USE OF WEB SERVICES FOR THE LOCALIZATION OF ROLLING STOCK WITH UTILIZATION TECHNOLOGY ORACLE SPATIAL

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ABSTRACT
This article deals with utilization of web services for the localization of rolling stock on the railway network using Oracle Spatial technology. Attention is focused on the description of the rolling stock location in a designed model of the Czech Republic railway network. Further attention is aimed on the design of web services for localization of rolling stock position on the server side with additional information for passengers.

Keywords: Railway infrastructure models, train positioning, web services

1. INTRODUCTION
Rolling stock localization is a constantly discussed topic involving a lot of companies. The problem of rolling stock localization may be divided in two main areas of interest: localization for the needs of (i) security technology (ii) information and telematics systems.
In the first case the reliability and safety are emphasized. Nevertheless, these components are often connected with higher realization costs since they often require adding further communication or identification elements/devices to railway infrastructure.
In the latter, a certain scope of inaccuracy or reduced reliability can be accepted, which often results in a significantly (lower implementation of such solutions).
Rolling stock localization has recently been connected with the use of satellite navigation system (GNSS – Global Navigation Satellite System).

2. POSSIBLE TYPES OF LOCALIZATION
Generally, localisation is prone to a wide range of approaches on how to identify the position of rolling stock on a track. Put simply, localisation may be divided into the following three groups:

- localization without the use of GNSS,
- GNSS using localization,
- GNSS-based, involving further support systems.

2.1. Rolling stock localization without the use of GNSS
This type of rolling stock localization often requires complementing the rail network infrastructure with additional construction elements, which entails higher costs of the actual implementation. On the other hand, this type of localization shows a high accuracy and reliability and is often used in the railway signalling technology. Essentially, it relates to the system of:

- ETCS (Ghazel 2104; Lieskovský and Myslivec 2010),
- Automatic train control (Chudacek and Lochman 1998; Lieskovský 2004),
- Track circuits (Dorazil 2008),
- RFID.

2.2. Rolling stock localization using GNSS
When using GNSS for various application levels, it is necessary to take an indicated position error into consideration. Indicated position error is generally based on the nature of the satellite navigation. If we use systems that operate with position information on an informative level only, we can tolerate a certain error. However, such inaccuracy is unacceptable in the railway signalling technology. However, various additional systems can be implemented to eliminate error (completely or at least partially), thus making the position of the tracked object more accurate. The following systems can be listed in this group:

- EGNOS (Senesi 2012),
- Differential GPS (O'Connor 1997).

2.3. GNSS based localization involving additional support systems
As mentioned above, precise localization of rolling stock using GNSS, especially for the needs of signalling technology, is a practically impossible. Nevertheless, the position of a rail vehicle can be determined significantly more precisely with the use of additional systems. This especially concerns solutions using inertial systems (Standlmann 2006); but also less known

systems such as those based on GNSS and contactless eddy current measurement (Becker and Poliak 2008).

3. RAILWAY NETWORK MODEL

An undirected graph, as defined graph theory, is a natural candidate for a railway network model. Based on an analysis of data provided by the company SŽDC-TUDC (consisting of service regulations, passports and codebooks), sets of algorithms were subsequently created, with which it was possible to generate a three-layer model of the rail network (Fikejz and Kavička, 2011). Roughly speaking, the track can be divided into individual so called supertracks, which consist of define supra-sections (TDNU), where each supra-section contains track definition sections (TUDU) with mileposts (in hectometres). Basic aspects of the description of the rail network are collectively shown in Figure 1.

Mileposts (in hectometres) are shown in Figure 1 with the distance in kilometres and are graphically represented using gray points. TUDU is recorded using a six-digit code (163105, 163106, 16307, 173202) and are graphically represented using solid lines (red, black, orange, brown). Individual supra-sections (CLS 007, CLS008, REG023) are shown in light blue and supertracks (B421021 1 and B421021 1A) are shown in dashed lines. A place significant in terms of transportation (branch line) is symbolized by a green square.

