Distribution and interpretation of geo-referenced events for the purpose of road traffic shaping

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Abstract— In this paper the authors present an approach to the interpretation and distribution of geo-referenced information about road events for the purpose of road traffic shaping in the INSIGMA system. Particular focus was paid to the architecture and development of Registration, Distribution and Displaying Road Information on Variable Message Signs that implements the proposed mechanism. Created subsystem enables to inform road users about actual traffic information derived from variable sensors like: speed detectors (induction loops, GPS Tracker), Event Notification Service (ENS), route planning service (RPS). There has been described the problem of events’ interpretation, need for analysis and correlation in space and time as well as messages prioritization for the purpose of support for the traffic safety and being quickly and precisely interpreted by the roads’ users.

Keywords-component; Variable Message Signs, RDDRI, INSIGMA, road incident, road message, route planning

I. INTRODUCTION

INSIGMA stands for Intelligent System for Global Monitoring Detection and Identification of Threats. The main objective of the project is to develop a complex monitoring system that will allow to identify objects in the monitored environment and, based on the stored information and advanced algorithms, identify threats related to both the traffic and suspicious behavior of people. The system can be also used for traffic management and route planning for individual users and for the public safety services. The route planning will take into account also dynamic complex parameters that provide the possibility to select the route in special circumstances, e.g. after a road accident or a natural disaster, in difficult weather conditions, etc.

One of the most important purposes of data collection and processing in the INSIGMA system is notifying users about the current traffic situation and road difficulties based on the traffic analysis in order to make the traffic flow more fluent. One of the forms of notifying users is to display information about current situation (traffic incidents, estimated travel time, forecast weather conditions) on Variable Message Signs (VMS) boards. Retrieving traffic information in that form is important feature that have an impact on traffic control on particular monitored area.

II. STATE OF THE ART

Design of the subsystem responsible for transmission of information to VMS boards was preceded by the analysis of the currently available technologies for manufacturing information boards and a review of the available systems generating and displaying road information based on road traffic data on the monitored area [1, 2, 3, 4]. The traffic control centers are the most crucial part of the majority of the analyzed systems. The centers have access to various types of sensors enabling monitoring of road traffic (cameras, induction loops, measuring stations, weather stations, data on the traffic changes, traffic jams, collisions, etc. entered by the operators).

VMS allow displaying messages for road users depending on the current needs and available data. The dynamic form enables transmission of variable information.

The typical messages displayed on the VMS boards include information on traffic events (accidents, collisions, traffic jams, road works, traffic difficulties, closure of a traffic lane or the entire road, suggested detours), information on weather conditions (fog, glaze, slippery road surface, danger of slippery road surface), suggested speed limits, travel distances and travel times to the main junction points, as well as traffic control (traffic dispersion, directing to alternative routes, speed control).

The VMS boards display road information generated by appropriate traffic control centers. The Integrated Traffic Management and Control System located in Warsaw, Poland is one of the examples of such traffic control centers [1]. In June 2006 this institution realized a project the main goal of which was to improve public transport traffic conditions, organize traffic on the streets of Warsaw and ensure its smoothness. The heart of the system is appropriate traffic control center. The system is highly automatic. Despite of that the center is supported by several operators that manage and monitor the whole system.

Currently developed systems of displaying road information on VMS boards are closed for updates from the external companies due to licensing solutions. In order to incorporate a VMS system into the INSIGMA and inform users about road events (incidents) in the form of messages displayed VMS boards, it was necessary to define dedicated mechanism of distributing and displaying road information. This approach
enables also to investigate the efficiency of road information propagation among drivers that do not use INSIGMA route planning for traffic smoothness improvement.

This article covers the architecture and development of a subsystem for Registration, Distribution and Displaying of Traffic Information on Variable Message Signs (RDDRI) intended for the INSIGMA system.

III. RDDRI ARCHITECTURE

RDDRI subsystem is one of the consumers of incidents identified by the INSIGMA system. RDDRI enables receiving INSIGMA road events and their transformation to appropriate road messages that can be displayed on VMS boards.

The described subsystem assumes the following road data to be transferred to VMS boards:

- traffic events including car collisions, car accidents,
- traffic difficulties (road works, traffic jams, turn off lanes),
- speed limits,
- information about weather conditions that may influence driving safety (rain, fog, snowstorm, etc.),
- distance and travel time to the main junction points,
- optionally – advising drivers on alternative routes, information about current and planned detour.

