viaRODOS: Monitoring and Visualisation of Current Traffic Situation on Highways

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Abstract. This paper describes methods of traffic monitoring based on on-line retrieval of big data both from cars equipped with GPS devices and stationary sensor systems. Various visualization methods and styles of presentation are discussed with focus on linear structure of gathered traffic data along observed routes. Visualized data is available via interactive web interface which uses modern vector graphic standard and enables presentation of as much information as possible with common, well-known traffic symbolism.

Keywords: Traffic Monitoring, Traffic Visualisation, Current Traffic Situation, Floating Car Data.

1 Introduction

Increasing number of new mobile devices, touch-screen and alson large video screens has brought about the need to publish information in a different way. These new trends emerge also in the field of traffic data processing and result in publishing of current traffic status based on on-line information transmission directly from the road network. There are several aspects that affect the way in which the results of traffic data processing are made accessible. New type of screens force the developers to adjust graphic concept of the output so that users receive important information. This has to be selected in an appropriate way and placed on a screen area.

An attempt to control traffic resulted in building of Intelligent Transportation System (ITS). Several projects focused on traffic data processing were established, for example [6] and [9]. The projects address different aspects: detection of current traffic, modelling of traffic flow, traffic data publication, traffic control, etc. All of these activities rely on valid input data. Processed data is offered for a variety of users. Different types of users need different styles of presentation of results. In order to satisfy users' needs several styles of visualization have been introduced: [1], [5], [2].

In our work, we focused on selection of a visual concept that considers such effects and we make an attempt to outline possible ways of traffic data publishing in specific tasks. First we describe data types and sources and then we indicate necessary traffic information characteristics. We also introduce visualization approach that was selected for our application with regards to above mentioned trends.

2 Car Data Sources in the Czech Republic

As number of cars has been growing and growing, traffic gets heavy and the probability of an accident or other problems increases. Every such unnecessary delay during the delivery of goods means a waste of resources, an increase in costs and a reduction in profits. For these reasons, drivers and shipper dispatchers need up to date information describing current traffic situation in order to efficiently plan routes and necessary stops. Generally, data sources describing actual traffic situation can be divided into two groups - stationary data sources and floating car data sources. The following paragraphs briefly describe both types of data sources and summarize their advantages and disadvantages. Finally, benefits of both data types are also outlined.

2.1 Stationary Data

In the Czech Republic, traffic situation is mostly monitored and evaluated using the stationary data. Stationary devices are integrated in traffic infrastructure and can have a form of: *camera systems* presenting current traffic situation; *inductive loop systems* detecting traffic intensity; *electronic toll system* collecting data from vehicles; *complex systems* combine more traffic detectors. This type of data is usually collected through a network of toll gates and inductive loops installed along the road.

Advantages: One of the biggest advantages of this approach is the fact that there is no need for equipping vehicles with special electronic devices. By this way, absolutely all vehicles (both personal and corporate, including foreign visitors) going through a measuring point are recorded. For example, camera systems or inductive loops work properly without any car alteration. Moreover, since the position of measuring devices is well known, it is easy to immediately calculate some important traffic indicators, such as average speed, traffic density, spacing between cars, etc.

Disadvantages: However, in the Czech Republic, this network of measuring points is relatively sparse and only about 17% of the road network is covered (about 1200 of the total of 7000 kilometres). This low density is caused, of course, by related necessary expenses – installation of such measuring points is quite expensive. For instance, installation of inductive loops requires disruption of asphalt surface, electronic toll requires building of special masts or gates etc.

Regardless of this density, there are other limitations. Electronic toll gates divide roads into fragments of various length, some of them may extend to many kilometres. Thus, data obtained from electronic tolls relate to the fragment as a whole. For example, it is possible to detect that there is a congestion on a fragment, but it is impossible to detect if its cause is located just a few metres behind electronic toll gate or many kilometres from it.

2.2 Floating Car Data

The opposite to stationary data is Floating Car Data (FCD), which describes exact movement of individual vehicles, including their trajectories, actual speed etc. Nowadays, an on-board unit including a GPS receiver becomes a standard equipment of corporate fleet cars. Moreover, increasing expansion of smart phones brought GNSS technology to our personal lives, where with combination of cheap connectivity, each vehicle can become a source of this type of data. There are many available applications which can send its data to a data centre. For example, Open Street Map gained most of its data in this way.

Advantages: The number of cars equipped with a GPS unit has doubled over the past five years. It can be expected that the trend will continue. It implies that the number of potential data sources will increase. Moreover, data from GPS receivers cover is not limited to predefined places. It is, unlike stationary data, available for all roads.