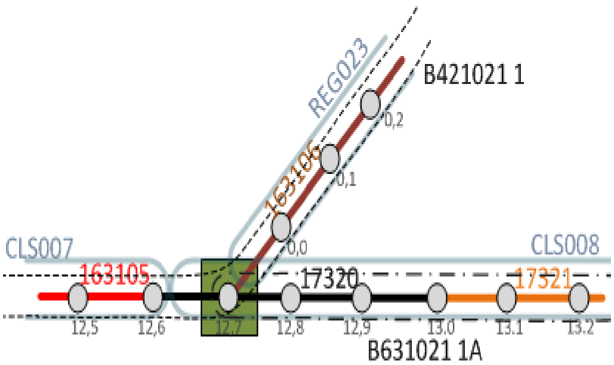

Figure 1: Basic aspects of the description of the rail network

The algorithm of a railway network model (Fikejz and Kavička, 2011; Fikejz and Řezanina 2014.) was implemented directly on the database level using PL/SQL language. However, the algorithm had to be adjusted and generalized several times since there are various nonstandard conditions in the data. These include, jumps in the mileposts (nonlinear growth of the kilometre succession between the mileposts) or change of an increasing kilometre sequence into a decreasing one. The final model includes three data layers:

- **Data-Micro**, consisting of vertices and edges,
- **Data-Mezo**, include mezo-vertices and mezo-edges
- **Data-Macro**, containing super-vertices and super-edges.

Figure 2 presents the overall concept of a complete three-layer railway network model.

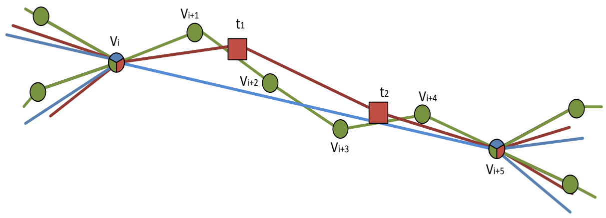

Figure 2: Illustration overall concept of a three-layer module

The data structure, non-oriented graph was finally implemented directly in the ORCLE database using the ORACLE Spatial Network Data Model (Kothuri et al. 2007) technology. This technology enables the user to build a various network representation, also involving the object scheme and the communication interface API.

The objects scheme includes metadata and network tables. The interface contains PL/SQL API (an SDO_NET packet) on the server side for the creation, control and analysis of the database network. It also includes a middle layer Java API (on client´s side) for the network analysis. The actual network is then defined by means of two compulsory tables:

- Node table,
- Link table.

For the work with spatial data, ORACLE with Spatial technology defines a special object data type SDO_GEOMETRY. This enables its user to store a number of spatial information and geometric types, such as various points, arcs, linear chains or polygons.

4. LOCALIZATION

The idea of rolling stock localisation access to tracks is based on the correct pairing up of GPS position. This position is provided by communication terminals, with the nearest vertex or edge of the graph. The discovered vertex/hectometre post not only consist of a multi-dimensional key in the form of a GPS coordinate, it is also linked, through definition sections, to further information concerning the railway network infrastructure.

Considering of the situation, that the model of railway infrastructure is stored in the database Oracle, we can use the native database functions and operators. The `SDO_NN` (*nearest neighbor*) operator was selected in view of realising this unique rolling stock localisation approach. The aforementioned operator searches for a geometric object that is closest to the object entered (like a point, for example). In other words, it is possible to find the nearest vertex, or more precisely the edge in a model, from the current rolling stock position (Figure 3).

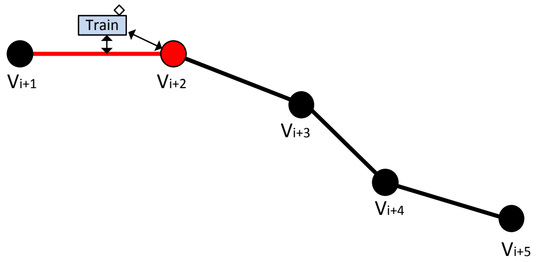

Figure 3: Main concept of localization

The actual detection of the current position of the rolling stock can be divided into the following steps:

1. **Finding the nearest vertex and edge of the graph** – from the current position of the rolling stock given the three-layer railway network model
2. **Assessment of the relevancy of incoming GPS information from the communication terminal** – verification whether the current position is not burdened by a disproportionate error (like, for example, that the distance of the rolling stock from the nearest vertex/edge is a mere few meters or tens of metres, or that the rolling stock is still assigned to the same super-edge, provided that it should still be located on it)
3. **Calculation of the exact position of the rolling stock on the edge of the model** – using perpendicular projection of the point (current rolling stock position) onto the line

The rolling stock position data was collected from the communication terminals. These communication terminals sent position information to the central database every 30 seconds (Figure 4).

