Automatic Railway Track Surveillance using a dGNSS enabled Mobile Onboard Unit in loading optimization

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Abstract

This paper describes how a dGNSS enabled mobile on-board unit on a railway vehicle and appropriate software tools are used to acquire surveillance data from railway tracks in an efficient way and without disturbance of the daily shunting work. It supports the optimization of processes of loading and dispatching in an oil refinery. We describe the motivation, the challenges of using dGNSS in such environment and the practical technical solution.

Keywords: railway; GNSS; surveillance; system optimization; loading support

I. Introduction

For the seamless integration of all information sources in the loading and dispatching processes in an oil refinery an "Integrated Rail Operating Framework" (IROF) is under development and test. This Framework shall coordinate the customer and the responsible railway operator. The „Rail Transport Mobility Optimization" (RTMO) application developed in this project supervises the capacity management and act as optimization tool for an "end to end (e2e) integrated rail supply chain (SC)" from the rail hub/feeder line of the consignor, to the rail hub/feeder line of the consignee. Goal is the combination of the currently different IT systems and processes of the industrial partner with those of the rail operator (RO) to create a unified transport information system, which results in an increase of efficiency for both companies in logistics and production. Through this first of its kind cross-enterprise-wide planning and coordination of rail logistics processes, customers are ensured of a perfect e2e integrated rail logistics service.

Permanently knowledge of the current position of the shunting locomotives is vital for the control and update of the planning and execution processes. For that issue, an onboard unit with proper and high accurate tracking & tracing functionality was developed to report continuously the actual position of the shunting vehicles. Additionally we also developed tools for automatic aquiring the geographic track layout which is further used to display the actual positions on an electronic map generated from this data and extend the position information by also track number and track section where the shunting device is currently moving around.

FFG-Austrian Research Promotion Agency, RCA -Rail Cargo Austria.

II. Motivation

A. *Support of loading process*

The loading processes of railway wagons for refinery products is time consuming and complex. Wagons first have to be checked for their technical status (open valves, beeing empty, status of wheels and breaks), then have to be in sequence according the load planning and after loading beeing prepared for departure at the scheduled time. In bigger yards more than one shunting locomotive are used and the movement of all vehicles have to be coordinated for maximum throughput, safety and efficiency. Therefore knowing the actual location of all vehicles on the track network of the loading yard all the time is highly essential. To equip each wagon with an location tracking device is too expensive and even not possible as wagons are often taken from a wagonpool and no one will bear the cost for equipment and operation. But to locate only the shunting vehicle (shunting locomotives) is an reasonable aproach as they will normally stay on the yard. Together with the order processing software which tracks the wagons currently handled on the yard the above mentioned goal can be achieved. Communication between the onboard-unit and the host(-software) is done by wireless communication like Wi-Fi or using the Global Services for Mobile communication (GSM).

B. *Challenges for the system design*

The system design faces following challenges:

- The shunting equipment is not owned by the loading company but offered by an railway partner. They are often replaced by other vehicles. Therefore the tracking system must not be installed fix on the shunting locos.

- The accuracy of the location message must meet the special requirements raised by the narrow distance between the railway tracks which is about 4-6m. Standard accuracy of position messages gathered from a satellite based global navigation system (GNSS) show deviations of 5m to 12m or more. This will lead to misinterpretation of the current location and therefore cannot be used.
- No other infrastructure for the tracking of the railway equipment may by erected within the yard.
- The onboard equipment shall send the high accurate location information in intervals of 1 seconds to support the loading processing software as requested.

III. System Concept

The system concept is based on an fully self contained low power onboard device with embedded modules for power generation, -storage and -management, a 16/32 bit processing device, local storage (SD-Card), GSM-communication module and last not least a GNSS receiver module with ability to accept real-time-correction data and very low power operating modes.

The unit is powered by a solar cell which also generates enough energy to load an internal battery which takes over the power in times of loss of sunlight.

Fig.1 shows the first prototype of the onboard unit. The unit is mounted on the locomotive by use of magnetic mounts and secured against fall down in case of forces generated during the shunting process when wagons are connected to or disconnected from the train.

The onboard unit has no user manageable parts and is simply attached at the beginning of the work and detached at the end by an trained employee of the operator. All functions are configured and controlled remotely including also updating the software.

