SPECIFIC REFLECTION OF THE OBJECT SPACE OF THREE-DIMENSIONAL MODELS OF STATIONS

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ABSTRACT

Development of a model of a railway station with formation of three-dimensional objects of a track, rolling stock and artificial structures, functioning in full accordance with the technology of a separate point, is considered. Each process operation is assigned with a set of formal procedures that adequately reproduce the station processes. Reproduction of a certain sequence of such formal procedures on model sites allows us to reconstruct a dynamic image of a railway station.

Keywords: *railway station, object space, three-dimensional modeling, formalization of technological operation, dynamic image model adequacy.*

Background. *Modern features of information technologies allow to form a three-dimensional design of track development and technical equipment of railway stations, functioning adequately to real object with reflection of its essential features. At the same time, sufficient accuracy of reproduction of external forms of station objects can be supplemented with certain properties of the physical and technological plan, reproducing the system structure of integral model of a railway station.*

All objects of a model station, by analogy with a prototype, are affected by various external forces. As in real conditions, these forces must be generated by some objects with traction effects (locomotives, loading and unloading equipment). For example, locomotive traction force ensures movement of cars coupled to it, pressure force from a loaded car leads to the corresponding load on a railway track. If the pressure from the car exceeds a certain threshold value, then inelastic deformations occur in the rail and tie grid design, leading to changes in the coordinate position of track elements in the plan or the profile (longitudinal and transverse slopes). In some cases, a significant wind load also forms a sufficient force capable of dislodging from rest and driving the car on the station track. These conditions are modeled as external factors, under the action of which there can be changes in the states of objects at the model station [1, 2].

The calculation of the values of the parameters of motion objects is performed at specified intervals. The new coordinate positions of cars are input data for the following cycles of calculating the dynamic states of station objects. The visualization of successive pictures of model reproductions suggests an animated image of technical and technological space-time reconstruction of a railway station.

Objective. *The objective of the author is to consider specific reflection of the object space of three-dimensional models of stations.*

Methods. *The author uses general scientific methods, comparative analysis, simulation, scientific description.*

Results.

Object classification

The infrastructure of a separate item includes a specific list of static and mobile objects. The main mobile object is rolling stock moving along various station tracks and switch turnouts. At the same time, it is correlated with such static objects as warehouses, passenger platforms, railway stations, and so on. Railway tracks are considered as coordinate changeable objects that can move under the influence of various loads.

The realistic image of the model image of the three-dimensional installation is achieved by technically and technologically correct transferring the associated object structure of the mobile and static bodies of the real station to the prototyped reconstruction. That is, a number of connected subsets of similar and different objects are formed, interacting with each other according to some regulated rules and reproducing the work of a railway station. Rolling stock objects are considered as a set A of model structures. Similarly, there are sets of objects of track B, buildings and structures C, transportation objects D.

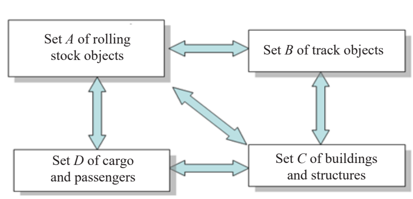
All cars are included in the subset a_1, locomotives – a_2. Differentiation of cars according to their purposes leads to allocation of subsets of cargo a_{11} and passenger a_{12} fleet, which, in turn, are divided into types a_{11i} (type of freight rolling stock), a_{12i} (different categories of passenger cars, diesel trains, motor-car sections, special cars). It is possible to divide it into inventory a_{13} and non-working a_{14} fleets, the general network a_{15}, private a_{16}, etc. All locomotives are divided into a train fleet a_{21} and a shunting fleet a_{22}.

Station tracks of set B are subdivided into b_{1i} (main b_{11}, receiving and departure b_{12}, sorting b_{13}, loading and unloading b_{14}, hump b_{15}, running b_{16}, connecting b_{17}). The list of infrastructure facilities, buildings and structures C includes railway stations, posts c_{1i}, various storage rooms c_{2i}, platforms c_{3i}, and other artificial structures c_{4i}. The set of transportation objects D includes subsets of cargo d_1 and passengers d_2. All objects of such sets interact with each other in a certain way (Pic. 1).

A coherent scheme of objects $A \leftrightarrow B \leftrightarrow C \leftrightarrow D$ allows to construct the correct environment of the interacting model structures in full accordance with the technology of the railway station.

