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Concept of Digital Platform at Marshalling Yards



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ABSTRACT

Implementation of the Industry 4.0 concept is considered in the context of automation of railway transport. The analysis refers to prerequisites for creation of a universal digital platform integrating automation systems at a marshalling yard.

The example of JSC Russian Railways has contributed to describe the main goals of Digital Station concept, aimed at fusion of data from low-level local automation equipment. The presented functionality of the system for control and processing information on movements of wagons and locomotives at the station in real time (SCPI MWL RT) implements the set goals by integrating initial data from all automation and centralised traffic control systems operating at the station, checking it for consistency, eliminating information redundancy and generating in real time the current model of a marshalling yard regarding trains and wagons and based on data «from the wheel».

Description of the existing functionality of SCPI MWL RT, implemented at a facility, is followed by the analysis of the advantages of this system for the railway cargo transportation network. The objective of the paper is to present some previously unpublished technical solutions for implementation of the specified functionality. The methods of the research are based on fusion of heterogeneous data received from floor devices, specialised video cameras, as well as from real-time wagon positioning models.

It is shown that adoption of new technical solutions for SCPI MWL RT will allow to considerably improve the quality of planning of technological process of classifying railway wagons and of forecasting the need for infrastructure maintenance. Deep learning algorithms presented ensure functioning of the developed solutions in real time with high accuracy. Further steps described refer to implementation of a digital platform in the form of a digital twin of a marshalling yard, creating thus a prerequisite for development of an intelligent automatic machine to control the marshalling yard, as well as for further planned ways to implementation there-of.

Keywords: railway, marshalling yard, intelligent technologies, digitalisation, real-time models, automation systems, digital station.

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BACKGROUND

The use of modern technologies within the framework of Industry 4.0 concept in terms of digitalisation and intellectualisation [1] of the railway infrastructure in general and of marshalling yards, as of the most complex components of cargo flows' servicing system in particular, should lead to a sharp increase in labour productivity, a reduction in operating costs, and a transition to low-population operation technologies followed by a simultaneous increase in safety of technological processes [2].

Now, the most important junction stations of the railway network of JSC Russian Railways, in conformity to the approved «Updated layout and development program of marshalling yards, considering development of auxiliary (technical, pre-junction) stations» and its subprogram «Digital marshalling complex» are subject to on-going design works and implementation of digital modules, the latter ones include:

- Integrated post for automated reception and diagnostics of rolling stock at marshalling yards (PPSS / RPMY[1]) [3].
- Integrated system of automated control of the marshalling process (KSAU SP / ISAC MP) [4].
- Automatic shunting locomotive signalling (MALS / ASLS) [5].
- Interactive console of ISAC MP [6].
- Automation of shunting movements on the hump.
- Automated fencing/securing on stations' tracks.
- Extended information exchange with the automated control system of the station (ASU ST / ACS ST).
- System for control and processing information on movements of wagons and locomotives at the station in real time (SKPI PVL RV / SCPI MWL RT) [7].

A significant drawback in existing information systems at marshalling yards, resulting in significant distortions of the developed values of indicators and limiting the effectiveness of automated operation planning, is associated with the manual input of information about technological operations at the marshalling yard.

Various devices and systems for automated and centralised traffic control are used at marshalling stations: system of automatic identification of rolling stock (SAI PS / SAI RS); subsystems intended for the hump system (ISAC MP), ASLS, automatic system of wagon and train commercial monitoring (ASKOPV / AS), several control and diagnostic systems comprising automatic diagnostics system of signalling, blocking and centralised traffic control equipment (ADK SCB / ADS SBCTC), hardware and software system of dispatching control (APK DK / HSS DC), etc. But none of these systems can develop a full-fledged, adequate station model comprising information on wagons and trains in real time since information in each of the listed systems is not complete and self-sufficient. So, for example, SAI RS does not provide control of wagons not equipped with identification sensors, and provides control only at the station entrance and exit; ASLS system is able to control only shunting locomotives equipped with appropriate on-board equipment; systems intended for the hump system control only the area of the hump and of sorting tracks, etc.