Disadvantages: On the other hand, GPS device as a part of GNSS technology, fails to provide precise outputs or the outputs can be intentionally distorted. The quality of outputs can also be influenced by the device quality, location, weather or other unpredictable and uncontrollable phenomena. All of this can have an impact on positioning, ranging from meters to tens of meters.

GNSS is based on satellite technology. GPS receiver has to be able to receive signals from several satellites. However, in some cases it is difficult. Typical example is an urban area with tall buildings which form obstacles between receiver and satellites. Then, GPS receiver is not able to report its position.

Both stationary and floating data has its strengths and weaknesses. The main goal of our work is to eliminate the above drawbacks and improve presentation of current traffic. The strength of one data type may overcome weakness of the other.

3 viaRodos Data Processing

The viaRodos system is not only a visualizer of collected stationary and floating car data. It also aggregates other essential data sources for assessment of the situation and decision support. The following paragraphs briefly introduce main viaRodos' inputs.

Traffic Data: There are two sources of stationary data:

- Toll Gates Electronic system of performance imposition of a charge [7] provides data related to vehicles above 3.5 tons. System retrieves data from 220 stations (gates) refreshed every minute. Every car record consists of information such as timestamp, gate identification, car category, car emission class.
- ASIM [11] triple-tech traffic detectors use a combination of Doppler radar, ultrasound and passive infrared technologies in a single unit. Data is retrieved from 52 profiles located on highways, processed and offered every 5 minutes in form of aggregated value—intensity, speed, occupancy for 7 categories of vehicles.

Floating Car Data: At the moment there is nearly 130 thousand vehicles providing the data. That is enough to calculate current traffic on the majority of significant roads. Data is dispatched from cars every minute and consists of information such as timestamp, location, speed and azimuth. Floating Car Data is associated with direction-oriented segments according to TMC tables.

Maps: Map basis associates traffic information with traffic infrastructure segments [4]. It is retrieved from RDS-TMC system.

Meteodata: Local meteodata is retrieved from web pages with meteoinformation and associated with traffic infrastructure segments.

JSDI: Uniform system of traffic information for the Czech Republic (JSDI) provides data representing occurrences and events related to traffic capacity and passability in the Czech Republic.

4 Visualization

As stated above, the FCD can provide useful information of different kinds than stationary sensors data. The key feature is the mobility of the sensors (the cars), and consequently, detailed segmentation can be used for roads with high FCD density (highways, main roads). There were situations observed where the FCD data signalized significant slowdown in the traffic flow 10–15 minutes before the national incident service system confirmed that there was a situation (Fig. 1).

On the other hand, the stationary data (where present) can provide different types of information (e.g. vehicle counting) and also helps validate the FCD set thus it should not be omitted.

For these reasons, it was decided to build a visualization which merges the stationary sensor data and FCD data. The basic visualization should contain static data which defines the route of interest (road infrastructure, places of interests, road network information etc.). The next layer of visualization should contain dynamic data (i.e. FCD and stationary sensors data). Moreover, other types of dynamic data can be incorporated into visualization (weather information, known incidents etc.).

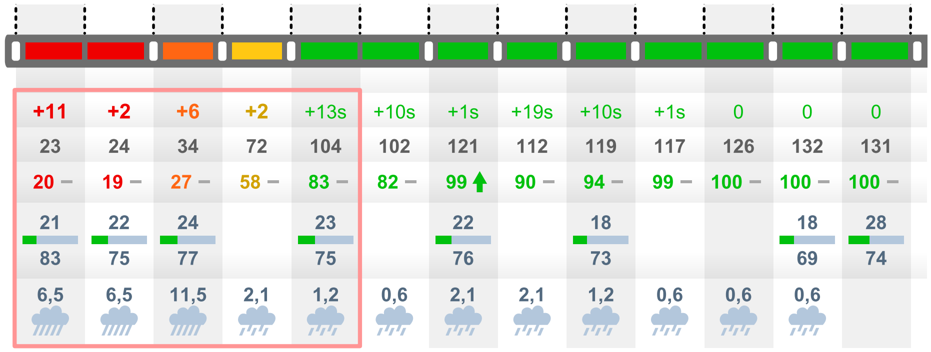

Fig. 1. FCD set an incident emergence: heavy rain caused a significant slowdown in the measured traffic flow (see the next section for detailed information about visualized data).

