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Online Web Service based Solution for Urban Traffic Management

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***Abstract*—**In this article, we present a web server based solution for implementing a system for intelligent navigation. In this solution we use real time collected data and traffic history to establish the best route for navigation. This is a low cost solution that is easily to implement and extend. There is no need any infrastructure at road network level except only a device that collect data about traffic in key road crossing. The presented solution creates a strong base for traffic pursuit and offers an infrastructure for navigation applications.

***Keywords*—**navigation, real time, route, traffic pursuit, web service.

I. INTRODUCTION

TRAFFIC has serious consequences [1]. The estimated cost of traffic is more than 100 billion euro (in fuel and wasted time), and that doesn't take into account factors like environmental damage or health costs due to pollution. The traffic congestion results affect not only the budgets but, more worst, affect the life quality.

Many factors can contribute to traffic congestion, but the most basic explanation is that the number of drivers trying to use the same road is so high that it exceeds the road's capacity. That's a pretty simple explanation -- too many cars in one place causes congestion. Unfortunately, the underlying reasons for too many cars in one place at one time are more complicated. University departments and civil engineers dedicate hundreds of hours and require millions of dollars in funding research that tries to understand how traffic congestion forms and what can be done to avoid it.

City planners, civil engineers, environmental advocacy groups, homeowner associations, politicians and the general population can have a significant impact on how to address traffic congestion. Traffic is a political and sensitive issue since almost every proposed method of addressing it carries a hefty price tag, raising the question of who pays the bill.

As for in-car navigation systems, European legislation on what may be displayed inside a moving vehicle is rather rigid, only allowing a screen showing a single bold arrow [2]. A full map can only be displayed when the vehicle is still. Voice messaging has no such restrictions. Both visual and audio output have a potential for distracting the driver, which is why the newly revised Highway Code includes an admonition against the careless use of route guidance and navigation systems. Bearing in mind the current debate in Europe over banning the use of mobile phones in cars, in-car navigation may face the same argument.

In this article, we'll present a solution for implementing traffic control in an urban area. This solution is easily to be implemented and extended. More, this is a low cost solution. There are no needed any infrastructures at road network level. The presented solution creates a strong base for traffic management and offers an infrastructure for other urban traffic applications.

II. BASIC PROBLEM

Tracking systems depend on GPS for finding the exact location of a vehicle. Modern GPS receivers have an accuracy of between 3 and 30 metres in good conditions. Using so-called differential GPS, the accuracy can be increased to a few centimetres. With a moving object, this is more difficult. Curiously enough, none of the manufacturers advertising their navigation systems on the Internet sites that are listed as reference actually mention the accuracy or possible deviation of the system. On large-scale maps this will seldom generate a visual error, even when roads may be slightly displaced on the map to create a clearer distinction between roads or to highlight certain features along the road.

One aspect that needs to be mentioned is the fact that in-car navigation also can serve as a tracking device, leaving behind electronic signals of a vehicle and its whereabouts, adding up just another of the many electronic footprints a person might activate during a day.

The range of products and applications in the transportation sector indicates that these are tools that are in high demand. It has been estimated that some 80% of all information that any business manages has a geographic context [3]. Crucial to any organisation's success is access to good and valid information. In the field of transportation much of this information is constantly moving, thus increasing the demand for up-to-date information. GIS can help manage this information.

Traffic management implies the existence of an infrastructure that can provide the authorities with real-time information about the traffic evolution in the sighted area. This information is related and action is taken in order to prevent congestion [4], and if it has happened, to find a way to clear the adjacent roads in order to allow the release of a much

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higher number of cars from the sighted area.

A. Network overload

If there are highways or surface streets that suffer from heavy traffic congestion, no matter what the actual road conditions might be, they fall into the category of network overload. These are the bottlenecks where demand always outweighs capacity.

The congestion doesn't immediately clear up -- it continues to shift slowly back down the highway because, as space opens up ahead of your car, you can accelerate and escape the congestion. The person behind you can accelerate a few moments later, and the person behind them a few moments after that. Congestion can clear if traffic becomes light enough to stop the traffic-wave effect.

B. Traffic disturbances

Accidents and breakdowns, road construction and repair, and harsh weather conditions are all considered traffic disturbances. You can't always predict where these disturbances will occur, but they still heavily impact traffic flow.