Information about traffic events is derived from the INSIGMA Analysis and Correlation of Data Mechanism (ACDM), which generates traffic events on the basis of data collected from the INSIGMA sensors. One of the sensors that provides data to ACDM is the GPSTracker subsystem [5]. It enables determination of travel times on the individual road sections based on the analysis of trajectory of vehicles using the Global Positioning System (GPS) technology, for reading the current geographical position. The Event Notification Service (ENS) is also the source of events. It allows transmission of information on traffic events identified by road users to INSIGMA with a dedicated application installed on mobile phones [6]. Information about travel times is provided by the Route Planning Service (RPS) [7]. It informs about distance and estimated travel time on the requested route based on dynamic data about traffic parameters provided by the Traffic Data Repository (TDR).

The purpose of displaying road information on the VMS boards is to improve traffic safety and achieve one of the following reactions of the road users:

- adjustment of the vehicle speed to road conditions,
- decreasing the amount of congestions by adjustment of the routes selected by the road users,
- informing the users on traffic difficulties,
- increasing the focus of drivers' attention into to possible dangers.

The RDDRI architecture consists of the following modules (Figure 1):

- Traffic Information Receiving Module (TIRM),
- VMS Registration Module (VRM),
- Events Analysing Module (EAM),
- Road Message Distribution Module (RMDM).

The architecture of the solution assumes the possibility of transmission of the information not only to the "physical" VMS boards but also to the dynamical map, from where information can be displayed on the maps specifying the travel route calculated by RPS.

A. Traffic Information Receiving Module

ACDM generates information about traffic situation on the basis of reported road incidents derived from independent data sensors. One of the data parameters about an incident is lane_id: identifier of particular road segment on the static map. It allows to locate the incidents in terms of geographical position. ACDM also generates "time-space" incidents. The most important attributes of such incidents is their duration and area of occurrence.

The RDDRI subsystem also enables displaying information about expected travel time and distances to main junction points. For this reason the subsystem communicates with RPS which returns the required parameters. The authors also assume the possibility to transform in the subsystem events reported by the INSIGMA operator. He can manually insert information about incidents and current or planned detours.

B. VMS baord registration

Due to the fact that the road events are related to a particular area (geo-referenced) it is necessary to identify each VMS by its location. Registering a VMS board is a process used for its assignment to a specified location. During the registration process the system generates unique identifier (ID) for each VMS board (Figure 2). It is necessary to define the area of responsibility that describes set of lane_id’s for which road information will be displayed. VMS board location is
expressed in the form of geographical location (longitude and latitude coordinates) and location on the static map (lane_id, street name and traffic direction).

Figure 2 RDDRI VMS board registration process

It is assumed that, in addition to information related to traffic incidents in the assigned area, each VMS board will be able to display information about the distance and travel time to the main junction points. In INSIGMA they result from the analysis of the main traffic flows through the city. This helps to improve travel times of transit routes on the main streets as well as make the traffic in the morning and afternoon hours smoother (directions suburbs – city; city - suburbs). Therefore for each VMS board there are also assigned those road IDs (lane_id) from the static map that are part of defined cruising routes.

Generally, it is required to insert the following parameters in order to register a VMS board (see Figure 3):

- street name to which the VMS board will be assigned,
- VMS board geographical location,
- VMS board IP address,
- set of road segments within the VMS area of responsibility (in the form of lane ids),
- information about assigned junction points to particular VMS board.

C. Events' interpretation

As already mentioned the RDDRI has different sources of events on the basis of which it creates messages for VMS boards. The events may relate to different occurrences, however they may also describe the same occurrence seen from different perspective. This is particularly important when the event is notified by the road user, who may not be so accurate both in terms of the location and time of the happening (e.g. the location of the road accident). Moreover the number of event sources may give different (e.g. a few notifications of road accident in the same time in a very close but not the same location) or even contradictory information (e.g. notification about the traffic jam when independent GPSTracker system indicates the route as passable). That is why in INSIGMA there has been created Analysis and Correlation of Data Mechanism (ACDM) that takes into account the time of event occurrence, its location and the veracity of the information source to generate one event on the particular area and with particular type. This important mechanism is based on Complex Event Processing tool that uses INSIGMA events’ ontology [8] and a set or rules. It is able to process single events with different set of parameters (e.g. description of road accident with different characteristics – number of wounded people, number of vehicles involved, etc.) as well as space events describing what happened on particular area.