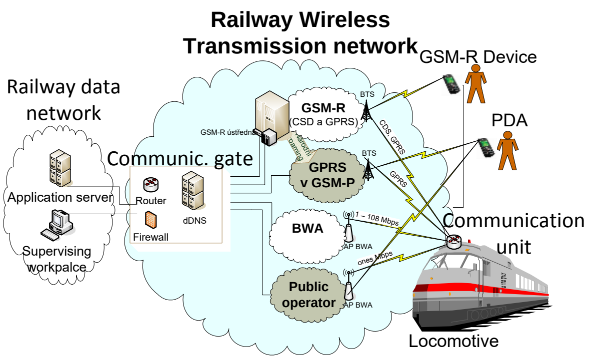

Figure 4 : Communication between the rail vehicle and dispatching centre

4.1. Searching for additional information

In addition to basic position information of the selected rail vehicle (kilometric position of selected train and definition sections), there also further additional information can be collected which is related to the railway network infrastructure. This additional information can then be used, for example, for railway information systems that are working with the position of rolling stock.
If we connect this information with the civil timetable, then we are able to find out additional information as follows:

- name and number of train under civil timetable,
- occurrence of the train within the railway station,
- previous and next railway station,
- distance in kilometres from the previous, or to the next railway station,
- current delay of the train,
- arrival time at the station.

4.1.1. Search algorithm of previous or next railway station

Searching for the previous and next railway station utilises an iterations algorithm on Data-Micro layer. This algorithm allows finding the nearest railway station, despite the fact, that within the one TUDU, there exists more stations, Figure 5.

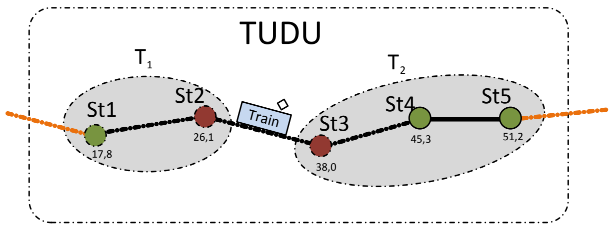

Figure 5: Finding nearest station

The concept of search algorithm consists of the following steps:

1. Sort the railway stations within the same TUDU considering the kilometric values
2. Divide the sorted railway stations into two separated subsets T1 and T2 by current position of rail vehicle
3. Select the first railway station from the subset T1 with the highest value of kilometre and the second railway station from the subset T2 with the lowest value of kilometre

As a next step, the shortest path algorithm is used for finding the real distance from the current train position to both already found railway stations and according to the civil timetable, we are able to calculate the actual time of arrival to the next railway station – and actual train delay.

5. WEB SERVICES

For exploiting the localization position of rolling stock by other applications, web services were designed. These web services provide a basic set of information about the position of rolling stock. The main advantage of this approach is the hiding of application logic of localization mechanism from the final application. In the JAVA environment, we can use two different approaches. Their main difference is in the internal request processing, and in their architecture. The Web services were carried out using:

- REST (REpresentational State Transfer),
- SOAP (Simple Object Access Protocol).

5.1. REST

REST is very often used for designing of web services. The architecture is not related to some specific port, and the HTTP protocol is very often used. In the JAVA language, we can use, for example, the well-known JAX-RS specification, and its reference implementation in the Jersey or CXF from Apache company. The main specific is HTTP API and POJO (Plain Old Java Object) complaint.

5.2. SOAP

Unlike REST, the SOAP architecture is a protocol designed for web services with a different approach because the SOAP uses strict XML messages for the communication and is oriented to RPC (Remote procedure call). In the JAVA language we can use the well-known JAX-RS specification and its possible implementations, as Metro form GlassFish company or CXF from Apache company.

5.3. Design and implementation of web services

For both approaches the set of the localization methods were prepared, which performed selected localization tasks. It possible to use these methods, which according to the train number, is able to find out the position of selected railway vehicle on the railway network. Using the JSON protocol, this position data is then returned to the client in the final application. The concept of use of a web service is shown in Figure 6.

