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Integrated Digital Railway Space

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ABSTRACT

The article offers the conclusions following the results of the study on de facto shaped integrated space of the digital railway. It is shown that the digital railway The integrated space of the digital railway had the information space as a primary source, but in the process of development became more complex and specific differences have appeared making it more diverse and, thanks to the integration of the information space with the Internet of Things technology, closer to cyberspace.

The relationships between the integrated space, the geoinformation space and the coordinate space demonstrate multifunctionality of the integrated space comprising functions of communication, navigation, coordination, positioning and control that are implemented as a method to optimise train timetables and ensure uninterrupted operation in the transport infrastructure system based on complementary provision of control of groups of objects, corporate management and management of single objects.

Keywords: *transport, integrated space, control, digital railway, complex systems.*

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INTRODUCTION

The digital railway (DR) has emerged following digital technological transformation. It is based on dynamic spatio-temporal models of railway management [1]. The DR has greater freedom in choosing the modes of movement, but greater freedom is associated with greater uncertainty, in view of which it is necessary to use modelling [2] and uncertainty reduction [3] methods. The tasks of the DR require the use of reasoning and the selection of dominant factors in the conditions of fuzzy information [4]. The uncertainty that exists in DR-linked situations leads to the need to apply probabilistic measures regarding switch indices in the case of an unknown utility function [5].

The DR [6] can be considered as a complex «system of systems», and, particularly, its operation requires not only information, but also geoscience [7]. Like a regular taxi, the DR uses electronic maps and atlases [8] to plot routes and travel modes, while the solution to the problems of obtaining cartographic information models should occur in real time as well [9].

DR is developing complementarily with digital transport technologies: digital logistics [10], unmanned transport [11], digital communications [12], cyber-physical systems [13; 14]. As a self-developing system, DR belongs to the class of systems based on subsidiarity [15]. As a spatial phenomenon, DR is related to geoinformatics, geodesy and spatial economics [16]. Since modern management [17] is closely related to information spaces and other spaces as management tools, then DR also uses control space, which should be considered integrated. This space is formed by communication and information spaces and technologies.

The *objective* of the study was to analyse features and relationships within the integrated space of the digital railway.

RESULTS

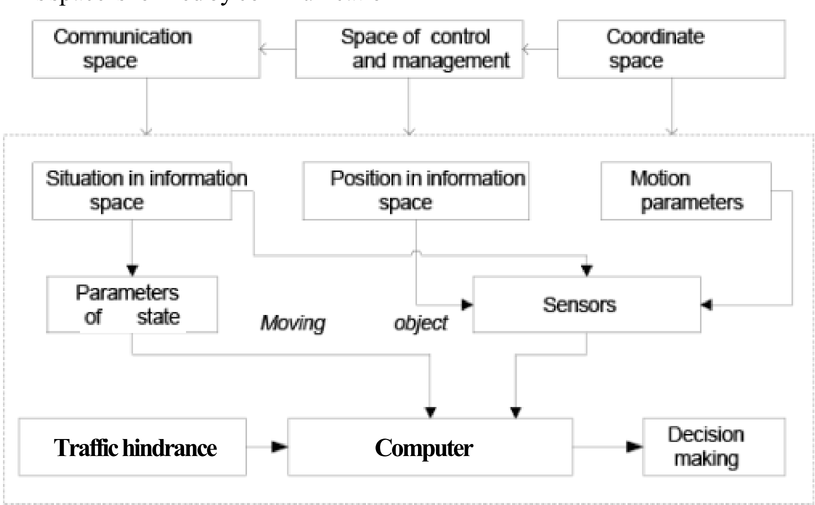
The Structure of the Integrated Space of the Digital Railway

To help to better understand the features of an integrated space, Pic. 1 shows its generalised structure.