Process design

The model interaction of station objects is expressed by certain relations [3]. The relationship of the elements of the set indicates the relative position of station objects. For example, $a_1 \rightarrow c_{2j}$ determines the fact that a car is located at a warehouse (or inside a warehouse); $d_{1j} \rightarrow a_{12}$ – cargo is in a car; $d_{2j} \rightarrow c_{11}$ – a passenger is at a station, etc. This relationship establishes a one-to-one correspondence between the elements of only different sets. If it is necessary to define a rule for connecting several elements of the



Pic. 1. Connected sets of station model objects.

Table 1

Basic technological operations and coherent relations of model station objects

Name of technological operation	Adequate model operation
Reception of a train at a receiving and departure track	$(a_{11i} \oplus a_{21}) \to b_{12i}$
Removal of a train locomotive from a train	$a_{21}(a_{11i}) \to b_{16}$
Ride of a shunting locomotive to a train	$a_{22} \to b_{12i}$
Delivery of a train locomotive to the fleet	$a_{21} \to b_{12i}$
Train departure from a station	$(a_{21} \oplus a_{1i}) \to b_{12i}$
Handling of a passenger train	$(a_{21} \oplus a_{12i}) \to b_{11}$
Delivery of a car for unloading to a warehouse	$((a_{11i} \oplus a_{22}) \to b_{14i}) \to c_{2i}$
Unloading cargo from a car to a warehouse	$d_{1i}\ (a_{11i}) \to c_{2i}$
Loading cargo from a warehouse to a car	$d_{1i}\ (c_{2i}) \to a_{11i}$
Sorting of cargo at a container site with loading on platforms by a container loader	$(d_{1i}(c_{4i}) \to a_{11i} \uparrow \Omega) \to b_{14i}$
Removal of groups of cars from cargo front to sorting park	$((a_{11i} \oplus a_{22}) \to b_{14i}) \to b_{13i}$
Rearrangement of cars from sorting park to departure park	$((a_{11i} \oplus a_{22}) \to b_{13i}) \to b_{12i}$
Reception of a passenger train to a station	$(a_{21} \oplus a_{12i}) \to b_{12}$
Embarkation of passengers to a commuter train	$d_{2i} \to c_{3i} \to a_{12i}$
Disembarkation of passengers	$d_{2i} \to a_{12i} \to c_{3i}$

same set (for example, stay of two cars on a loading track), then the add-on relation should be defined: $(a_{12i} \oplus a_{12j}) \to b_{1j}$.

The operation "a locomotive is coupled to a passenger car and moves it to a receiving and departure track" is determined by the record $(a_{22} \oplus a_{12}) \to b_{12}$. The technological operation of shifting a car to a receiving and departure track, performed by means of a shunting locomotive, can be represented by a formal entry: $(a_{11} \oplus a_{22}) \to b_{12}$. Taking into account that the locomotive is able to move independently, we obtain operation of moving a single shunting or train locomotive along connecting and receiving and departure tracks: $a_{22} \to (b_{17} \oplus b_{12})$, $a_{21} \to (b_{17} \oplus b_{12})$.

Loading and unloading equipment moves autonomously, subject to availability of appropriate transport links Ω (crane runways, auto approaches, etc.). Therefore, the formal entry of the general form $a_{3i} \to b_{1i}$ is not correct, since it does not take into account the additional requirement for designing the communication structure Ω, and a new inclusion relation of conditions $\uparrow$ should be introduced. Then the considered operations take the form: $(a_{3i} \uparrow \Omega) \to b_{14}$.

Thus, relations of communication $\to$, additions $\oplus$ and inclusions $\uparrow$ determine in the station model technological operations performed by reconstructive objects of sets A, B, C and D. The main list of technological operations reproduced by the model objects of the station and the corresponding relational connections of objects and generated operations are shown in Table 1.

The list of technological operations can be continued by designing their composition for a particular station, in accordance with the nature of its work. It should be noted that the model rules will not fully meet the technological requirements due to complexity and variability of the latter. The rules reproduce the most significant system elements of organization of work of the station, which are reflected in the model through the provided relations between the objects of the sets. Therefore, exceptions to the rules should be defined as a series of related conditions under which a particular condition can be corrected (soft constraints) or its fulfillment becomes impossible (hard constraints). For example, stay of cargo on a track $d_1 \to b_{1i}$ or a passenger car at a station $a_{12j} \to c_{1i}$. In the first variant, cargo may be located on a track in certain special cases connected, say, with reconstruction of a station (replacement of assembled rails and sleepers, temporarily acting as cargo delivered on platforms to the work site). The second example of a model situation indicates the impossibility of its occurrence on the object.

The scheme of the major mode turns out to be quite useful in development of special, catastrophic models that simulate the arising states of individual objects in the event of violation of work safety. In the world of conflict situations, a spontaneous and admitted by special rules violation of accepted requirements for performing technological operations, expanding the boundaries of established critical parameters, becomes a relative norm. Catastrophic station models can be viewed as reproducing the consequences of various technical and technological violations that have a non-zero probability of occurrence on a real railway.

