CONCEPTUAL BASIS FOR DEVELOPMENT OF 3D STATION ENGINEERING MODEL

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ABSTRACT

Fundamentals of development of engineering models of railway stations in 3D format, providing not only a photorealistic appearance of three-dimensional objects, but also simulation of physical laws of their interaction are demonstrated. The author formulates general methodological requirements at the stage of development of such a model, shows specificity of implementation of design solutions associated with the specificity of simulation tasks and information technologies.

Keywords: railway station, design, the laws of physics, simulation, 3D station model, information technologies.

Background. *Design works during reconstruction and development of new railway stations are based on large-scale plans, executed, as a rule, with the use of digital recording technology. Two-dimensional images of objects with precise gridding are successfully used by specialists to solve various design and research tasks.*

Design methodology involves the use of a precise scaled image in a model of two-dimensional station plan. However, such a plan cannot be a full-scale copy of actual station facilities due to the use of many symbols, not coordinated within a positioning system. For example, turnout switch in the image with the center, strictly speaking, is not an image adequate to reality. Shunting and train signals are also in stark contrast to the established scale of station plan on which they are displayed.

For designers adopted rules for combining scale and non-scale graphic interpretations, however, are the norm, and a positive side is due to long practices. Nobody relates the actual size of a traffic light to the size of a graphic symbol on the station plan on a scale of 1: 1000, as the lens head of traffic light set in this case should reach a diameter of 1,5 m (in fact – up to 250 mm). Tracks of railway station park, depicted as axes, are also contrary to the logic of the scale (the plan should reflect real objects, rather than their «traces»). On the other hand, for large scale small elements of objects interfuse (rails of railway track, traffic lights heads of a signal, turnout curves of turnout switch), and as a result we have blurred contours of indefinite shape. Therefore, such pseudo scaled plans are widely used, where correct gridding is acquired only by individual milestones of graphic images (reference point of traffic lights, beginning of switch point on the track axis).

Currently, however, situations occur more often when getting a plan with drawn objects in a conditional graphical notation is not enough. If it is necessary to define engineering efficiency of the design solution for reconstruction of the station, only calculation methods with their limited arsenal of analytical, graphical and empirical approaches can come to assistance. If simulated use of full realistic image of station facilities were possible in the form in which we visually perceive exterior, panoramic image of the station, then there would be a real prospect for simulation of technological, operational problems at a designed station, thereby enabling adjustment of the plan based on simulation results.

There is a number of convincing examples, confirming the high price of design errors. So, if in a complex project of transport communications a mistake is made, the cost of its elimination at the design stage is 1 dollar, in the case of not detecting a defect in a project cost of eliminating the consequences of errors during facility operations' stage may reach $100 000.

Such a model can only be regarded as a three-dimensional visualization of the train station, fully adequate to real objects and, consequently, being executed in a large-scale in the strictest sense of the concept. One of the horizontal sections of the three-dimensional station via plane – it is, in fact, a large-scale plan with solution of various design and research tasks.

Objective. *The objective of the author is to consider conceptual basis for development of 3D station engineering models.*

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

Results.

General requirements for a model

Model railway station image should be formed in adequate physical and technological environment surrounding prototype station objects. Therefore, 3D station is positioned as a full-featured engineering model, which is an adequate analogue of the real world. This means that essential features of interacting station objects, being consequence of exerted physical laws and technical requirements, are transferred into the modeling world with sufficient accuracy to reproduce them. From this perspective, all the objects of the engineering model are immersed in a particular field of simulation of real requirements, rules, regulations and laws of conduct for information entities, vested with attributes of weight, speed, pulse, and so on.

At the heart of the entire model world we suppose the surface of the ellipsoid, compressed at the poles (the analogue of the geoid of the Earth). This proportionate in size to our planet but scaled surface is overlayed by a three-dimensional relief of previously surveyed premises location. This digital map becomes a substrate for subsequent recovery on it of a three-dimensional image of an existing reconstructed or projected railway station.

In the simulation model, which is of interest to us, the laws of gravity and inertia should act. In this case, any bodies falling in the model field are starting to behave in line with precisely defined consequences of these laws. In the collision of bodies (for example, cars on the railway line) a part of them lose their initial impulse in interaction with others due to friction of sliding and rolling, wind load, and so on. All of the model station objects are developed as material bodies, attracted to the surface of an ellipsoid. For example, a model railway car should roll off the hump in full accordance with the law of conservation of kinetic energy imparted by the shunting locomotive at the dissolution, and by the potential energy of the body, raised to the level of the top of a hump, collectively providing the execution of work referred to car rolling on a particular profile of the drain section to the fixed point of under-hump park.

