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Theoretical Aspects of Creating Digital Twins of Transport Facilities

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Abstract

Digital twins of transport facilities are virtual models of real vehicles, infrastructure and systems that are used to analyze, optimize and manage their operation. The article discusses key aspects of the use of digital twins in the transport sector, including their creation, integration and machine learning algorithms. Description of monitoring, diagnostics and forecasting methods using digital twins allows to improve the maintenance and operation of transport facilities, increase safety, reduce costs and increase environmental sustainability. Prospects for the use of digital twins in various transport segments, such as road, rail and air transport, as well as in urban transport systems, considering examples of successful implementations and future technologies.

Keywords: Digital twin, transport object, terminal, method , bottlenecks , optimization, software AnyLogic , Unity , 3dsmax.

Introduction

Digital Twins (DT) are virtual copies of physical objects that integrate data on their condition, behavior, and environment. This concept is actively developing in various industries, including manufacturing, energy, medicine, and transportation. In recent years, digital twins of transport objects such as cars, trains, ships, and airplanes have become an important tool for improving the efficiency and safety of transport systems. The transport industry faces a number of challenges such as aging infrastructure, increasing passenger traffic, improving environmental sustainability, and reducing operating costs. With the rapid development of digitalization technologies, the use of digital twins for monitoring, analyzing, and managing transport objects is a promising solution. Virtual models can not only track the current state of vehicles, but also predict their behavior in various situations, which allows for timely maintenance, minimizing malfunctions, and optimizing operating costs. The concept of digital twins was first proposed in 2002 by Michael Grand of GE, but has only gained widespread acceptance and development in recent decades as the Internet of Things (IoT), big data, and artificial intelligence (AI) technologies have become available for mass

application. In the transportation industry, digital twins are used to model and analyze vehicles, infrastructure, and even entire transportation systems.

Main Part

Creating digital twins of transport objects requires the use of advanced technologies for modeling, collecting and processing data. The key components are:

Data collection from transport objects uses various sensors (temperature, vibration, speed sensors, GPS sensors, etc.), installed both on vehicles and in the infrastructure. These devices allow real-time information about the state of the object and its surroundings.

Modern big data processing systems provide storage and analysis of huge volumes of information received from sensors and other sources. To work effectively with data, it is important to have powerful computing resources and algorithms that can quickly process information and identify patterns that will help predict the behavior of transport objects.

Digital twins of transport objects are built using 3D modeling methods, as well as specialized simulators that reproduce the behavior of an object in various conditions. For example, for cars, models are used that take into account aerodynamics, mechanical properties, and for rail transport - the behavior of the train on different types of rails and under different loads.

The purpose of the work is to consider the basic principles of creating and using digital twins of transport objects, as well as their role in optimizing management, monitoring and forecasting processes in the transport industry. With the AnyLogic environment We will analyze current approaches, technologies and examples of successful implementation of digital twins in various transport segments, We define the bottlenecks of a transport enterprise or technological processes in the enterprise's work, and also highlight key trends and prospects for their further development.

To create digital objects of transport objects, software products such as AnyLogic , Unity , 3 dsmax are used , let's consider each of them separately 1- table.

1-Table

Software name	Logo	Product Note
3ds Max		The program provides a comprehensive, flexible toolkit for creating first-class projects with full control over the artistic concept. Creating Large-Scale Worlds in Computer Games Visualization of high-quality architectural projects Modeling interiors and objects with a high degree of detail Bringing characters and objects to life using animation and visual effects .
Unity		This is both a development environment and a game engine, with the help of which projects are created for different platforms: PC, mobile devices, game consoles and Internet platforms - that is why it is called cross-platform. Unity has tools for creating objects, moving them, working with graphics, textures and sound, so you can even make a full-fledged game with its help alone.
AnyLogic		The only professional-grade agent-based modeling software . The agent-based approach makes it possible to apply simulation modeling in areas where it was previously unavailable: marketing, social processes, epidemiology. Agent-based modeling allows using big data to fill models with input data from the real world.

