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IT&C SOLUTIONS FOR INTELLIGENT TRANSPORTATION SYSTEMS

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Abstract: Road traffic congestion has incredibly high social costs, due to unnecessary fuel consumption, environment pollution, wasted time, and increased risk of accidents. As the road infrastructure obviously grows slower than the number of vehicles, the situation constantly deteriorated in the past decades, thus requiring immediate attention from both researchers and decision makers. This paper presents a couple of IT&C based solutions for Intelligent Transportation Systems, which make the object of two patent applications submitted to the Romanian Patent Office OSIM. The first solution is an improved GPS navigation assistant for road vehicles, capable to produce real-time estimations of the traffic fluency. The other describes the principles of implementation of "virtual road signs" based on Vehicular Ad-hoc Networks (VANETs).

Keywords: GPS Navigation, Intelligent Transportation Systems, Traffic Congestion, Virtual Road Signs, VANETs

I. INTRODUCTION. INTELLIGENT SOLUTIONS IN ROAD TRANSPORTATION

In the past decades, the growth of the number of vehicles constantly outstripped the investments in the road infrastructure. Thus, the problem of traffic congestion became acute in most large cities, with rising social costs. According to some estimates (e.g. Goodwin, 2004) the cost of traffic congestion for UK only, in 2010, was 30 billions pounds.

Beyond the direct economic losses, some researchers (e.g. Quddus et al, 2009) investigated a possible correlation between traffic congestion and crash severity, with an obvious influence on the overall number of casualties in road traffic accidents.

Given the importance of the topic, the problem of traffic congestion has been approached from a wide variety of angles, including the development of modeling and simulation tools (Martinez et al., 2011), video processing applications (Kastrinaki et al., 2003), GPS-GIS based techniques (Imran et al, 2006; Leduc, 2008), multi-agent systems (Hernández et al, 2002), inter-vehicle communication (Luo and Hubaux, 2006), and artificial intelligence (Ma et al, 2009). Other interesting approaches worth to mention here are: tracking the mobile phones in certain geographic areas to detect traffic congestions (Bar-Gera, 2007), or charging a special toll for the access in traditionally congested areas such as London downtown (Litman, 2006).

This present paper presents a brief description of two IT&C based solutions for Intelligent Transportation Systems, submitted as patent applications to the Romanian Patent Office OSIM. The first solution (Susnea and Vasiliu, 2010) is an improved GPS navigation assistant for drivers of road vehicles, capable to produce real-time estimations of the traffic fluency. This application proposes a multi-agent approach to allow vehicle drivers to select optimal routes based on data collected in real time. The other application (Susnea and Vasiliu, 2012) describes the principles of implementation of "virtual road signs" based on Vehicular Ad-hoc Networks (VANETs).

Apart from this introduction, the paper is structured as follows:

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- Section II presents an improved GPS navigation assistant for drivers of road vehicles, based on a multi-agent systems approach;
- Section III describes a possible implementation of the concept of "virtual road signs", generated through the interaction and communication between some on-vehicle electronics with roadside devices, according to the principles of VANETs (Vehicular Ad-hoc Networks).
- Finally, Section IV is reserved for conclusions.

II. AN IMPROVED GPS NAVIGATION SYSTEM FOR ROAD VEHICLES

Among the thousands of existing solutions for improving the traffic conditions, one of the most popular is the GPS navigation system, also known as PNA (Portable Navigation Assistant)..

In this approach, the GPS locator supplies the position information to a microcontroller, which extracts from its internal memory and displays a predefined map of the corresponding geographic area.

The main drawback of this solution derives from the fact that it uses static maps, which don't contain any information about how practicable are the roads, whether some restrictions are in effect (e.g. one way traffic, speed limitations, restricted access in certain time intervals etc.), or about the actual fluency of the traffic on the respective roads.

To overcome this limitation, a variety of solutions have been proposed. For example, the patent US2006/0094443 (Dowling et al, 2006) describes a device that uses the GPS information to automatically select and display o series of web pages (accessed via a mobile Internet connection), whose content is related with the current position of the vehicle (e.g. tourist attractions, shopping centers auto service centers, hotels, etc.).

A similar solution is proposed by the patent application WO2010/073053 (Liotopoulos and Karypidou, 2008), wherein the additional information is provided by a dedicated server that collects (from human operators) and delivers updated information about traffic conditions.