It is important to note that in this case we speak not just about visual consistency of the observed effects on the 3D station, but also about internal coordination of behavior of model objects in accordance with existing physical theories. Usually, three-dimensional models of rail transport facilities have presentational purpose, providing reality of submitted forms. With a high detailization of object performance it is sometimes possible to achieve photorealistic images. However, structural content of such model objects is missing. A simulated freight car, even consisting of many individual elements, and repeating in detail structural features of the body, chassis, traction devices and brake equipment after installation on a 3D track will not be able to reproduce the movement by turning the wheel.

With the help of manual handling (for the model it is external force of unknown nature) such car can be moved to the designated location, positioned; even through simulating coupling with another car, but the physical link of objects cannot be achieved with such operations. The model with unstructured objects is capable of forming a «non-physical world» of realistic, recognizable forms, ready to display certain interim or final states, adequate to relevant prototypes. However, it will show only static images that transform into each other through some unusual, «above-model» (made by the creator or user of the model) operations.

Thus, we can consider two types of models: presentation, capable of reproducing objects at the level of visual similarity, and engineering, which along with reality offer a three-dimensional world of structural objects with certain properties and ensuring their interaction with each other.

The specifics of implementation of engineering models

The present level of development of information systems allows to create holistic engineering models, in which facilities with pseudo-physical nature operate. Studies of various systems (PhysX, Havok, Newton Game Dynamics, Unreal Engine), ready to imitate the action of physical laws in some medium, have shown that it is possible to effectively use such software products that emulate an adequate behavior of model objects as material bodies. The use of such engines (physics engines) does not require a fundamental restructuring of the objects that need only «to be equipped» with required parameters. For example, objects created in 3D MAX, placed in the world of physical simulations Unity 3D and endowed with gravitational and inertial characteristics, immediately begin to change their status and position in accordance with action of model physical laws.

External physics engine is used as a kind of out-of-object force field in which model images sink having not only external geometric contours, but also certain attributes. Perhaps a more detailed study of effects of the used model field will reveal some deviations from expected results, calculated and theoretical trajectories, etc. It should be taken into account that physics engines' algorithm of simulation of laws supposes some (and in some cases significant) error.

Existing physics engines were designed for specific purposes, particularly for gaming. So they fixed only individual, most significant for gameplay consequences of such laws. Naturally, for an engineering model of the train station it will be much more important to correctly describe behavior of objects during collision of the car with a prism of dead-end subgrade, fluid motion at a certain level of filling in the tank during collision of cars in sorting park after dissolution, the results of prolonged exposure of track superstructure to dynamic loads from rolling stock, etc. These tasks have never been formulated in the framework of existing physics engines, and therefore difficulty can be encountered in solving them in the created engineering model.

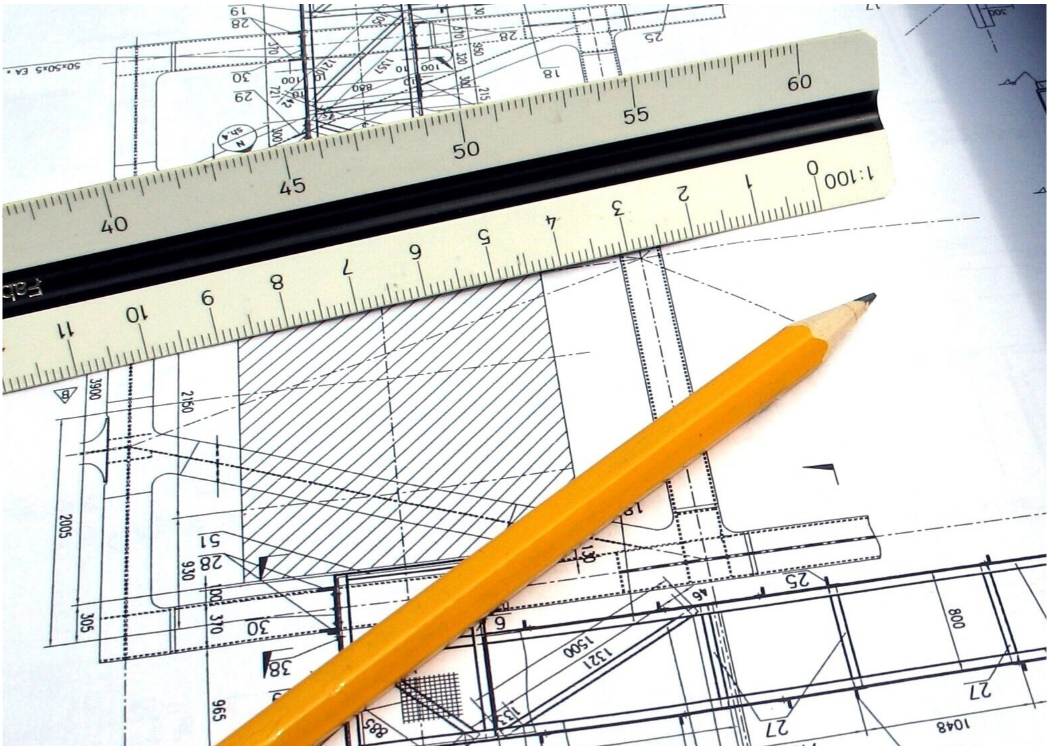
The decisive advantage of «implantation» of simulation physics in 3D model of railways and stations is their recovery. For example, a three-dimensional model of the car wheels, placed in Unity 3D environment with the engine PhysX, and endowed with the property of RigidBody [3], immediately rolls down along an inclined plane with the trajectory corresponding to the volume configuration of the wheel, shifted arrangement of the center of mass, movement surface relief and so on. As a result, a model, that has reflected before only some statically fixed state of objects, is converted into a model video recording of dynamic processes occurring in a certain harmony with the laws of physics.