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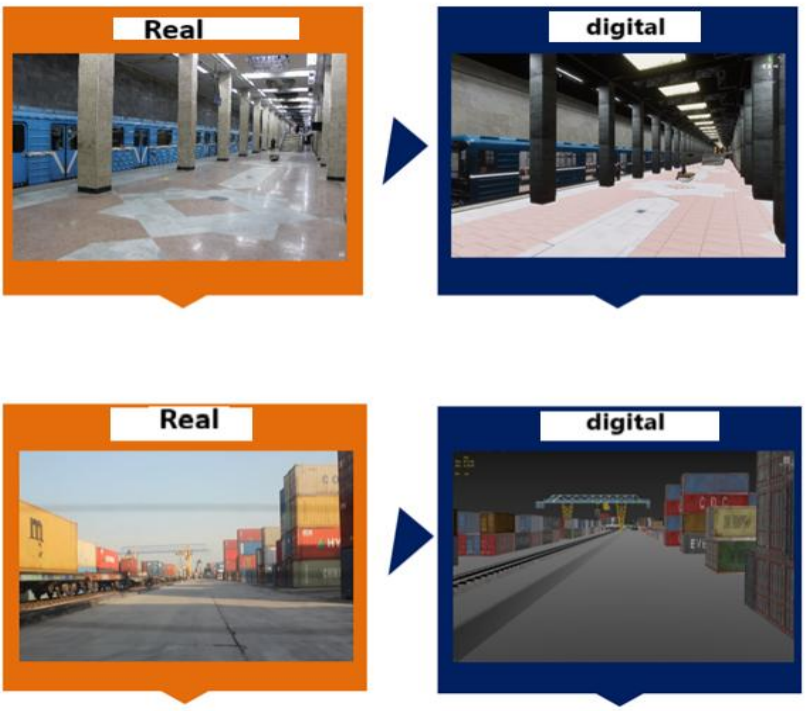
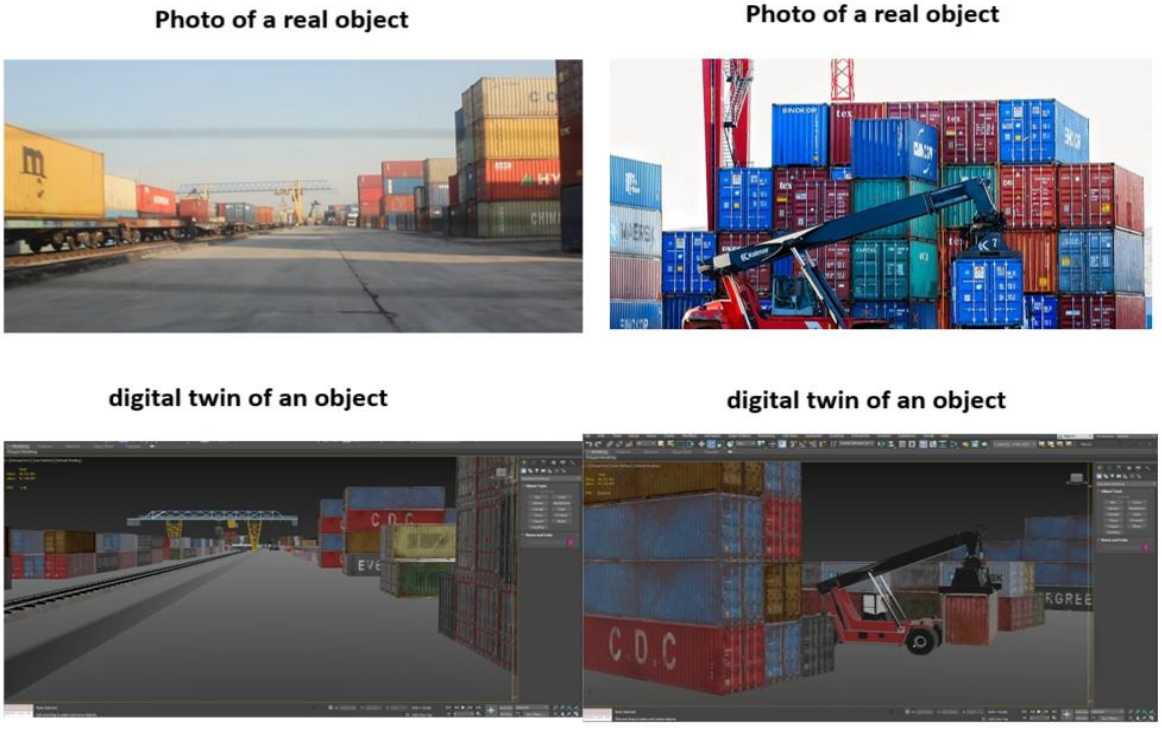
Application of digital twins in various transport segments

Digital twins are widely used in various areas of transport infrastructure, from individual vehicles to entire transport systems (Fig. 1, 2).



1- figure. Real and digital views of transport enterprises



2- figure. Real and digital views of transport enterprises

***Digital twins* of objects are created for:**

1. Improved performance: Digital twins allow you to model and analyze objects in a virtual environment, which helps optimize their operation and improve productivity.
2. Resource Management: Digital twins of assets enable efficient management of resources such as energy, water, transport and others by monitoring and optimizing their use.
3. Behavior Prediction: Digital twins of objects help predict the behavior of objects in the real world, allowing for more informed decisions and preventing potential problems.
4. Training and education: Digital twins of objects are used to train and educate people in various fields such as medicine, aviation, construction and others by creating virtual simulations and training.
5. Improved safety: Digital twins of assets help improve the safety of assets by analyzing risks and taking measures to prevent them.
6. Innovation and Development: Digital twins of objects facilitate innovation and development of new technologies by testing and simulating new ideas in a virtual environment before they are implemented in the real technological process.

After building a digital twin various transport companies in the Unity environment and AnyLogic, when changing the parameters of the transport flow, identifies the “bottlenecks” of the enterprise, the transport process and provides scientific recommendations for improving and optimizing the process.

Conclusion

Digital twins are a revolutionary technology that can significantly transform the transport industry by improving the efficiency, safety and sustainability of transport systems. Their applications cover a wide range of areas, from the design and operation of vehicles to the management of urban transport and rail infrastructure. The use of digital models allows not only to predict malfunctions and optimize maintenance processes, but also to improve safety, reduce operating costs and reduce environmental impact.

Despite the challenges associated with high implementation costs and data protection, technological development and the integration of new solutions make it possible to significantly expand the possibilities for using digital twins. The prospects for the development of this technology in the coming years promise to be large-scale. Digital twins are expected to become the basis for the creation of autonomous and smart transport systems capable of adapting to changing conditions and effectively interacting with the environment. In the future, digital twins will be able not only to optimize the operation of individual transport facilities, but also to become an integral part of smart cities, ensuring their sustainable development and improving the quality of life of citizens.

Thus, the introduction of digital twins into the transport industry opens up significant prospects for improving its efficiency, safety and environmental sustainability, and also contributes to the creation of new innovative solutions for optimizing transport systems in the future.

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