It's easy to imagine a construction site, an accident, or a policeman giving a traffic ticket causing congestion -- drivers slow down either to change lanes or to see what happened. Road work might shut down one or more lanes, requiring drivers to shift over into open but crowded lanes. Bad weather might cause some drivers to maintain a slower driving speed out of concern for safety.

There are two kind of solution for traffic management: road network management and traffic control management.

III. Solution for traffic management

The solutions adopted for traffic management consist in the management of road network and in the management of real time traffic [4], [5].

Road network management [6]-[8] implies the continuous adjustment of roads to match the community's needs in order to increase the maximum car flow and determine coherent traffic rules that can ensure the traffic's fluency. There is a theory according to the increase of lane number and maximum allowed speed lead to the increase of maximum flow capacity. This theory, however, cannot be applied in crowded areas due to legal limitations of the lane number that can be built. The second aspect considers the creation of flow passes with the help of traffic rules.

All the factors taken into consideration for the problem's solution from this perspective are static. If the traffic flow exceeds the considered model‘s margins it can easily lead to local traffic congestions, that diffuse into adjacent areas. Congestions cannot be completely covered in simulations achieved from statistical data because statistics implies mediation.

Even though a certain margin of error is considered, there is still a limit that cannot be passed. The solution to situations that exceed these boundaries can only be a dynamic traffic control system that can adapt to the practical situation.

Traffic control systems imply, in the first place, the collection of a high quantity of information from a sensors network that observes traffic development in the sighted area. The sensor network is made from elements that can determine the car number, the driving speed, the emissions etc. All the sensors must be connected through a communication network to a central system that can give meaning to the collected data and provide the necessary data for taking decisions or it can contain an automated system that can take decisions in certain boundaries and warns the operators if the decisions that should be made overtake the required limitations.

Installing sensors into the road network is an expensive operation concerning the cost of the equipment, manufacture and maintenance.

An easier way is not to fix the sensors on the road network. Most vehicles are provided with navigation systems GPS that can collect information about the covered distance, driving speed and eventually road obstacles etc.

Starting only with this information, a traffic control system, more reduced than a conventional one, can be imagined. More, costs are divided between the local authorities who implement the system and traffic participants. The envisaged system is concerned with:

- Providing drivers with traffic information;
- The elimination of updating maps regarding traffic rules (speed, limitations)
- Providing optimum routing information in accordance with various criteria (distance, speed, time, facility, usage) for drivers
- Providing drivers and authorities with real-time information about the traffic evolution
- Collecting information about the traffic evolution in real-time
- Ensuring protection over cars steeling
- Making the logic for the cars endowment:
- Material transportation
- Persons transportation
    - In common transportation
    - Cab transportation

IV. SOLUTION'S PREZENTATION

The presented system is formed by:

- a data storage system and a data processing system
- a communication network between the collection of data points and the data storage system
- secured wireless communication systems
- devices installed on vehicles contain
    - a GPS module
    - a wireless communication module
    - a module for data storage and processing
    - an application of voice synthesis
    - an application for navigation
    - optionally an alternative transmission system (GPRS for example)