A. *Energy management*

The energy management is the biggest challenge as the available energy for operation and (re-)charging of the internal battery is minimal. The main energy source is a solar panel integrated in the enclosure. A alternative charging option is a wireless power transmitter/receiver which is used to preload the equipment when the unit is not used and stored in the office.

A high sophisticated operation scheme using sleep modes of all components whenever possible help further to ensure availability of the device when in use day and night. The power consumption can be reduced to 10% or less compared to the power needed in full operation mode.

In the case the energy drops below a specific level, the onboard unit sends an alert to inform the host software before switching into an „recharge-mode“ and stops communication. When enough energy is re-charged, the unit switches back to full operation and again informs the host about that.

B. *Communication and GNSS module*

The communication from the onboard unit to the host is handled by an GSM-module operating in data mode. Those unit handles all communication channels needed during the operation. The local position is gathered by an GNSS module which is enabled for dGNSS-correction. The module can be exchanged by other ones according the availability of new modules with improved functions on the market.

IV. Information Flow

The information generated by the onboard-unit (geographic location, speed, moving direction) is forwarded in real time to a communication management host, which serves two final destinations: on first hand the information is sent to a standard tracking & tracing application where the actual location of all shunting locomotives (or other vehicles equipped) is visualized on electronic maps for getting a fast overview about the situation in the field. Furthermore the geographic information is mapped to the tracknumber and section where the locomotive is currently moving around. This information is the vital information for the RTMO-application which is the receiver of that results. Fig. 2 show this information flow . The correction information is received via data channel as stream from the dGNSS-Provider.

The tracking & tracing platform is a implementation of the Open GTS geo server [1]. The electronic maps use are taken from the open streetmap initiative (OSM) [2]. The access is done using a standard web browser. The communication channel to the RTMO is implemented as a fixed TCP/IP-connection.

Fig.1 – GNSS-onboard-unit prototype

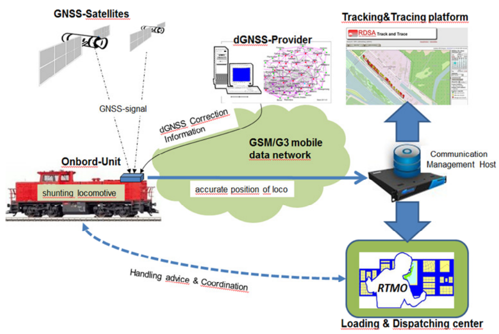

Fig.2 – Information flow

The message interval of 1 second generates a significant amount of data on the communication channels, mainly the tcp/ip connections using the mobile communication.

Tests showed, that even using update rates of 1 second or less on the onboard unit's GNSS receiver, the timespan between the generation of the geolocation information in the field by the onboard unit and the availability of this information in the RTMO application takes up to 5 seconds. This sounds not much but during this time the shunting process may have been moved forward for about 35m assuming a speed of 12km/h which is more or less the length of two railway vehicles.

V. dGNSS and Surveillance

A. Why a high accurate location information is needed

It is necessary to exactly pinpoint the location of the locomotive on the respective track and track section of the railway net within the loading yard. Standard GNSS-Signals are not as reliable as needed.

Fig. 3 shows the situation of track layout compared to available accuracy of a standard GNSS-location information. The distance between two railway tracks is about 4-6m while the accuracy of GNSS signal lays within a radius of up to 12m. The maximum acceptable deviation is maximum 1m. So the raw location, gathered from the GNSS-Satellites, has to be adjusted to a high accuracy position information. This is done by using the differential correction information supplied over the air from an differential correction information provider (dGNSS-provider) as shown in Fig. 2.

The stream of correction information, supplied in real time is used to adjust the "raw" GNSS-measurement to the requested high accurate position. This position is then forwarded using the GSM data channel to the host applications.

The accuracy of the transmitted position thus can be within the requested radius of less than 1m and even better according which correction service is used (and payd). For the standard operation – the tracking of the shunting locomotives - a cost efficient accuracy of 1m was used. The service was stable and showed good results in the first field tests.

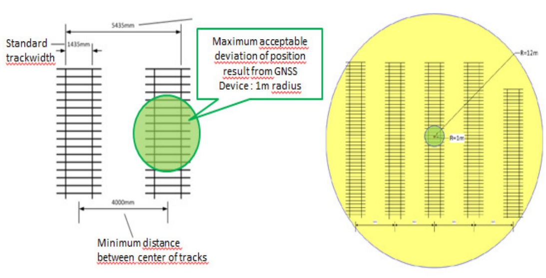

Fig.3 – GNSS-accuracy versa railway track layout

VI. Surveillance function

That a position of a locomotive can be displayed on the right track on the digital map, this map must comply with the real world and the geographic positions reported from the GNSS device. Additionally, knowing the exact geographic layout of the tracks, the reported location of the locomotive can be mapped to the track and section of track and extend the value of information offered to the RTMO.