The objective of «Digital Sorting Complex» subprogram is to create a digital platform based on which fusion of data received from the low-level local automation devices is provided, namely:

- Integration of initial information from all automation and centralised traffic control systems operating at the station.
- Checking the received information for consistency.
- Elimination of information redundancy.
- Development in real time of the current marshalling yard's model considering wagons and trains and based on data «from the wheel».

The *objective* of this paper is to describe a part of developments within the framework of «Digital Sorting Complex» subprogram, namely, to present previously unpublished technical solutions aimed at increasing

[1] Hereinafter the former abbreviation is transliteration of the original term in Russian, the latter is based on the translated full term. Translated abbreviations are used further in the text. – *Interpreter's note.*

reliability of the model of location of mobile units.

The *methods* of the research are tools of fusion of heterogeneous data obtained from floor devices, specialised video cameras, as well as of real-time wagon positioning models.

RESULTS

The main tasks of the digital platform being developed

The *digital rail station* should provide comprehensive automation of control and monitoring of technological processes, the state of the station infrastructure in real time based on integration of systems of local low-level automation and on exclusion of manual input of information. The rail digital station, thanks to a dynamic digital model of the station, will allow building the schedule of the work performed (GIR/SWP) of the station only according to the correct and relevant actual data.

Based on this, a digital station should be built on the following principles [8]:

• Coverage of station tracks with control devices capable to maintain a reliable digital model of the station.

• Continuous monitoring of the state of all devices, mechanisms, mobile units via the Internet of Things, creating predictive diagnostic algorithms for predictable technical and technological maintenance of infrastructure facilities, adding station personnel to the system network.

• Continuous maintenance of the digital model of the station at several levels: the schedule of completed and planned operations, the actual state of floor devices, location of rolling stock, location of locomotives, location of personnel.

The implementation of the above principles to one degree or another, independently or in conjunction with other modules of the digital sorting complex, as well as with upper-level information systems (ACS of the station), is carried out by a system for control and processing information on movements of wagons and locomotives at the station in real time (SCPI MWL RT). SCPI MWL RT was developed by the specialists of JSC NIIAS based on many years of experience in automating sorting and classifying processes at the most important stations of the railway network of JSC Russian Railways.

The development of SCPI MWL RT is aimed at:

• Construction of a single system for recording events at the marshalling station in real time, independent of the specific type of low-level local automation systems and floor equipment.

• Providing the station's ACS with reliable information about the actual movements of rolling stock, the start and end times of technological operations at the station according to real data.

For these purposes, the system has already implemented:

• Collection of information from the systems of low-level automation and ACS of the station.

• Tracking and recording the movement of rolling stock at the station.

• Transmission of information on changes in accumulation of rolling stock on the tracks of the marshalling yard to ACS ST.

• Transmission of information on beginning and completion of technological operations on the station tracks to ACS ST.