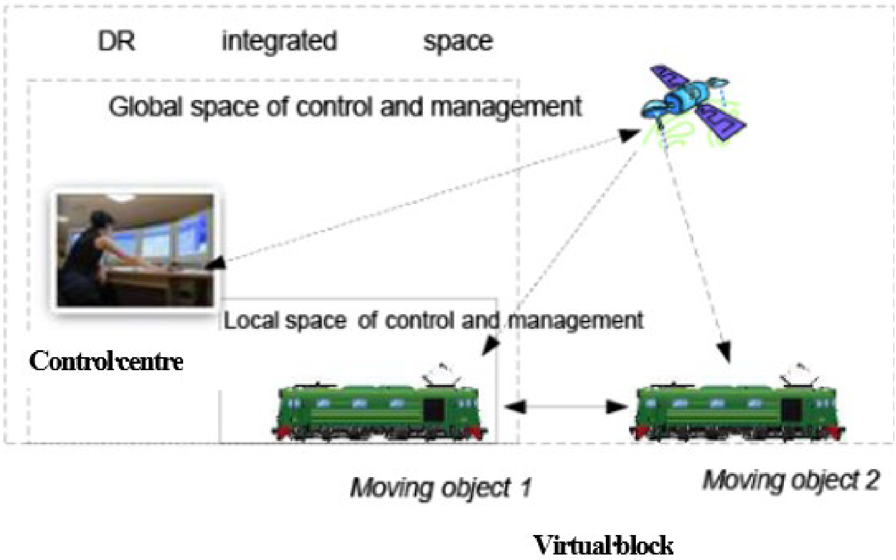
The integrated space of the Digital Railway includes three main spaces: *communication, coordinate* spaces and that of *control and management*.

Since the Digital Railway is a spatial system, it uses spatial control and applies spatial logic [18]. Spatial control requires a *coordinate space*, which is created using geodetic methods. The coordinate space englobes global navigation satellite systems (GNSS) technologies, with the help of which the coordinates of a moving object are calculated in real time. The coordinate space is created based on geodetic networks (state geodetic network) and local networks while dedicated survey grids are used for railways.

The *communication space* englobes communication networks and digital communicology devices, mobile communication, which is a mandatory component of the Digital Railway [12], as well as a radio relay information space, which provides radio surveillance of moving objects in addition to visual surveillance in conventional transport systems, being a necessary component in unmanned transport control [18]. The communication space contains also the satellite communication space, the



Pic. 1. The structure of the integrated space of the Digital Railway [compiled by the author].



Pic. 2. Global and local space of control and management of the Digital Railway [compiled by the author].

satellite navigation space and the satellite coordinating space. These spaces are supported by GNSS. The satellite navigation space solves the problems of orientation and navigation of a moving object.

Coordinating space is actually a coordinate space, it solves the problems of determining the location of an object in an absolute and relative coordinate system, and then GNSS is included in both the coordinate and communication space.

The satellite communication space supports communication through space communication systems. The communication space solves information security problems.

The space of control and management of the Digital Railway is an information control space. It is divided into local and global ones; the difference between them is shown in Pic. 2.

The global space of control and management of the Digital Railway includes many local spaces and has a core in the form of a control centre (Pic. 2). The global space of control and management of the Digital Railway implements also the technology of the «Internet of Things».

The local space of control includes a static and dynamic (sliding) information situation. The static information situation is associated with stationary objects of the route environment and traffic hindrance [15], and the dynamic information situation is associated with a moving object and so moves with it. Information from this situation enters the intelligent systems that controls this object or global ITS.

Technological Features of the Digital Railway

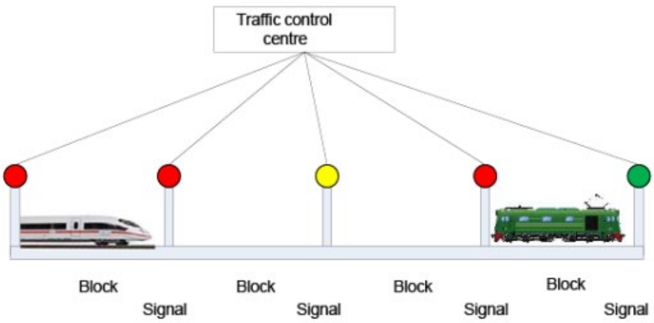
The first technological feature of the Digital Railway is the use of integrated space. The second technological feature of the Digital Railway is the use of moving blocks. This feature, also called Moving Block Signalling (MBS), is shown in Pic. 4. The normal movement is shown in Pic. 3.