If some of the consequences of model laws do not fully describe the corresponding simulation (e. g., momentum transfer to three empty gondola cars with the impact of laden 120-ton tank car), there is a possibility of program correction of script action by its substitution with a more perfect one. Most likely, such a procedure will be quite difficult, but in any case it is easier to adjust some conflicts of existing software tools, which as a whole have proved their usefulness, than to develop them from zero point.

It should be noted that the practice of firms-developers of computer games is based on mandatory use of own physics engine or of an engine developed by a third party manufacturer as a basis for realistic gameplay. Today high quality software tools are created to describe solid and deformable body physics, fluid flow, geometry of ropes and cords under the action of gravity, and others. Some of these laws have no special significance for the qualitative modeling of processes taking place at the railway station, others may not be sufficient for the required accuracy of description.

The most important in this case is the ability to quantify the result of the action of the model physics laws through a relatively simple registration of required parameters. It is possible to «hang» a virtual sensor (e. g., on 3D-track) at any point of the model object, and at certain intervals of model time to produce retrieval of necessary information. As a result of the experiment it is sufficient to compare the obtained data with the settings of real-world objects and to conclude on quality of action of model law or its consequences.

In this connection, it becomes possible to effectively address many theoretical problems associated with modeling of such complicated and still not fully investigated processes, such as interaction between rail and wheel; critical stresses in the train when driving on complex track profile, which includes horizontal and vertical curves; dynamics of longitudinal and transverse displacement of railway track, including curved tracks and tracks



used for high speed trains; deconstruction of correct (designed, fixed by pre-construction survey) curvature of circular or transition curve in the plan due to uncritical casual and directed effects of rolling stock and others. Such work is quite difficult to be done in real conditions that require significant costs for obtaining representative statistics and its qualitative processing. Physical model simulations can help to achieve those goals, greatly reducing the cost of full-scale investigations.

Conclusions. *Development of an effective engineering three-dimensional model of the railway station is expected to lead to a qualitatively new level in solving all complex tasks of design and survey, construction and operations. The effective implementation of model's capacity will provide for a detailed study of many tasks of imitative nature, solved now during designing through sampling and estimation calculations, inaccurate and labor intensity of which does not allow to systematically assess the quality of options adopted for implementation. As a result, many properties, including reconstructed and newly constructed railway stations, do not fully satisfy the practical needs assessed by criteria of transit capacity of subsystems, loading of individual elements of necks, delays at the intersections of routes, etc.*

The present level of development of information technologies allows to develop engineering models with a high degree of authenticity with real systems, reproduction of correct response of model objects to the action of physical laws. Application of basic software products followed by tuning of simulated consequences of such laws for the purpose of describing the technology of the station work and by complementing physical properties of three-dimensional station objects supposes getting a new effective tool in the form of a completed 3D model of the train station, which is realistic not only in displayed geometric shapes, but also in the dynamics of processes taking place in accordance with the objective laws of the real world.

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