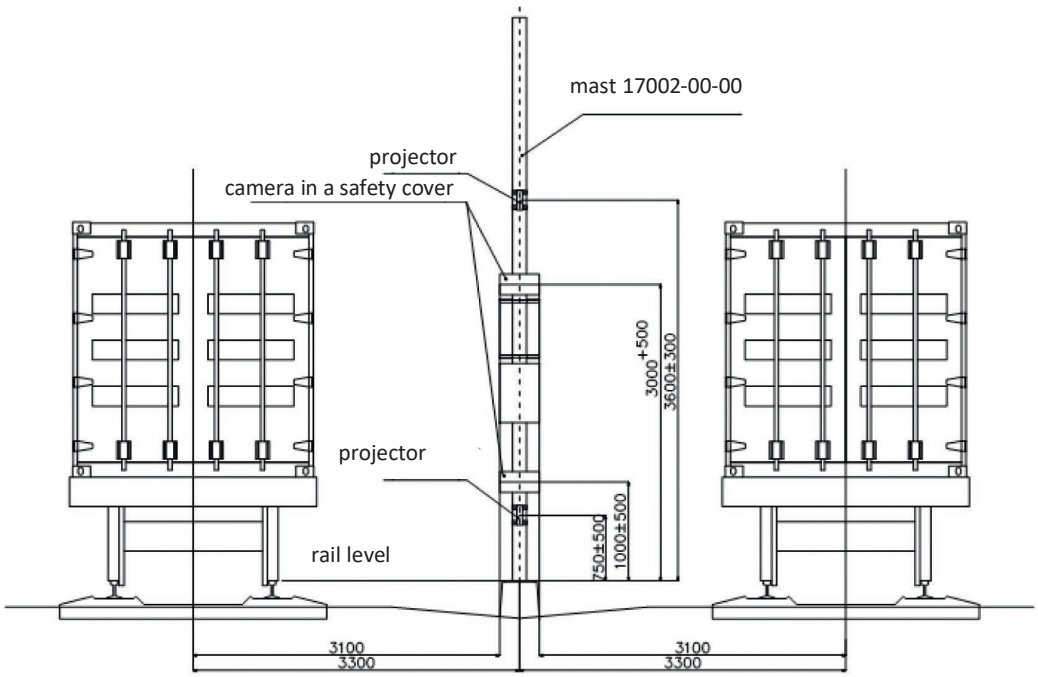
• Displaying the current location of rolling stock on AWS screens (including remote ones) and on the board intended for collective use by the station's operational dispatching personnel.

• Logging of the recorded movements of rolling stock at the station.

• Logging of messages during exchange with other ACSs.

• Diagnostics of the fixed and floor devices of the signalling, blocking and centralised traffic control system of the marshalling yard.

In fact, at present, SCPI MWL RT is not only an independent system for collecting and processing information from devices of low-level local automation equipment but is also an aggregator of information from automation systems controlling individual zones of the station (ISAC MP, RPMY, fencing control systems, etc.).



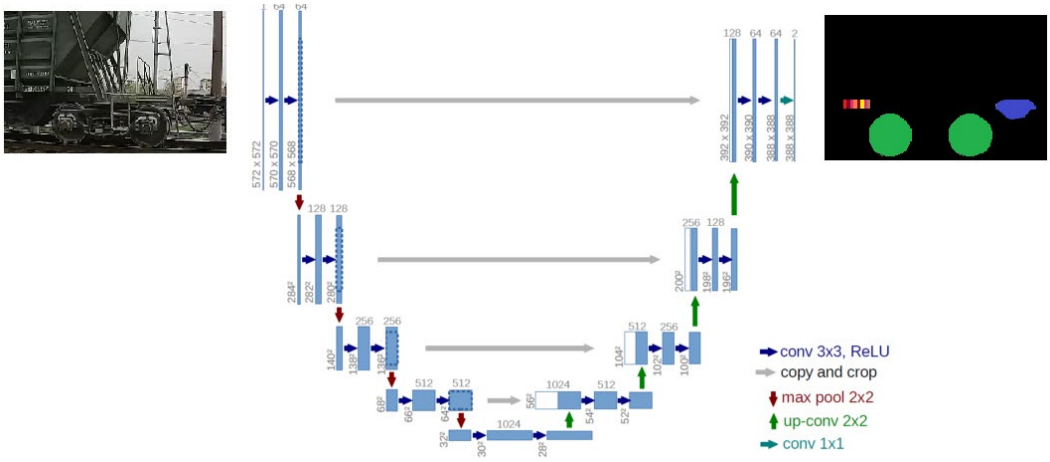
Pic. 1. Placement of the UCP (JSC NIIAS).