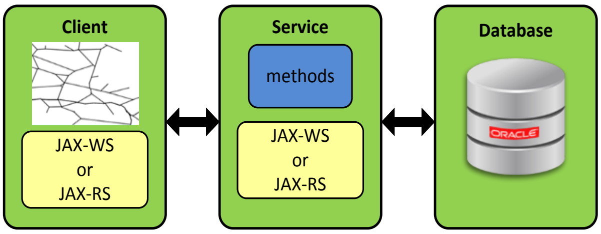

Figure 6: Concept of communication

The layer of web API is created from two different technologies (REST and SOAP). Due to this fact, we have the possibility to make a request in two ways. That means that it is only up to the client, which way is preferred.
The main web service is designed as a five separate parts, Figure 7.

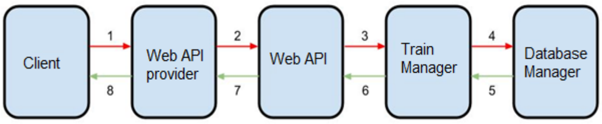

Figure 7: Concept of web API structure

Below are described the steps of communication:

1. Client is connected to the provider of the Web API,
2. After successful connection the request is sent to API for executing,
3. The web service validates the request and passes the information to *TrainManage*r class (this class is responsible for all information about train),
4. *TrainManager* class at this moment does not have any information about this train, and so sends information to *DatabaseManager* class. This class is responsible for the communication with the database and performs the desired functions,
5. Information from the database is sent back to *TrainManager* class,
6. *TrainManager* class processes the information in into the desired objects and further sends them back,
7. On the base of request of input data format, the web service converts the objects and sends back the information about train position,
8. Provider sends to client the requested information (information about train position).

6. TESTING

In order to test, a supportive software application was designed with an integrated core of discrete simulation. This supporting application allows the simulation of railway traffic of rolling stock on the railway network. Based on historical records and data generated, it is possible to save the current positions of rolling stock to the database in the defined time intervals. This train position data is subsequently used by testing application for localization of rolling stock within the monitored segment of the rail network.
The testing application was designed a mobile application based on the Android platform. This testing application uses a designed web service, which is based

on the input parameter/s (for example the train number). This provides a complex set of information on the selected train position. Information is shown about:

- current GPS position,
- definition sections (TUDU),
- current kilometre positions,
- route,
- current speed,
- name of the next railway station,
- distance to the next railway station.
- estimated time of arrival,
- current delays.

The testing application also allows us to view the civil timetable for the selected train vehicle and the service which is available on board the train. Also, the actual train position is shown on the interactive base map. The testing application for the Android platform is shown in Figure 8.

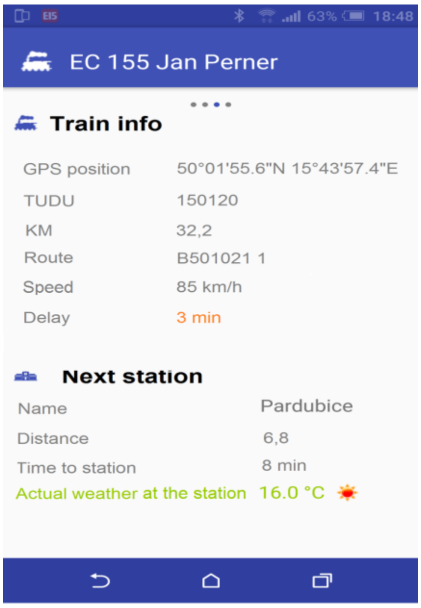

Figure 8: Android application

CONCLUSION

Attention was paid to the possible use of GNSS technology for utilization of web services for the localization of rolling stock. Oracle Spatial technology was employed. A multi-layered model (based on undirected graph) of the railway network infrastructure was designed. Further, algorithm for identification of the position of rolling stock was implemented in the railway network. This algorithm included the search of the previous or next railway station. For exploiting the localization position of rolling stock by other applications, the web services REST/SOAP were designed. These web services provide the basic set of information about the position of rolling stock. For the testing, as mobile application based on the Android platform was designed. This testing application uses a designed web service, which is based on the input parameter/s (for example the train number), provides a complex set of information about the selected train position.

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