D. Events Analysing Module

EAM module is responsible for INSIGMA incident identification based on its parameters and then creating appropriate road messages. The process of building a road message dedicated to VMS board takes into account the principles of their construction, requirements and test methods in accordance with the existing set of normative documents including PE-EN 12966-1[9]. It is important to build only clear messages, allowing to read them quickly and make no place for different interpretations by the road users.

Generally, each road message on VMS should fulfill the following criteria:

- limited number of characters,
- it should be displayed in the appropriate number of line and text layout or pictogram. The form of road message also determines the technology in which the VMS board was built including the maximum number of characters that can be displayed,
- it is recommended to use short, concrete, standardized messages, e.g. CAR COLLISION, ROADBLOCK, ROADWORKS, TOUR, etc. Using standardized
messages facilitates the way of reading, interpreting the information and taking appropriate actions by the road users.

For the purpose of incoming road incidents interpretation in the RDDRI there has been defined dedicated conceptual dictionary that supports the process of building road messages based on incident’s properties.

**TABLE 1 RDDRI CONCEPTUAL DICTIONARY**

<table>
<thead>
<tr>
<th>INSIGMA event type</th>
<th>Displayed VMS information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INSGIMA operator/sensors</strong></td>
<td></td>
</tr>
<tr>
<td>Road closed</td>
<td>B-1/B-2</td>
</tr>
<tr>
<td>Car Collision</td>
<td>A-34</td>
</tr>
<tr>
<td>Roadworks</td>
<td>A-14</td>
</tr>
<tr>
<td>Traffic Jam</td>
<td>A-33</td>
</tr>
<tr>
<td>Slippery surface</td>
<td>A-15</td>
</tr>
<tr>
<td>Fog</td>
<td>A-30</td>
</tr>
<tr>
<td>Speed limit</td>
<td>D-7</td>
</tr>
<tr>
<td>Speed control</td>
<td>D-51</td>
</tr>
<tr>
<td><strong>ENS users</strong></td>
<td></td>
</tr>
<tr>
<td>Car Collision</td>
<td>A-34</td>
</tr>
<tr>
<td>Roadworks</td>
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<td>A-15</td>
</tr>
<tr>
<td>Fog</td>
<td>A-30</td>
</tr>
<tr>
<td><strong>RPS – distance/travel time</strong></td>
<td></td>
</tr>
<tr>
<td>Poznan – distance x km, expected travel time – y min.</td>
<td>-</td>
</tr>
</tbody>
</table>

On the basis of the conceptual dictionary, the EAM maps INSIGMA incidents on specific messages that will be sent to appropriate VMS boards. According with the INSIGMA event type and its description, the module prepares relevant road messages including data that will be displayed i.e. sign code that indicates the type of pictogram and the message content (e.g. TRAFFIC DIFFICULTIES. POSSIBLE DELAY !!!). The defined conceptual dictionary also indicates the road message priority in order to display information in the right order.

According to the defined concept, the road messages should be displayed with right priority. The priority is used to displaying the most important road information in case of multiple messages with referred to the same areas (see Figure 4).

The priority of displaying road messages on VMS board depends on their source type (1- incidents coming from the INSIGMA operator and sensors, 2 - incidents detected by the sensors, 3 - travel times to the main junction points) and type of reported incidents (see Table 1). In the first place the algorithm checks the priority of the source type. The most important are these events that impose safety threats for the INSIGMA operator and INSIGMA sensors (e.g. video camera, sound detector). Additionally, road messages are queuing according to their priority of event type (lower priority number means a higher priority), so that CAR COLLISION is more important than e.g. ROADWORKS and TRAFFIC JAM. Road messages with lower priority should be queued until the higher priority event expires. In case of incidents with the same source type and event type priority, the messages should be displayed on VMS board alternately.

**E. Distribution of RDDRI messages**

RDDRI VMS board’s messages must be reliable and displayed on the relevant board. Incorrect messages (out of date or irrelevant to the current road conditions) endanger the road safety and also contribute to the misinformation of the road users.
Each road event derived from ACDM consists of information about the event type (car collision, roadblock, traffic jam, etc.), event’s location in form of identifier of the road (lane_id) and information lifetime. On the basis of those parameters the RDDRI module builds appropriate road messages. If the event applies to a way, which is monitored by the VMS board, then it will be displayed on that board (see Figure 5).

