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Analysis of Software Products for Simulation Modeling of the Operation of the System of Shuttles for Warehousing

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Abstract: In this paper, the analysis of simulation systems for the work of a warehouse of a chaotic storage method with a high density is carried out. The authors analyze warehouse operation modeling strategies within the framework of Warehouse 4.0 concepts, and also consider existing modeling systems. During the analysis, attention is paid to parameters, such as the energetic calculation of the shuttle system, which directly affects the throughput of the simulated warehouse.

Keywords: Industry 4.0, Warehouse 4.0, Shuttle Systems, Discrete Simulation.

I. INTRODUCTION

The introduction of new technologies such as robotics, cloud computing, artificial intelligence, and IIoT gave impetus to the creation of cyber-physical production systems as an integral part of Industry 4.0 [1-3]. One of the important elements of ensuring cyber-physical production is the concept of Warehouse 4.0 [4,5]. Warehouse 4.0 is a complex ecosystem that implements warehouse management functions using modern computing systems, robotic platforms and IoT technologies to achieve optimal production conditions and customer satisfaction. The development of such systems is a very complex and economically expensive project, as a result of which, before its implementation, it is necessary to conduct simulation modeling of its operation under maximum load in order to identify "weak" points in order to achieve economic efficiency and optimal performance of the specified functions. Given that modern Warehouse 4.0 is equipped with shuttle systems that allow to automatically manage the flow of loading and unloading goods from warehouses

II. ANALYSIS OF MODELS AND STRATEGIES FOR MODELING SHUTTLE SYSTEMS

To solve the problems of simulation modeling of the operation of a warehouse with a shuttle Shatolov system, developers use different software packages such as: ARENA [6], AutoMod [7] and AnyLogic [8]. Let us consider them from the point of view of achieving the set tasks of simulating the work of a warehouse with a shuttle Shatolov system.

ARENA Simulation Software is a discrete event simulation and automation software developed by System Modeling and acquired by Rockwell Automation in 2000. It uses the SIMAN processor and a modeling language.

AutoMod simulation reality - is software for simulations of production and logistics systems. The software is designed for detailed analysis of operations and flows. Although mainly used in manufacturing and material handling systems analysis, AutoMod's flexible architecture allows it to be used in a wide range of application areas, from airports to semiconductor industry.

AnyLogic is a simulation software developed by The AnyLogic Company. The tool has a modern graphical interface and allows to use the Java language for model development.

Discrete event modeling is used mostly; accordingly, model variables change only when an event occurs. While analytical modeling usually only considers random warehousing, and other types of strategies are not included in the calculation due to their complexity, several types of strategies are explored in simulation modeling:

- formation of the order;
- formation of the game;
- zoning;
- lifting strategy;
- storage strategy;
- outsourcing strategy;

These models calculate throughput for single shelf shuttle systems FEM-9.860 [9] and are known for their double depth shelving systems and related strategies. Throughput simulation allows many aspects of shuttle systems to be taken into account, such as latency, delays, prioritization, etc.

Using a simulation environment to develop and test situational storage strategies is, in addition to experimentation on real systems, the most efficient way to determine throughput. Consider the factors that affect the throughput of the warehouse:

- energy calculation of shuttle systems. According to VDI-2692 [10], a distinction is made between decentralized and centralized energy supply. In a decentralized version, batteries or supercapacitors are used to control vehicles. In the case of a central power supply, vehicles are connected to the main network using cables.
- energy consumption of shuttle systems and flow factors. All factors have a decisive influence on throughput, initially affecting the power consumption of the shuttle system. Therefore, the following factors should be taken into account:
- the mass of transported cargo units and / or shuttles,
- construction and integration of vehicles,

- if any, building a feedback system,
- building a control system,
- consumption in standby mode.

Depending on the type of shuttle system, containers, shuttle vehicles, or both are transported. Accordingly, the mass of the transported unit has a different effect on the consumption of the shuttle system.

The design of vehicles (shuttles) affects energy consumption through the coefficient of friction or efficiency. The way vehicles are integrated into the shuttle system also affects overall consumption. If an energy recovery system is installed, energy is recovered when the shuttle vehicles decelerate or when the elevator moves down. The design of the regenerative module plays a role in the amount of energy that must be recovered from the regenerative efficiency, and if this amount of energy is used in the shuttle system, it reduces the energy consumption of the shuttle system.

The control system takes over the various tasks in the shuttle system. It can perform everything from simple coordination tasks between top-level systems and the shuttle system to complex overall control of the shuttle system. Correspondingly, the corresponding energy consumption is also reduced.

The shuttle system does not work in standby mode, but still consumes power in order to be able to start working immediately after receiving the order. Depending on the design of the shuttle system, various uses are available for this purpose.

In the specialized literature, various publications on the calculation of energy for shuttle systems are presented. All approaches separate individual vehicle trips and determine the energy consumption for each trip. Handling equipment or reserve consumption are not counted as small quantities. The energy consumption per trip is calculated differently. FEM-9.865 [11] provides a model for calculating the energy of a number of internal logistics systems, including shuttle systems. Energy E is referred to as the ability to do mechanical work and as the integral of power $P_{Total}(t)$ over the period from t_0 to t_1, during which power is performed, as represented in next way:

$$E = \int_{t_0}^{t_1} P_{Total}(t)dt$$

Two methods of calculation are also shown to determine performance.

1. A simple calculation method assumes that the overall efficiency of shuttle vehicles is 70 percent. In other words, only 70 percent of the energy produced by the shuttle system is converted into propulsion. The remaining 30 percent are considered losses. E is determined by calculating the force of movement. This calculation method is recommended with an accuracy of 30 percent after validating the model against measurements, if the advanced calculation method is not possible due to an unknown degree of performance.