4.1 Selection of Features

There are many indicators present in the FCD set (see chapter above) and it is difficult to judge what kind of information is crucial and should be prioritized in the visualization. Also, we believe that the human recognition abilities along with the local experience of the real traffic managers is far better than any analytical/classification system we are able to implement right now and a rich visualization will enhance such abilities. For these reasons, the visualization should contain as many data types as possible without overwhelming the user. Finally, due to the experimental nature of the FCD set, there can be undiscovered flaws in the system and such visualization may help to identify them.

Unfortunately, these requirements appeared to be very difficult to implement with common types of traffic flow visualizations. The most serious problem is the amount of data we want to show for every road segment. The usual way how to visualize such data is put them in a geographically accurate map. But, if one wants to show more than one or two data elements for every road segment then it is almost impossible to build a well-arranged and clear visualization based on a map. Our solution to this problem was to sacrifice the spatial context in favour of the readability of the visualization.

4.2 Linear Visualization

We decided to use linear visualization [8] of a set of selected routes that were identified as interesting by traffic experts. Such simplification allows us to incorporate many "layers" of data with no degradation in readability. The linear visualization structure is shown in the figure 2.

As it is shown above we choose a tabular visualization structure as it is suitable for a large amount of data per segment. In the real application (*ViaRODOS*) the user interface allows to enable or disable every row and thus the user can customize the visualization according to his or her needs. Also, the natural

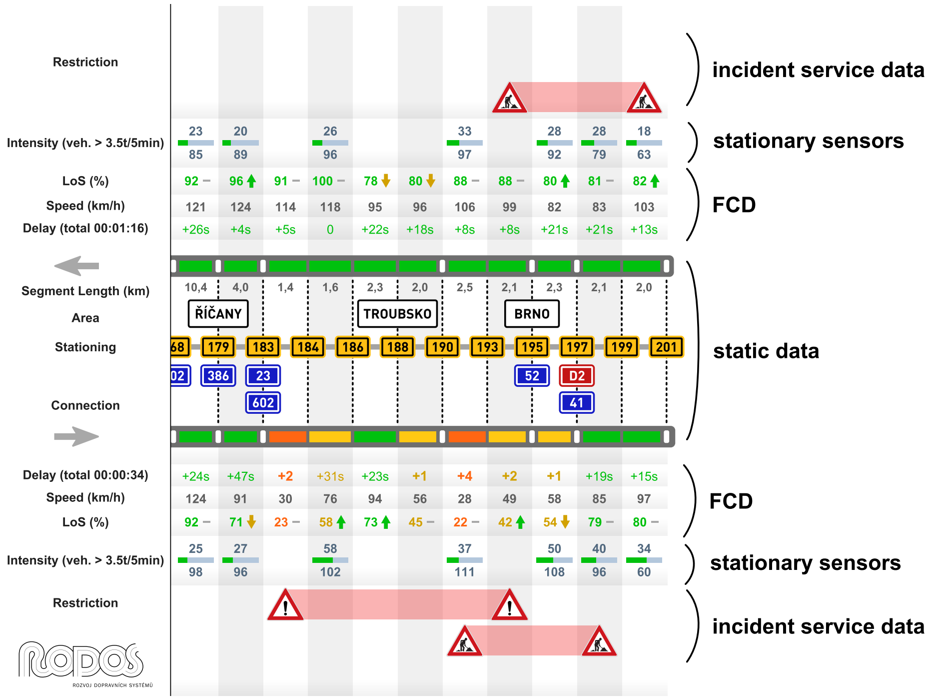

Fig. 2. Linear data visualization – detailed view: merged dynamic data is visualized above and below static route data

shape of visualization (long horizontal box) comply with front displays used in most control centers.

4.3 Spatial Relationships Versus Topology

Even though the spatial context is omitted and the user might not know the real geographical layout, there are some advantages this approach brings:

A natural view focused on route and from/to paradigm, which might be more suitable for many people. It is important to point out that the map layout is usually learned from other instances of maps than from reality. In real life, people think more topologically in terms of starting points and destinations.

The ability to represent detailed information where needed. From traffic management point of view, there are locations which have to be visualized in a higher level of detail, for example highway crossings, exits etc.. When the real scale is applied (i.e. on a map), there is significantly less space to provide necessary information in such areas. In our visualization, this is solved by higher segment granularity.

Extensibility based on linear approach. There is only one dimension used for the road itself and the other one can be used for some continuous value, e.g. temporal data can be visualized in the same manner (Fig. 3) or a classical heat map can be constructed [3].