The authors assumed that each VMS board has a list of road IDs that concern the area to which the board was assigned and to those main roads that constitute interchanges (e.g. ring road). This situation is presented in Figure 6. The message about a car collision that took place on Pulkowa street was assigned to VMS board displaying incidents on road with lane_id = 2267. The VMS board displays information about reported incidents. However this information will also be displayed on VMS board located in a different area of Warsaw, on Pulawska street, since this board also includes the lane id = 2267. This results from the analysis of the main traffic flows in Warsaw and the fact that the main traffic flow goes through these two points and the car accident will be important for many road users driving Pulawska street.

The users should be informed in the first place about incidents concerning the area in which they are actually staying. In case of reporting several incidents belonging to the same road ID, and because of the necessity of keeping the information clear and easy to understand, the road messages should be displayed in the right order. For that reasons we provide mentioned above prioritization of messages. Road message with lower priority should be displayed in the second place or, if it is still valid, after information about incidents with higher priority will expire.

As already mentioned, it is assumed that VMS boards can also display information about distance and travel time to the main junction points. The idea is to give to users driving into/out of the city basic information about current traffic condition and possible traffic difficulties. The drivers that enter to Warsaw from the South on Pulawska street are informed about distance and expected travel time to the main junction three points - road to Poznan, Gdansk and Lublin (see Figure 6). The junction points are defined in INSIGMA system based on the analysis of the averaged statistic of traffic flows.

IV. IMPLEMENTATION BRIEF

At the current stage of the project we have already developed the proof of concept of RDDRI. The discussed subsystem was implemented in .NET environment in C# language. The software consists of two main components:

- server side which is responsible for receiving INSIGMA incidents, their transformation, preparing road messages and their distribution to the VMS boards and,
- client side responsible for registering boards and displaying road messages generated by the server.
RDDRI was developed in publish-subscribe architecture (see Figure 7). The server (publisher) enables listening to the VMS boards’ subscription requests (sent by subscribers) wanting to receive road messages’ notifications. The boards are clients, who can subscribe to road messages generated by the server. RDDRI server uses topic-based approach in order to publish road messages. The topic in our case is related to the lane id parameter. Each VMS board subscribes to these particular topics. After the registration process, subscription to topics enables to control the process of road messages’ dissemination to each VMS board.

The basic functionality of the developed proof of concept has been tested in the experimental system environment. The defined scenarios included ACDM, ENS and RDDRI mechanisms. Based on incidents reported by ENS users, the ACDM generated correlated information about traffic situation. Afterwards, verified road incidents where sent to RDDRI, which prepared appropriate road messages according with the incident description and then they were displayed on particular VMS boards. In the example scenario a few ENS clients reported information about a car collision on Aleja Jerzego Waszyngtona street. The data was correlated in ACDM to prepare a single event that was then sent to the RDDRI subsystem which prepared and displayed suitable road message on the VMS board (see Figure 8). After a particular time interval the INSIGMA operator (Authority) got information that the incident is no longer valid and revoked the reported incident. Then the VMS displayed information that the street is passable again (see Figure 9).

The functionality of the developed RDDRI subsystem was verified for several scenarios. Generally, the mechanism works properly. The main problem we have encountered was proper prioritization of messages that enables to select message to be displayed in case a few of them assigned to the same road at the same time.

V. FUTURE WORK

Currently the team is working on the implementation of the final version of the RDDRI subsystem. The developed solution needs to be extended to include mechanism of displaying information in terms of multiple massages with different priority referred to the same areas. After that the performance tests are planned, especially in terms of multiple road incidents reported by INSIGMA sensors to check scalability of the publish – subscribe mechanism. The above mechanism has not been yet implemented.

We are also planning to integrate RDDRI subsystem with existing developed systems of displaying road information.

VI. SUMMARY

The created RDDRI was developed for the need of the INSIGMA system. It enables displaying information about current traffic situation on the monitored area on VMS boards. The existing VMS boards are dedicated solutions and enable displaying road messages previously defined taking into account particular specific system requirements. The described RDDRI enables retrieving, transforming and displaying information generated by the sensors, both coming from credible system operators and different road users. Each road message is built on the basis of reliable traffic information previously verified by the ACDM. The proposed mechanism assumes fully automated process of registering VMS boards.
and adapting the form of road messages (including display time and priority) according to the type of incoming incidents.

RDDRI subsystem can be integrated with existing user notification traffic systems. This process requires to develop appropriate adapters, which would allow to customize the data structure to the form used by each system.

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