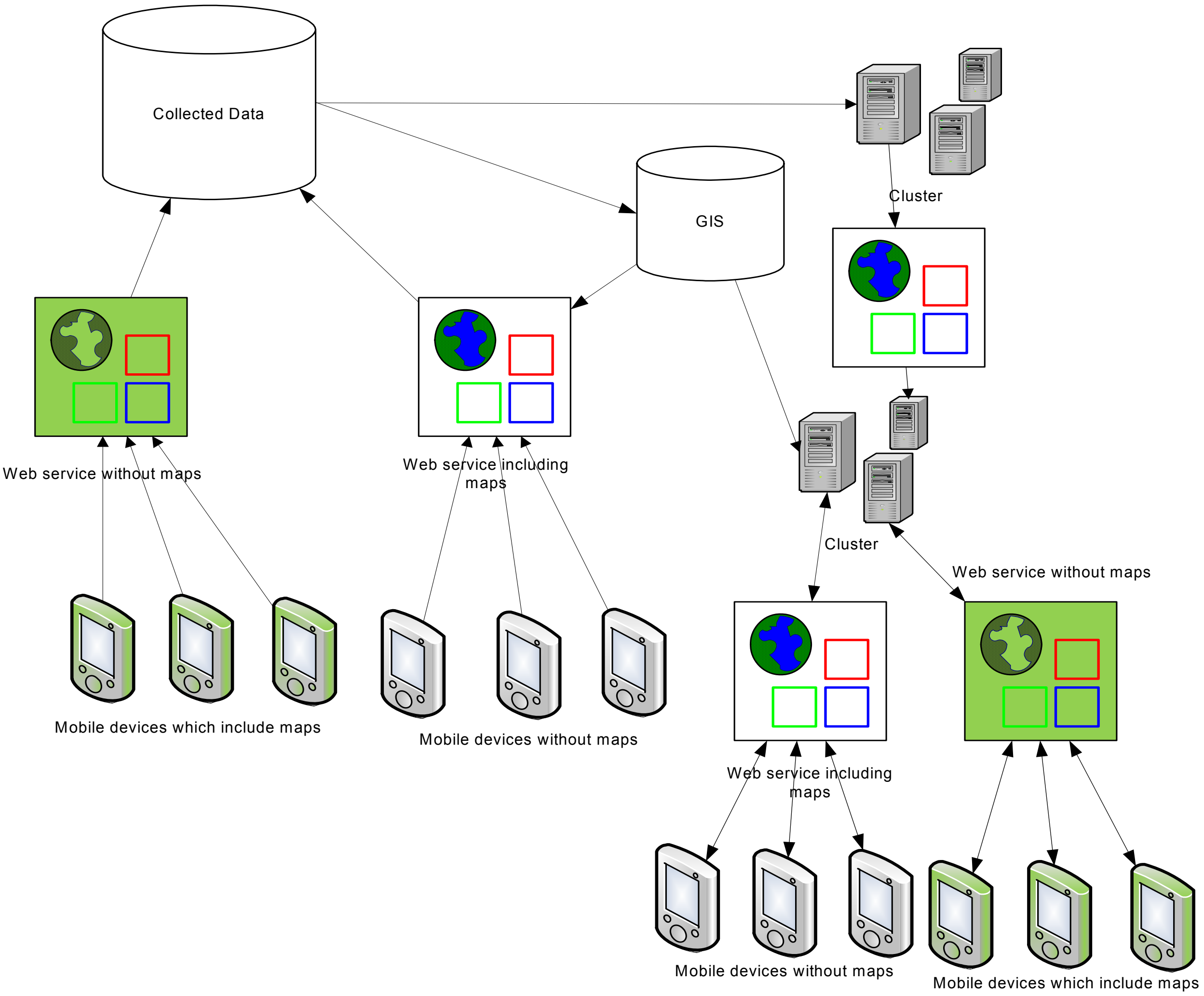

Fig. 1. System architecture

Brief system architecture is presented in fig 1.

In the system are implemented algorithms for:

- Collecting traffic information
- Correlating traffic information with the map of the sighted area
- Transmission of navigation information to the traffic drivers

A. Gathering data

The devices installed on the cars collect data about the way in which the car travels. Those are formed by coordinates and the moment of time when the coordinates have been collected. Information is stored into a buffer memory until their upload on the server becomes possible. During their transfer to the server, the device identifier is added. Therefore the server knows from which unit the data come from. The uploaded data is analyzed this way: the closest street to the transmission point is computed and a range of points for each street and device is created. From a range, only the first and the last point are retained (fig.2).

The other points are irrelevant because they describe the way in which the street was travelled, without affecting the global values. The application actuates the street's travel time and the passing course between crossroads. Those values are stored in a database. The minimal database structure is presented in fig. 3.

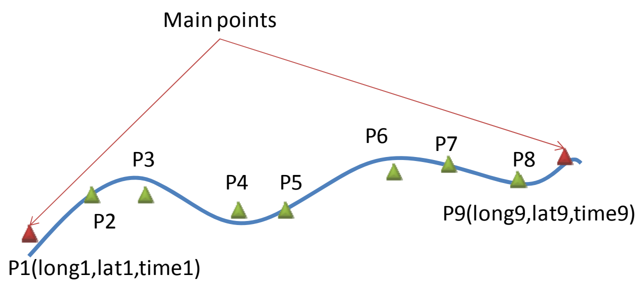

Fig. 2. Collected data

The database is used to extract information about the traffic course on certain streets a year, a month or a day before. With the help of these data and some dynamic weight factors, a medium travelling time of a street is computed.