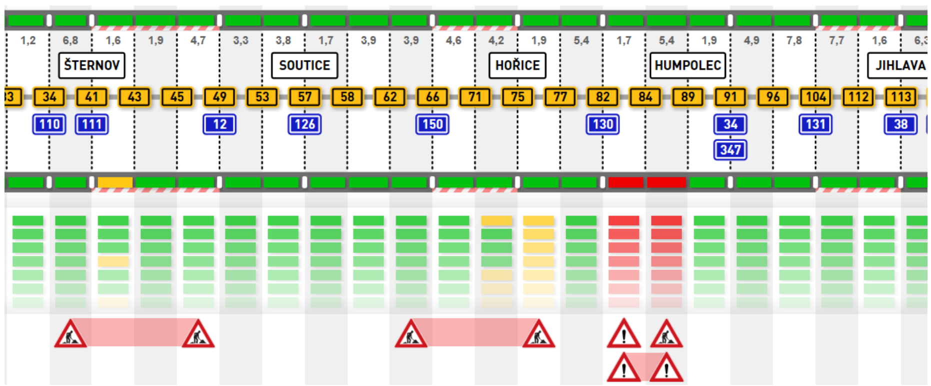

Fig. 3. Temporal data visualization: concept of two-dimensional data visualization with time as vertical axis

On the other hand, the lack of spatial context can lead to false beliefs. For example, segments appear to be of the same length (which is not true) and consequently, incident which is visualized halfway the road might not be spatially present and one neesd to be aware of this when analyzing such situations.

Also, we found that the ”route” visualization is not enough when dealing with more complex road network and if relations between the routes need to be shown. For example, there is a large reconstruction of the national main highway in progress and it is important to visualize other possible routes and traffic status there. For such cases we build a two level linear visualization. The first level shows the topological view of the road network, where only basic attributes are shown. On the detailed level, accessible by hyperlink, the customizable linear route visualization is used (as described above). Figure 4) shows the first level of the two-phased visualization and its real geographical shape.

Finally, there are situations, for example city centres, where the topology is quite complicated and the planar visualization tends to be almost identical to the real geographical shape. In such scenarios, we are forced to switch back to the common map visualization and show only basic traffic status data. Figure 5 shows Prague city center visualization along with congestion info depicted as estimated minutes of delay.

4.4 Visualization Style – Traffic Signs

When such complex visualization is made, one must stick to as many known features as possible to maintain the visualization clear and understandable. Usually,

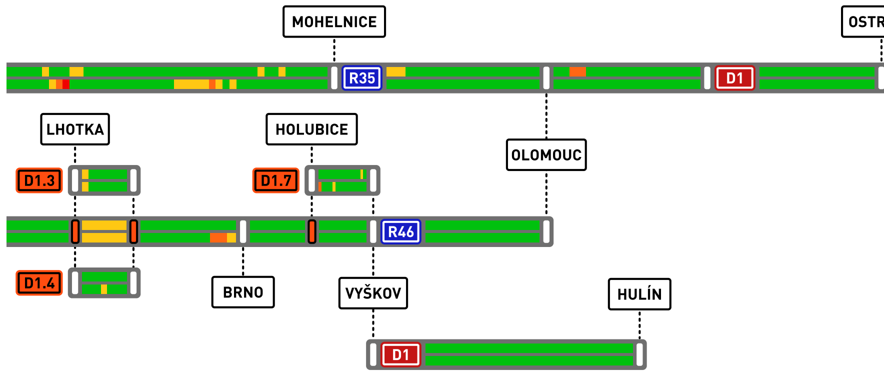

Fig. 4. Topology preserving linear visualization: Same nodes (towns) are visualized as vertical lines connecting roads at their crossings

attributes like visual style used to be marginalized but in areas where it is strictly specified (i.e. traffic rules and traffic signs) there is no reason to not follow the same visual style. Therefore, as a rule of a thumb, our visualization uses the same colours, shapes and symbols as traffic signs defined by the national traffic ordinance (Fig. 6). We believe that such approach makes the visualization familiar and more readable.

4.5 Implementation – ViaRODOS

The whole visualization of ViaRODOS system is based on web standards i.e., HTML5 & JavaScript languages. These technologies provide many advantages. For example, HTML5 standard is widely supported among various browsers thus the cross-platform support is assured. However, the main reason why the web technologies were chosen is the SVG [10]support. The main advantage of the SVG (***S****calable* ***V****ector* ***G****raphics*) approach is its scale independence. It is a standard XML based markup language which is send to the client (web browser), where it is interpreted and arranged as a graphic object. This means that the visualization will always be rendered at the best possible quality as it only depends on the size of the client's display and its resolution.