The signalling system used in conventional traffic is called exactly signalling block system since it uses a system of blocks fixed in space and a signalling system separating the blocks. The signal gives a command to move or stop. Pic. 3 shows the traffic density when using signalling block system and with which some blocks (from 30 to 50 %) are empty.

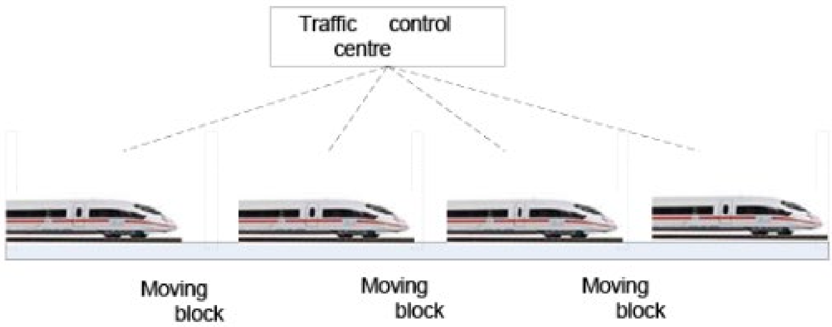
As an alternative, Pic. 4 shows a diagram of digital traffic with the technology of moving blocks (or «envelopes»).

The moving block is implemented through a communication system. The mobile object calculates the permissible approach to the next object and moves synchronously with it, thus fixed signalling and fixed blocks are not needed. The moving block is a sort of a dynamic information situation that slides along the route, and the mobile object is inside such a situation. With such movement, there are no empty blocks, and the intensity of traffic increases significantly.

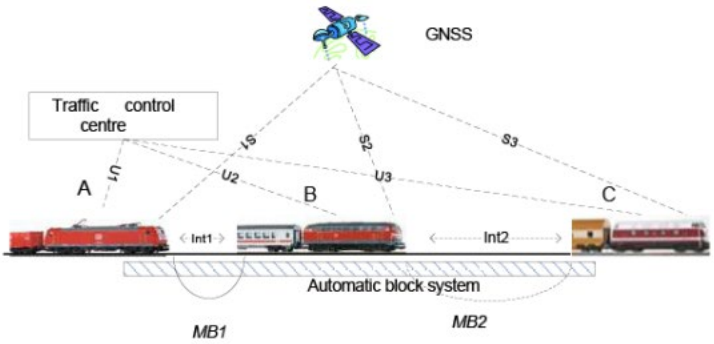
In MBS technology, the mobile object has a built-in computer that forms the dimensions of the block and through the communication space



Pic. 3. The principle of conventional traffic [compiled based, i.e. on [6]].



Pic. 4. The principle of digital movement [compiled based, i.e. on [6]].



Pic. 5. The operating principle of the integrated space of the Digital Railway [compiled by the author].

carries out communication interaction with other mobile objects.

Basics of DR Operation

Pic. 5 shows the operating principle of the integrated information space of the Digital Railway.

Three mobile objects (A, B, C) shown have satellite communication and satellite coordination. This communication is shown as S1, S2, S3. Besides, there is a coordination and information communication (U1, U2, U3) between the traffic control centre and the mobile objects. There is a coordinating and information communication (Int1, Int2) between the mobile objects. Through this communication they transmit information about their own position, traffic speed and acceleration that is used in the traffic control centre for adaptation of transportation, traffic optimisation and for calculation of mobile blocks.

Pic. 5 shows in substance the objective need for the integrated space of the Digital Railway as a tool for transportation management. Using this technology, the intensity of transportation increases significantly (Pic. 4) together with the complexity of traffic management and control.

CONCLUSION

The integrated space of the Digital Railway born based on integration of the information space with the technology of the «Internet of things» and having englobed functions of communication, navigation, coordination and positioning, has predetermined its own role of a quite uncontested backbone framework of railway management and development.

For example, the technology of virtual coupling, closely linked to virtual blocks [20], increases the efficiency of the Digital Railway and, referring to the local information space of the moving object, can be considered as a technology of the integrated space of the Digital Railway.

Besides, the integrated digital railway space allows solving optimisation problems within itself, without resorting to external computers.

Generally, the study has shown high promising nature of applying the concept of integrated digital railway space to analyse, system developing and implementing of interrelated technological solutions focused on growing efficiency of railway transportation.

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