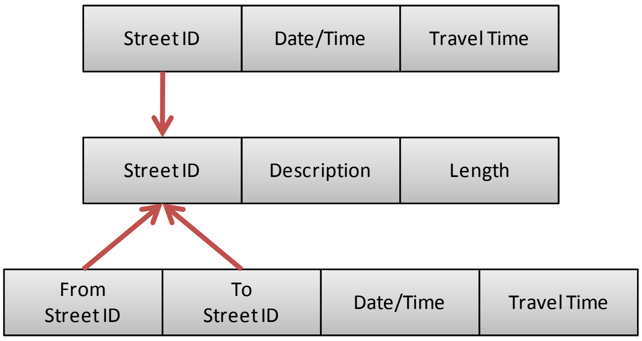

Fig. 3. Minimal database structure

B. Compute streets' medium travelling time

In order to estimate the medium travelling time of a street at a certain date and hour, the application uses 6 elements of information from the database: speeds at the same hour a year before, in the crossest each day of the week, a calendar year before, a month, a week or a day before, but also the last available value. The usage of these data starts from the following conditions:

1) A year ago, in the closest each day of the week, there were the same activities, when talking about usual days.

2) A calendar year ago, for the situations in which there are specific activities to some days of the year.

3) A month or a week ago and the last available value, in order to consider the recent traffic evolution.

For each of these six speeds rated with, a weight factor of its influence over the estimated value will be used. The estimated value v_e will be computed with the following formula:

$$\frac{w_1v_1 + w_2v_2 + ... + w_6v_6}{w_1 + w_2 + ... + w_6} \qquad (1)$$

The weight factors are used for the whole map (they don't make differentiations on areas).

When a new medium value is received, the speed value is compared to the six speed values extracted from the database, like it would be desirable the speed estimation for the moment the data has been received.

Speeds' weight factors that differ much from the received speed are reduced, and the speeds' weight factors close to the received speed are raised.

In our application has been considered that if the speeds differ with more than $\Delta v_{high} = 15km/h$, then the weight factor is decreased with $\Delta w_{high} = 5\%$ and if the difference is smaller than $\Delta v_{low} = 5km/h$, then the weight factor is raised with Δw_{high}.

On the other side, if the medium weight speed is smaller than the received speed v_r , than all the inferior speeds' weight factors are decreased with $\Delta w_{low} = 1\%$. If the medium weight speed is smaller than the received value, than all the larger speeds' weight factors are raised with Δw_{low} and all the smaller speeds' weight factors are decreased with Δw_{low}. This algorithm is presented in fig. 4.

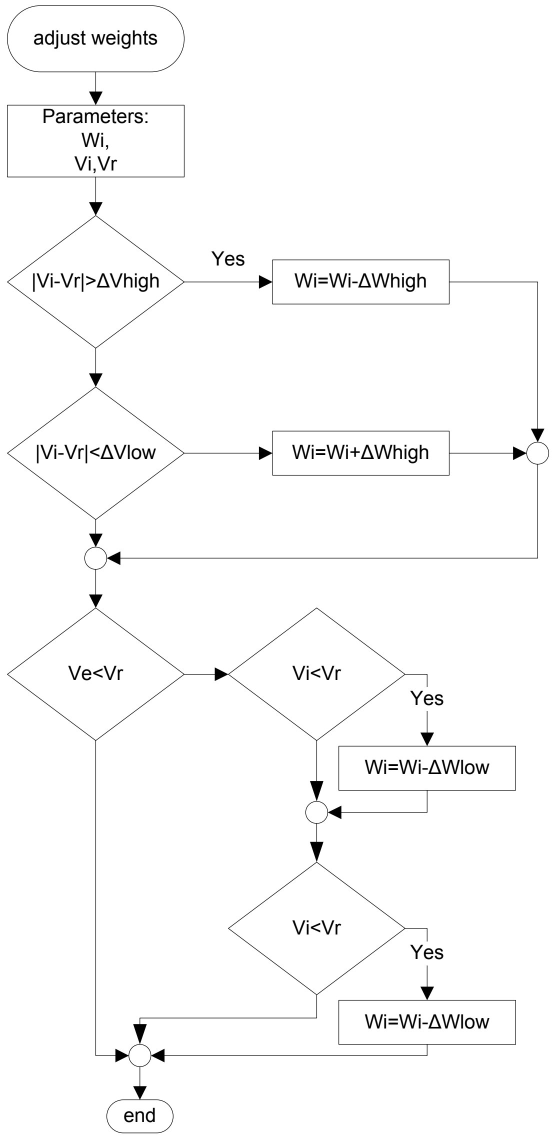

Fig. 4. DFD for weight adjustment

The use of this methods ensure a correct traffic estimation, even thought there is unexpected behavior during its development. Because the application takes always into account the historic, the weight factors variation has enough „inertia" not to denaturize the result.