For the project purposes, a component model was built where several cascading phases provide the visualization:

1. Logical elements are created and arranged to a tree structure where the topmost element is the SVG page itself.
2. There is an SVG template for every logical element. These templates are parametrized through logical elements attributes and resulting SVG snippets are created.

Fig. 5. Common map visualization of Prague city center: complexity of city topology disallows linear visualization

3. The final SVG document is built from the snippet tree.
4. The SVG is send to the client. Possibly, JavaScript is used if interactivity is requested.

It should be pointed out that we are aware of the existing SVG wrappers for various programming languages but we decided to not use any of them. The main reason for this decision was that we are not interested in the low-level SVG elements but rather in topic related logical elements (e.g. traffic signs, symbols etc.). It would be inefficient to build such a complex SVG page through assembling basic SVG elements manually where annotated SVG snippets can supply the same functionality with only a little flexibility sacrifice.

4.6 Dynamic visualization

As explained above, the first step in the visualization building process is the construction of a logical-element tree. Such a tree must be defined somehow, and we are using proprietary XML format for this purpose, and therefore, the visualization process is dynamic but the input XML must be manually constructed. We are currently implementing a back-end user interface for route definitions as the construction of the XML input files are not very intuitive and user friendly. Figure 7 shows the first snapshot of the *Road Designer* application currently developed by our team.

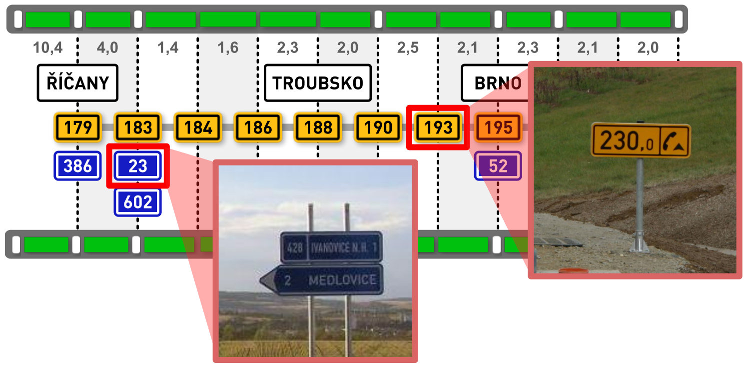

Fig. 6. Traffic signs: The ViaRODOS visualization uses the same signs, colours and symbols as defined by national traffic rules

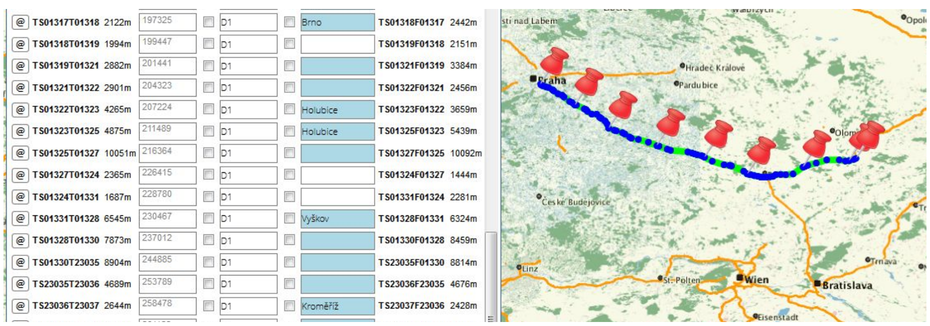

Fig. 7. Road Designer: an application for a user-friendly construction of route definition data

5 Conclusion

Overall concept of the applicable visualization approach has been created in cooperation with the dispatchers from the National Traffic Information Centre. The developed visualization design was tested in NDIC in the daily operation. This allowed subsequent addition of the dispatchers' feedback. Their knowledge of traffic monitoring and management in real situations has been taken advantage of.

Roads classified as highways and expressways have been selected for current version of the viaRODOS system based on analysis of the road network in the Czech Republic. The selected roads present significant transport network segments within the framework of transport serviceability. They have been included to our outputs and visualized in a way appropriate for a dispatching centre.

Our future research will focus on new methods of visualization of the traffic flow prediction based on the historical traffic data analysis for selected lines. For this purpose, methods from the field of time series analysis, pattern mining, string alignment and neural network will be used. As a next promising area of interest, a utilization of wireless mobile services for mutual communication between vehicles will be studied [12]. The information about weather forecast will be used for the more accurate traffic prediction.

Acknowledgments

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