The solution presented in the patent US2004/0249569 (Saeng, 2004) adds an input device to the system, so that the user is allowed to define routes by specifying the start point and the desired destination. Furthermore, the system accesses an external source and displays additional information about the selected route.

The patent GB2431261 (Watson and Atkinson, 2005) extends the geographic information stored in the maps of the common PNA devices with data about the applicable speed limits, and introduces a „cost function" for each possible route in order to provide a means for comparing and selecting best routes.

The solution proposed in the patent US2010/0057334 (Ramaswamy and Horiguchi, 2008) relies on the communication between the PNA and a remote computer located in a base station, which centralizes the information provided by a plurality of GPS enabled smart phones. The central computer estimates the traffic fluency and reports the results to the users upon request.

All the above listed solutions have a common major drawback: building and updating the knowledge base about the traffic conditions, stored in one or more external devices, is difficult and costly.

Our solution (Susnea and Vasiliu, 2010) completely eliminates this drawback because the knowledge base about the traffic conditions is created ad-hoc, in the process of communication between a plurality of on-vehicle PNA devices, and a ground based server.

The general structure of the equipment involved in this solution is presented in figure 1.

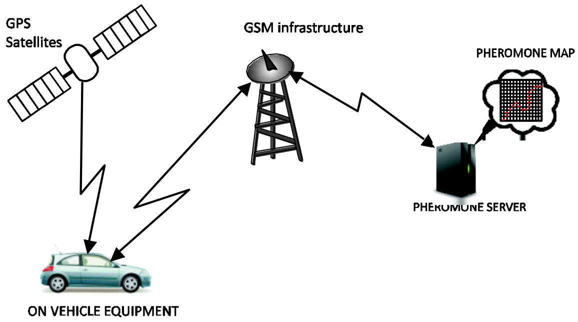

Fig.1. The structure of the proposed solution for an improved GPS navigation assistant

In a multi-agent systems approach, the key element of this solution is the concept of „virtual pheromones" defined as traces left by the agents not in the environment, but in a representation thereof – a map. This concept has been extensively described in (Susnea et al., 2009; Susnea, 2014).

Basically the virtual pheromones are records in a data structure, built as a grid 2D array, called "pheromone map", created and updated by a computer called "pheromone server". Since all the agents are in communication with the pheromone server, the pheromone map acts as a common memory, shared by all agents. Following a model similar to the natural pheromones, virtual pheromones diffuse in space, decreasing their intensity with the distance from the source, and also diminish with time ("evaporation"). Assuming linear variations with distance and time, the resultant effect of N pheromone sources aggregate in every point of the map according to (1):

$$\overline{P_R} = \left(1 - \frac{t}{\tau}\right)\sum_{k=1}^{N} p_k \bar{\iota}_k \left(1 - \frac{d_k}{\sigma}\right) \quad (1)$$

where σ is the sensitivity range, and τ is an evaporation constant, p_k is the intensity of the pheromone source k, located at distance d_k.

The proposed improved navigation system is composed of two subsystems – one located on the vehicle, comprises a GPS locator, and a microcontroller system capable to display geographic maps just like the existing PNAs. The microcontroller system is also capable to communicate via a wireless communication link (e.g. a mobile Internet connection) with the second ground-based subsystem, called pheromone server, implemented as a computer running a dedicated software application (see figure 1).

Periodically, each agent uses its on-vehicle GPS locator to determine the position of the vehicle, and sends short data packets to the pheromone server, reporting its current position. Upon receiving these packets, the server updates the entire pheromone map, and sends back to the reporting agent a fragment of the pheromone map, corresponding to its current position.

The map containing the pheromone trails (represented with different colors or shades of gray) is superposed over the existing GPS navigation maps as transparent layers, and the resulting map is displayed by the on-vehicle device.

Obviously, an alternate implementation may use smart phones or tablet PCs as on-vehicle devices, and a web server as pheromone server. The pheromone maps can be fused with GIS data by the application running on the server, and delivered to the users as a web page.

The entire system operates in a way similar to Google traffic, with the important difference that Google traffic provides just *an estimate* of the traffic conditions, based on past records, while the solution described here provides *real-time data* on the actual traffic conditions.