Fig. 4 shows the evolution of the raw GNSS-signal to the high accurate information and final the mapping to track/section information

A. Reason for own survaillance of track network(s)

Many available digital maps are already quite actual, but even if the available map has acceptable accuracy, only the display of the actual position of the locos on the right position of the map can be offered. There is no relation to the track number and sections of tracks which is essential for the RTMO-application.

To support the RTMO, this information is vital. Also – as Fig.5 shows – often the available maps are not identically with the real world: the example show an open street map (OSM) representation where the tracks are well located but the two track-ends in the red circle are not as in the real world! The read dots are reference positions, measured in the project with surveillance equipment.

To achieve material reflecting the real world, one way is to order the surveillance of all tracks from an surveillance office. This is expensive and time consuming, and – even more important – has a negative impact on the loading processes which are running 24 hrs 7 days a week. Surveillance needs tracks to be closed down during the surveillance work or even production output will be reduced by the disturbancies.

The solution is to make our own surveillance using the tracking & tracing equipment on board.

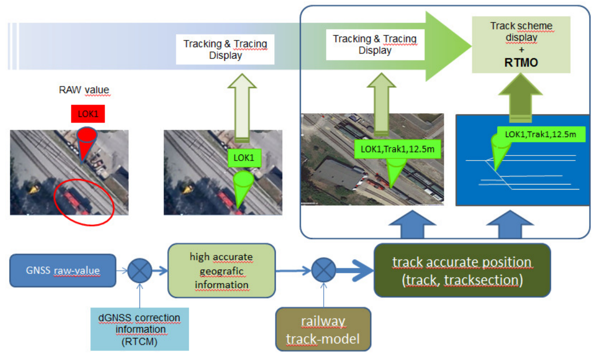

Fig.4 – From the raw-GNSS signal to an high accurate position information

B. The Solution: "Surveillance Mode" of onboard device

The functionality of the onboard unit was therefore extended by an additional operation mode – the „surveillance mode". The accuracy level of the GNSS-correction information received from the dGNSS-Provider can be set to „high accuracy" by an remote command sent from the monitoring console of the system (located in the communication management host' center). Immediately after this command is accepted by the onboard unit, the unit start to deliver position messages with „surveillance grade accuracy".

The higher costs of this service is anyway less than to order this work from a surveillance office and also there is no influence in the operation on the yard as the "surveillance" is done during the normal work by collecting the information over some hours or even days.

C. Get the track scheme from the GNSS-"surveillance" messages

To extract the track scheme, the "surveillance" messages received by the onboard unit are collected and stored in a local database file. In the next step, all implausible location information and/or location messages which do not comply with the accepted accuracy are discarded.

The rest of messages is moved to a software application, called the "track model builder". The generation of the track scheme is based on a grid of cells, where each cell has a center location allocated to a geographic position (lat/lon) and covers an area of 5x5m. This grid covers the area of the loading yard respectively the area where the track scheme shall be generated for.

The track scheme builder work in two steps. In the first phase all position information are allocated in an array as displayed in Fig. 6. Each message is allocated to the respective cell by searching for the minimum distance between the cell's center and the reported position. Each cell has a counter, which is incremented each time a location is allocated to that cell. This Process can be stopped and/or repeated or continued any time until the amount of data is sufficient to create a track scheme.

In the second step, shown in Fig.7, lines are identified using image processing tools. After that, the findings have to be classified to object classes of "rail tracks", "switches", "other objects" or artifacts. Then we have to find out, where the connection points between the objects are. Then we have to identify the exact boundaries of the object and the connecting points. The result is at the end a list of objects describing each part of the railway track network.

In the final stage, all identified track section information are manually verified and extended with further property-information as track number, mode of usage, and other relevant information. Then the results are ready to be used in the application.

Also a vector or raster map can be generated which is then used in the tracking & tracking application for the display of the locos.