Within the framework of the paradigm of the Internet of Things and other intelligent technologies of Industry 4.0, considering the large number of already implemented automation systems at stations and the emerging new technical tools, there is the need to develop the SCPI MWL RT to the degree of a common digital station platform for interaction of all systems, devices, mobile units, and personnel at the station in real time through a common virtual network. The main functions of such a digital platform can include:

• Maintaining a single real-time model of the state of all floor devices at the station.

• Maintaining a single real-time model of location of all mobile units at the station (wagon, locomotive, shunted group of wagons, train). The model should include information on the type, dimensions, condition of rolling stock according to data received from RPMY, or from other points

Pic. 2. Illustration of the work of UCP (JSC NIIAS, photo).



Pic. 3. The architecture of the artificial neural network used to identify the contours of automatic couplings, axles, and identification numbers of rolling stock (compiled with the use of [9]).

of identification of movement of rolling stock through the station.

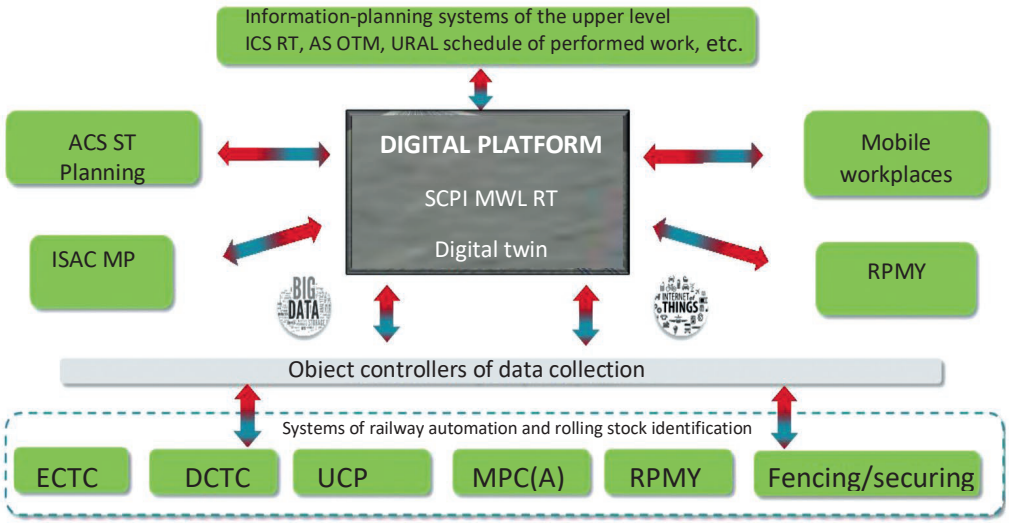
• Maintaining a single real-time model of location of all station personnel located in hazardous areas and having electronic tracking devices.

• Ensuring information interaction between adjacent subsystems according to a common universal protocol of interaction due to information from the real-time model.

• Ability to add new devices, personnel, and systems to the common network.

• Transmission of data on movements of the processed wagon flow and shunting locomotives, as well as on the state of floor devices to the upper-level system for development of plan of operations and of a work schedule according to data received «from the wheel».

• Saving all incoming information to the database.



Pic. 4. Block diagram of interaction between the digital platform and the subsystems of the digital station (compiled by the authors).
IMS RT – the intelligent management system for railway transport, AS OTM – the automated system for operative traffic management, GID URAL – an automated system for maintaining and analysing the schedule of completed traffic, EC, DC, MPC (A) – respectively electric, dispatching, microprocessor-based centralised traffic control systems.

• Using big data on accumulated statistics to analyse bottlenecks and possible additional performance capacity of equipment.

• Troubleshooting and issuing recommendations on necessary maintenance and the sequence of performance of certain technological processes.

The implementation of the above-mentioned functions of a digital platform based on SCPI MWL RT by specialists of JSC NIIAS is planned as part of implementation of the system at Chelyabinsk-Glavny station [Chelyabinsk Main station] as part of the «Digital Sorting Complex» investment program.