2. Using the advanced calculation method, friction losses and individual transmission efficiency are taken into account. This means that the calculation of the generated power is somewhat more complicated, but more accurate. In the instructions, the accuracy of this calculation method is indicated at the level of 20 percent.

The analytical model for calculating the energy consumption of the shuttle system in motion is divided into phases:

- acceleration;
- moving at a constant speed;
- braking.

In each case, the traction force on the rear drive wheel and the required machine power are calculated. Energy recovery through the use of energy generated during braking is also taken into account. It is assumed that the overall efficiency and friction coefficients are constant and known. In addition, the expected value of energy consumption per trip is formed as a quadratic function of the consumption of each phase, while the length of the trip is always equal to half the length of the passage. This normalized consumption, among other things, is multiplied by the number of trips per hour and the number of vehicles, number of vehicles, distance and shift hours to determine the desired consumption period.

To calculate energy consumption, a model is proposed that is calculated as a weighted average of energy consumption for each storage location.

$$E_c^H = \sum_{i=1}^{n} \rho_i \cdot E_i^H$$

ρ_i - is the probability that the vault i will be controlled, n - is the number of all storage bins in a single deep aisle and $\mathrm{E}_\mathrm{i}^\mathrm{H}$ - energy consumption. To store a loading unit from a storage and retrieval point to a storage location i, or to retrieve from a storage location i to a storage and retrieval point. E_i^H includes energy consumption both vertically and horizontally during shuttle movements. When calculating E_i^H the consumption of handling equipment, recovery efficiency and the coefficient of friction in the acceleration phase are also not taken into account. In addition, acceleration and transit delay values are equated. In this model, too, the efficiency and friction coefficient in the constant velocity phase are assumed to be constant and known.

III. CONCLUSION

In the course of the work, an analysis was made of modern simulation systems, which make it possible to study the throughput and performance of the storage system using shuttle systems. As you can see, the modeling of such systems is a complex scientific and technical task using a discrete approach to the description of the system. The authors conducted a study of existing modeling strategies that allow calculating the throughput and determined the parameters that make it possible to optimize such systems. In the future, it is planned to carry out improvements in the design of the shuttle, which will optimize the control system by reducing the time for unloading/loading products from the warehouse.

REFERENCES

[1]. Jamwal A, Agrawal R, Sharma M, Giallanza A. Industry 4.0 Technologies for Manufacturing Sustainability: A Systematic Review and Future Research Directions. Applied Sciences. 2021; 11(12):5725. https://doi.org/10.3390/app11125725

[2]. Vladyslav Yevsieiev, Nataliia Demska. Study of the Structure of Cyber-Physical Production Systems in Industry 4.0. The I International scientific-practical conference “Prob-lems of modern science and practice”, September 21-24, 2021, Boston, USA p. 431-434. DOI: 10.46299/ISG.2021.II.I

[3]. Jeff Morgana, Mark Halton, Yuansong Qiao, John G.. Breslina. Industry 4.0 smart reconfigurable manufacturing machines. Journal of Manufacturing Systems, Volume 59, April 2021, Pages 481-506. https://doi.org/10.1016/j.jmsy.2021.03.001

[4]. Vladyslav Yevsieiev, Nataliia Demska. Research Problems of Modern Warehouse Management Systems. With Proceedings of The in-ternational Scientificand Practical Conference «Theoretical And Empirical Scientific Research: Concept and Trends», December10, 2021, OXFORD, UK. P.141. Pp:15-18. DOI: 10.36074/logos-10.12.2021.v2.04

[5]. Igor Nevliudov, Vladyslav Yevsieiev, Oleksandr Klymenko, Nataliia Demska, Maksym Vzhesnievskyi. Evolutions of the Develop-ment of Group Management of Mobile Robotic Plat-forms in Warehousing 4.0. Innovative Technologies and Scientific Solutions For Industries, (4 (18), pp. 57-64. doi: 10.30837/ITSSI.2021.18.057

[6]. Kawthar A. Mohammed Hasan, Ali H. Kadhum, Ameer H. Morad. Evaluation of Yogurt Production Line Simulation Using Arena Software. Al-Khwarizmi Engineering Journal, Vol. 15, No. 4, December, (2019) P. P. 71-78. https://doi.org/10.22153/kej.2019.10.003.

[7]. Darina Dupláková, Ján Duplák, Dušan Mitaľ, Enes Sukic. Analysis of approaches to the material flow in the production process with the use simulation. Univerzitet za poslovni inženjering i menadžmen. Issue No: 1; 2020. Page Range: 36-44

[8]. Mohammed Farhan; Brett Göhre; Edward Junprung. Reinforcement Learning in Anylogic Simulation Models: A Guiding Example Using Pathmind. In 2020 Winter Simulation Conference (WSC), 14-18 December 2020. Conference Location: Orlando, FL, USA. DOI: 10.1109/WSC48552.2020.9383916

[9]. Tone Lerher, Matjaz Sraml, Iztok Potrc, Tomaz Tollazzi. Travel time models for double-deep automated storage and retrieval systems. International Journal of Production Research, Taylor & Francis, 2010, 48 (11), pp.3151-3172. DOI:10.1080/00207540902796008.hal-00580106.

[10]. VDI 2692 Blatt 1. Automated vehicle storage and retrieval systems for small unit loads. URL: https://www.vdi.de/richtlinien/details/vdi-2692-blatt-1-automated-vehicle-storage-and-retrieval-systems-for-small-unit-loads.

[11]. FEM 9.865 Energy consumption - determination methods (ECoDeMISE). URL: https://woe.eu.com/vi/p1221