C. Dynamic routing algorithms

The basis of the routing algorithm is the Dijkstra's algorithm for computing the minimum distance between two joints in a graph. The difference from the base algorithm is the usage of different costs for the travelled roads, because the travelling time differs from one moment to another.

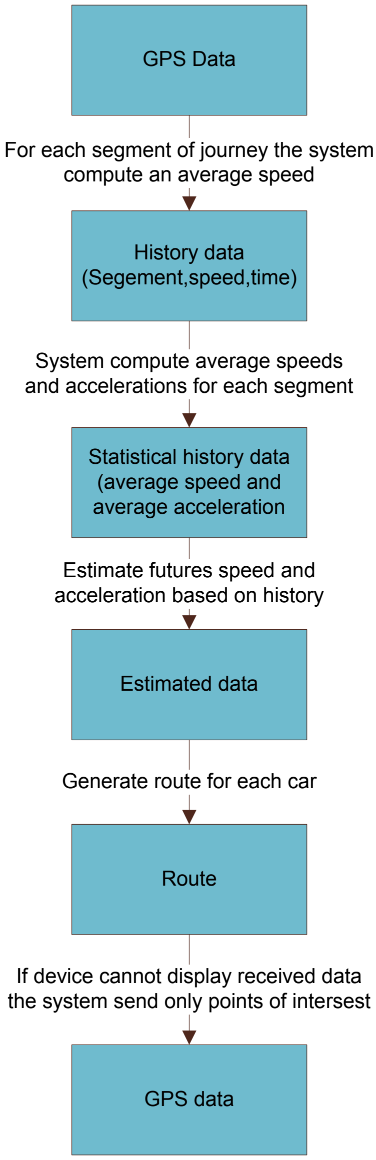

Fig. 5. System data flow

D. Dynamic routing algorithms

The basis of the routing algorithm is the Dijkstra's algorithm for computing the minimum distance between two joints in a graph. The difference from the base algorithm is the usage of different costs for the travelled roads, because the travelling time differs from one moment to another.

We have considered that the traffic variation is a relatively slow process, and an actualization of it every $\tau = 10\,\text{min}$ is sufficient.

During routing, with the aid of existent weight factors at that moment, speeds on all the roads in the map are estimated for an hourly interval ΔT (worst case movement trough modeled area from time perspective).

The speeds for the first interval τ is computed, and then the next intervals until the course coverage are computed using unchanged weight factors, but taking into account for the last speed (v_6) the value computed in the previous hourly interval ΔT .

When Dijkstra's algorithm is used, for each routed street is tracking the moment of time τ when the traverse starts from τ .

The traverse time is given by the value computed for the referred street in that time interval. The best solution is stored also in the guise of car sent on certain streets. This way, tracks and preferential streets can be determined through further analyses.

The application can be extended so that after the routing of a big enough cars number on a street in the same time interval τ , this could be considered charged and sending of other cars on that track in that time interval would be avoided as much as possible.

E. The use of the result for navigation

The result obtained with the aid of extended Dijkstra's algorithm is sent to the device that demanded the routing. The demand is used in two ways:

Devices with graphic display overlap the result on the map; Devices without graphic display use reference points through which they transmit the driver in audio mode what he must do in order to follow the received track (commands like „turn right at the next crossroad").

After a time interval τ has passed, the device makes a new routing demand to the server in order to achieve the latest data.

The entire data flow of the system is presented in figure 5.

V. Conclusions

The proposed system represents a viable solution concerning the implementation cost. The solution provides numerous advantages:

- It doesn't need the implementation of a sensors infrastructure which needs a system to code the collected information and resend it to a central point;
- It doesn't need the implementation of some systems to announce the traffic problems for those who have a device installed on the car
- These devices can be lent for those who spend a limited period of time in the sighted area
- The traffic data processing is shared between the central system and the devices installed on vehicles. (the central system can be also shared in a way that a part of the processing is done in the area where it is collected)
- It is not needed anymore the maps' update. The information for navigation is always up to date.
- Allows the quick implementation of a system for traffic management.

The solution can be used also for the implementation of an automatic system in order to follow stolen cars. A GPRS communication system attached to the device can activate when the car is moving and if this function hasn't been deactivated.

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