As part of implementation of the functions of the digital platform, specialists of the institute have developed and are developing a scientific basis and several additional technical solutions.

Technical solutions for improving SCPI MWL RT to implement the functions of a digital platform

One of the technical solutions designed to increase reliability of the model of location of mobile units at the station is the universal counting point (STU/UCP) developed by the institute's specialists. The structure of the universal counting point includes devices for fixing the axles of rolling stock (UFPO/DFARS), lighting projectors to create uniform illumination of the controlled area and specialised video cameras for identifying the type of rolling stock.

The universal counting point will provide not only identification of the fact of movement and fixation of the total number of axles of the rearranged group of rolling stock, but also control of the inventory [registration] number, the number of moving units and the number of axles of each rolling unit.

The plan of UCP placement in the intertrack space is shown in Pic. 1.

The performance of its functions by UCP is implemented by fusion of data received from floor devices (axle counting sensors, track circuits), from specialised video cameras and from a real-time model of location of all mobile units at the station.

The data received from specialised cameras are pre-processed based on computer vision algorithms (Pic. 2).

The use of deep learning algorithms (Pic. 3, basic architecture of artificial neural network is compiled based on [9]) and parallel computing mechanisms [10] enables data processing and transmission to the central control module in real time. A distinctive feature of the tools used is simultaneous detection of several indicators: automatic couplings, axles and rolling stock numbers.

At the same time, due to interaction of each counting point with the general station model of rolling stock placement, a very high identification accuracy is achieved with a minimum composition of the counting point equipment.

Further stages of project development

The real-time model for placement of mobile units at the station and the state of floor devices with reliable information «from the wheel» will significantly improve quality of planning of the technological process in upper-level information systems (ACS ST), considering the real condition and forecast of the need for infrastructure maintenance.

Only if the basic functions of the digital platform at the station, indicated above, are implemented, will it be possible to implement microprocessor-based centralised traffic control algorithms with the possibility of automatic execution of a route assignment program of any size. This, in turn, will allow solving the problem of creating an intelligent automatic device capable to replace the human when preparing and checking the routes of arriving and departing trains.

In that case, the digital platform turns also in fact into a digital twin [11] of the station for third-party's systems. This allows the use of augmented reality technologies: to present the predicted performance results of the station, i.e., to provide maintenance personnel with information about what will happen at different horizons of work planning; reflect

the current and predict the future state of the station infrastructure facilities, for example, the remaining service life of the compressor station and its maintenance timing.

The digital twin, as the elements, which are digital copies of infrastructure devices, as well as statistics of their functioning, are accumulated and thanks to many fixed variants of their interaction, becomes, in essence, a full-fledged carrier of artificial intelligence.

The proposed structure of interaction between the subsystems of the digital station and the digital platform will look as follows (Pic. 4).

The feature of the proposed structure is the ability to add new subsystems by connecting them to the digital platform using a single communication protocol.

Besides, a human operator will not be able to change physical parameters of the technological process (change in location of rolling stock, control signals of start/end of technological operations) if the proposed changes do not correspond to the readings of the system from technical devices.

The adoption of these systems and modules in various configurations is expected in the next 3–5 years at the 27 most important marshalling stations of the railway network of JSC Russian Railways.

CONCLUSIONS

The paper has described the tasks set during implementation of the Industry 4.0 approaches in automation of railway marshalling yards. The fundamentals of the concept of a digital platform have been presented, which will allow for complex automation of control and monitoring of technological processes in real time based on fusion of data received from various station devices, while the human factor will be excluded.

A newly suggested technical solution – the universal counting point – will allow to increase reliability of the real-time model of the station as part of the proposed platform, the algorithms of its operation are described. Besides, the current state of development and implementation of the proposed digital platform and further plans for the project are presented.

The proposed sufficiently universal approach to the shape of new solutions in terms of digitalisation of marshalling stations can be used at different railways once it is adapted to the existing automatic control systems and equipment.

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