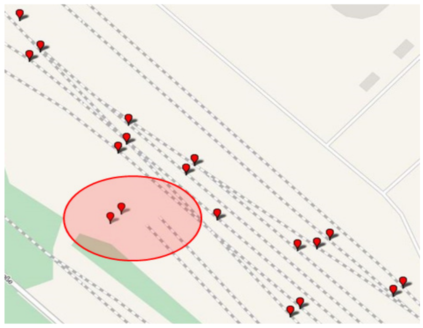

Fig.5 - available maps vs. real world

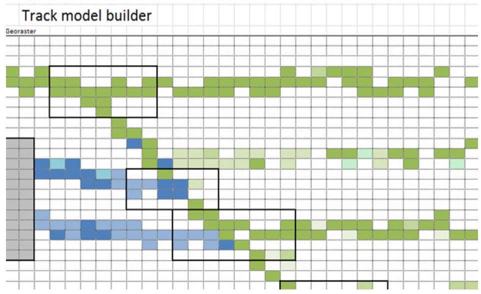

Fig.6 Track model building –step 1

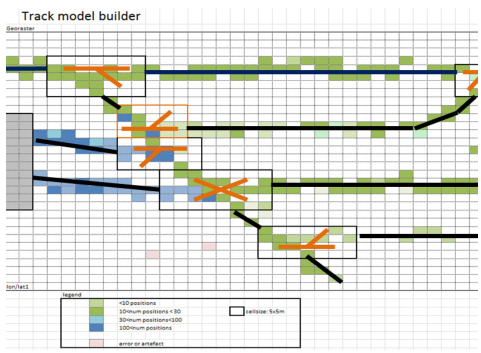

Fig.7 Track model building –step 2

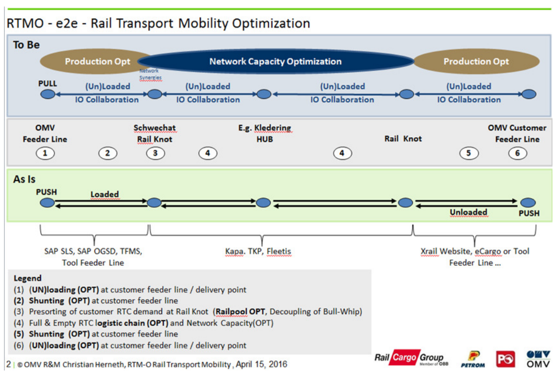

Fig.8. RTMO structure

VII. Impact on the (Un)- Loading and Dispatching Processes

A. *RTMO principles*

Fig.8 shows the principal structure of the RTMO-aproach. After developing the set of operational optimization strategies for the Feeder Line (FL) a simulator tool provides evidence of the improvement potential of each FL-SC strategy. The so gained insights guide development of optimization models for coarse & fine planning. The IT platform integrates all partner data and hosts the simulation and optimization-tools and visualizes results in cockpit like views. Fig.8 shows the depencendies and collaboration between the stakeholders.

Development & testing of organization-, process, information, data, interface and bus rule - requirements for the FL logistics organization for optimization and operational control helps to seamless integrate with the RO processes, organization & systems.

The constant changes in the industry and production (introduction of "just-in-time production") brings a change in supply chain requirements and for their transport partner, to which RO can-not respond with adequate flexibility to short-term demand changes. This is in strong contrast to the more flexible transportation by road. The result from this lack of information flows and thus non-aligned plans are over or under capacity at the RO or the industrial partner, each causing high costs for the company.

B. *Impact of the tracking & tracing unit's information*

An important objective in the project "RTMO" is maximizing the customers (un)loading capacities through a coordinated planning optimization and control of the RO's "execution process activities", coupled with a simultaneous minimization of the customer's "execution process activities".

As particularly far-reaching are considered the deep data integrations of operational work processes of each industrial partner and the resulting digitization of the currently still manually steered activities; To be determined as a special feature in the course of planned scientific research.

The optimization of the utilization of the RO's train system in direct coordination with the customer has several positive aspects. These include better utilization of existing rail infrastructure, the highest possible utilization of locomotives and a better planning of the personnel required.

These processes are highly supported by the information sent by the onboard units and the track / track section information generated from the track scheme gathered by the surveillance feature.

IX. Status and Outlook

The system is still under development but actually in the final pilot stage and operated using 2 onboard units for aquiring the information from the field. All hard- and software components are undergoing intensive tests and continuous improvements according the results and experiences from the test.

It is planned to bring the system to a commercial level in Q1 / 2017.

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