Moreover, pheromone maps can be recorded and used for offline studies of traffic fluency, and pheromone distributions obtained in a process of Ant Colony Optimization (ACO) with simulated virtual agents, may be used to guide real agents.

III. CREATING VIRTUAL ROAD SIGNS

A well signaled road can be an important traffic safety factor, and may improve traffic fluency, and reduce the risk of accidents.

One research direction on this topic is the development of so-called "driver assistants", consisting in devices capable to automatically recognize certain road signs (e.g. speed limit signs) in a stream of images captured by on vehicle cameras, and to generate audible warnings for the drivers (see for example Nguwi and Kouzani, 2006).

The efficiency of these devices is questionable, considering that voice messages can, in certain conditions, distract the driver.

A large number of inventions related to road signs use the RFID (Radio Frequency Identification) technology to trigger the display of certain messages similar to the "classic" road signs. For example, the invention WO2011094024A2 (Serex, 2010) proposes that the images containing the actual road signs are stored in RFID tags located on the road side. This information is automatically read by RFID readers located on vehicle, and displayed locally by a microcontroller system.

In the invention US6587755B1 (Smith and Van Leeuwen, 2000), the RFID tags are located on vehicles, and the devices for reading and displaying the information stored in the tags are deployed along the road side. This allows the identification of the vehicles and the personalization of the messages.

All of the above mentioned solutions have the drawback that they rely on long range RFID, which are relatively expensive, require their own power supply, and have a high rate of data errors.

An interesting alternate solution is presented in the patent application DE10238638A1 (Raddatz, 2002), which describes a system comprising a GPS enabled device locate on vehicle, and a "virtual road sign server" that can be accessed through a mobile Internet connection between the two. The on vehicle device uses the GPS locator to read the current position, and reports it to the server, which in turn extracts the corresponding virtual road signs from a database and returns them to the querying client.

The main disadvantage of this solution comes from the fact that it relies on a central server and a unique database of virtual road signs. Creating and regulary updating such a database is difficult and expensive, and a mobile Internet connection is not always available.

To overcome these drawbacks, we proposed in A00717/11.10.2012 (Susnea and Vasiliu, 2012) a solution wherein the information that defines the virtual road signs is no longer stored on a single server, but in a plurality of (embedded) computers deployed along the road side, which can communicate with the on-vehicle electronics according to the principles of VANETs (Vehicular Ad-hoc Networks).

The proposed system comprises two subsystems as shown in figure 2.

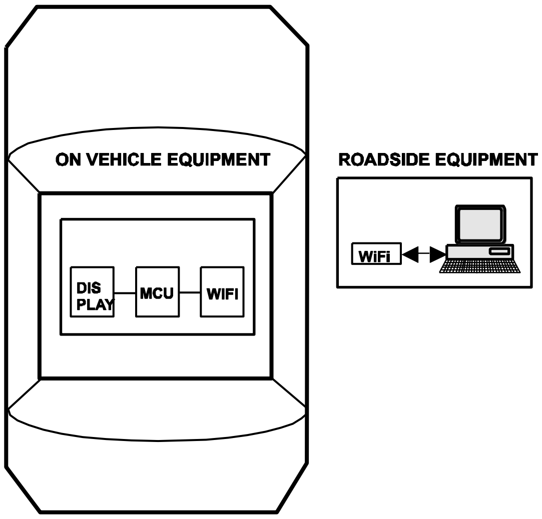

Fig.2. The structure of the proposed solution for creating Virtual Road Signs

The on-vehicle equipment comprises a microcontroller, connected with a WiFi (IEE 802.11) wireless communication interface, and a display. An optional input device (e.g. a touch panel) is not shown in figure 2.

The road-side equipment consists in a plurality of (embedded) computers, each having a WiFi Access Point.

In a basic implementation, each of the road-side computers store an individual road sign, structured as a PHP/HTML web page.

The software running on the on-vehicle microcontroller detects the existing WiFi networks in the neighborhood, and connects automatically with the access point AP having the highest signal strength. Once connected, the client is automatically redirected to display the associated information page. A timer breaks the connection after a few seconds, and the process continues with the next available AP.

IV. CONCLUSION

The solutions presented in this paper are based on a multi-agent, distributed approach on the problems related to the Intelligent Transportation Systems. This reduces the overall cost, improves the robustness of the resulting systems, and can contribute to and increase of the general safety of road traffic.

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