Special interaction patterns arise for the objects of D sets with the elements of A and C sets. The object of transportation (cargo, passengers) is provided with specific model forms. Each object of the set D is able to move within a certain closed space (cargo – due to strikes and collisions of cars, passengers – in the process of their own movement).

In the general case, a model image of an object of transportation «cargo» should be defined as an object capable to be moved using means of transportation (loading and unloading machines), which provide a change in its location (car, warehouse, sorting platform, etc.). A similar operation in the station model is considered productive. The inertial shifts of cargo as a result of a sharp change in speed of movement of a car are unproductive movements.

The subject of transportation «passenger» in the model interpretation is considered as a mobile object that can move independently to a station, a landing platform, in a car or using escalators, elevators, etc. For a 3D station, it is advisable to take passengers as a kind of avatar with a certain behavioral motivation inherent in this particular classification category of passenger traffic and the predetermined purpose of the trip.

The degree of mobility of an object of transportation from the set D outside transport and on transport is different (Table 2).

Unproductive mobility, denoted by the combination of symbols (– +), is inherent to cargo in cars after impact, collapse of cargo and under some other major circumstances. Limited activity (+ –) is observed in passengers on intermediate vehicles between a station and a car and in cars.

For model objects of transportation it is important to determine the space of possible movements, as well as the nature and degree of mobility in this space. The dual moving structure of model cars and goods with mandatory imitation of both movements of the car itself on wheels and the contents of the car is of fundamental

Table 2

Mobility of model objects of transportation of the set *D*

Object of transportation	Location		
	Outside a car	At a transport structure (at objects of subsets a_3, a_4)	In a car
Cargo	–	–	– +
Passengers	+	+ –	+ –

importance for the correct physical reconstruction of events. This will allow to model transport processes in various conditions of negative nature, aggressive external environment, fatigue stresses, subsequent critical deformations of the structural elements of the track and rolling stock.

Assessment of the adequacy of model constructions

The similarity of model rules for interaction of virtual and real stations allows development of a dynamic system of model constructs that change their position (cars, cargo) or state (railway track). All objects of these sets have certain properties defined through belonging to the corresponding type (cars, locomotives, railways, buildings, etc.), having a certain mass of cargo of this nomenclature and characterized by the state reached (defectiveness of the track, suitability for loading cars, locomotive mileage, etc.).

An object model construct (car, track section, consignment, building), supplemented with its inherent properties, is called a technological model object. Since a reconstructive image of a railway station is created as a self-contained and closed model system, objects with specified properties are generated by some software designer. After completion of work at the model station, images of cars, locomotives with initial or changed characteristics in the process of interaction with other objects are displayed outside the model space and are redeemed by a special deconstructor.

A program designer forms trains from technological model objects of rolling stock. Constructions of reception, departure, transit, and other parks are created from the corresponding track objects. The boundaries of the station's model space are input signals. Transit paths from these points are considered the main paths of the station model. In the model 3D reconstruction, the thesis is adopted, according to which all station objects are located between the planes, passing perpendicular to the main tracks through the points of the station boundary according to the position of the input signals.

A software designer can work in the mode of reconstructing model objects with random properties or according to a certain table of a certain task. Park station structures are emulated on the basis of a corresponding digitized scheme or plan for station development with known path lengths, types and marks of turnouts, the current condition of the track, etc. The cyclical nature of the technological processes of a railway station allows one to perform certain operations, presenting them as a series of fairly unambiguous formalized events repeated at certain time intervals.

An important requirement for correct development of events during the model reconstruction of the station is formation of a plan-task for the time during which the software control module will ensure that all stated requirements for servicing flows of various categories are met. In case of emergency situations, the controlling module should issue diagnostic messages with transition to the standby mode of control actions by an operator.

Conclusions. *Reproduction of information objects adequate to real prototypes of technical systems, in form (appearance) and functionality (ability to perform certain operations) makes it possible, on the basis of existing methods and approaches [4, 5], to develop a dynamic environment that reproduces the technology of separate railway points at model objects. An alternative 3D installation can be arbitrarily close to a real-life station, depending on a level of detail of description of a visual image and the physics of interaction of individual objects.*

The most difficult task is reconstruction of technological features of processing train, car, cargo and passenger flows at stations. Perhaps for this reason, when viewing the corresponding render video of functioning of a 3D station, there are visual and technological inconsistencies in development of model processes. The presence of control points to ensure that the operator's program designer stops operation and the possibility of making appropriate changes to reconstruction will allow for correction of space-time positions of model station objects.

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