithms from Artificial Intelligence (Sampaio et al., 2012). Outstanding solutions start from (Korf, 1990), who analyzes limits of traditional methods when applied to the real-time case, and proves that Genetic Algorithms are more performing. Kanoh (2007) improves these results using Virus-Evolutionary Genetic Algorithms.

The article is organized as follows: first, architectures and communication strategies in the reference scenario and numerical results about saved travel time. A discussion follows about genetic algorithms and their variants and a proposal is made for traffic control and prediction architectures. Current research trends are finally presented.

ARCHITECTURES AND COMMUNICATION STRATEGIES

This section describes the architecture in De Castro et al. (2010) and Bazzi et al. (2013) for real-time smart navigation.

Outstanding platforms are available, such as Google Now (Google Inc., 2014) and TomTom (TomTom, 2014). Google Now is an intelligent application for real-time routing. It runs on Android and iOS, uses natural speech and information about users' preferences, so as to predict requirements. TomTom is available as a stand-alone navigator or for Android and iOS devices.

Despite the disruptive evolution of these products, problems still occur in real-time management. Research, thus, is open. Crucial aspects are infrastructures and strategies of data exchange between vehicles and processing modules. Applied research reckons on an increasing number of vehicles worldwide, equipped with monitoring devices for the continuous collection and transmission of information about themselves and their surroundings, such as current position and actual speed. Such equipment generally embeds a Global Positioning System (GPS) receiver, a cellular interface for vehicle-to-infrastructure (V2I) communication and further sensors.

The information allows to carry out real-time vehicle routing and further smart navigation services. In fact, it can also be used for transport efficiency, pollution monitoring, tourist information, accidents alerts, surveillance, civil infrastructure monitoring (Al-Ali et al., 2010; Yu et al., 2010).

The Italian reference fleet (Floating Car Data - FCD) counts one million vehicles (over a total of thirty five) and belongs to (OCTOTELEMATICS ltd, 2014); the on-board equipment is called On-Board Unit (OBU). Figure 1 shows the smart navigation architecture considered: OBUs-equipped vehicles transmit their current speed and position (known through the on-board GPS receiver) to a "Control Center," using the cellular network.

Several vehicles (set VS_i in Figure 1) are stuck, while car v_j was informed before the crossroad and suggested an alternative route (dotted in figure).

The Control Center collects the information, determines and constantly re-evaluates the best path, so as to alert interested vehicles in time.

Several communication and path calculation modalities are possible, such as:

1. **Centralized strategy:** Evaluation of the best route at the Control Center;
2. **Distributed strategy:** On-board evaluation of the best route;
3. **Hybrid evaluation:** Of the best route.

In the centralized strategy, the user sends a specific trip request to the Control Center, which determines the best route on the basis of current traffic conditions. This route is transmitted to the user's on-board navigator, which acts as a "dummy" entity, simply receiving the path.

In the distributed strategy, the Control Center periodically transmits up-to-date road conditions to all users. The best route is determined by the on-board navigator, which becomes an intelligent device.

The hybrid strategy is a compromise: when a user requests a route, the Control Center returns him or

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