Hindawi
Mathematical Problems in Engineering
Volume 2022, Article ID 7778952, 10 pages
https://doi.org/10.1155/2022/7778952

Research Article

Digital Twin-Driven Performance Optimization for Hazardous Waste Landfill Systems

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Received 18 January 2022; Revised 9 February 2022; Accepted 17 February 2022; Published 14 March 2022

Academic Editor: Gengxin Sun

Hazardous waste landfill is the final way to dispose of hazardous waste and its environmental risk is different from that of domestic waste landfill. Its dangerous characteristics will not decrease with time, but will exist for a long. The environmental risks of hazardous waste landfills are concentrated in the probability risk of leakage of the impermeable layer. Therefore, it is of great significance to calculate the environmental risk of the leakage source intensity of typical hazardous waste landfills. In order to adapt to the personalized customer needs caused by social and economic development and to pursue new competitive advantages, the production mode of manufacturing enterprises is gradually changing to a small-batch and multi-variety customized mode. The complex and dynamic production environment caused by determinism puts forward higher requirements for the operation control accuracy of large-scale multiunit production systems. To support the efficient and coordinated operation of each link is a key challenge for process control of large-scale multiunit production logistics systems. This article proposes to accelerate the integration of information technology and manufacturing technology to promote the application of intelligent manufacturing process, intelligent logistics management, and other technologies in the production process. The research object is to study the multiunit linkage optimization problem under the framework of digital twin technology, through the real-time collaborative decision-making and feedback execution of the production, transportation, and warehousing multi-decision links to solve the "production-transportation-storage" decision-making in a dynamic environment. We analyzed the problems brought about by the dynamic interference of the execution process on the "production-transportation-storage" linkage operation process of the industrial park and analyzed the challenges of realizing the online linkage decision-making of "production-transportation-storage." Based on the classic digital twin framework, a cross-unit digital twin linkage decision information architecture is proposed. Compared with the conclusions of the original environmental impact assessment report of the project, the post-environmental impact assessment results basically conform to the relevant descriptions, and a few nonconformities have been resolved during the project operation. The environmental protection measures of this project are relatively complete, which can meet various environmental protection requirements and enterprise development needs during the operation period of the project. For some environmental risks found in the process of project operation, evasion measures are proposed to reduce the possibility of environmental pollution accidents, and emergency measures can be taken in time when accidents occur. The practice of post-assessment of the environmental impact of this hazardous waste landfill is generally successful, and it has certain reference significance for the subsequent post-assessment of the environmental impact of other hazardous waste landfills.

1. Introduction

With the rapid development of the national economy, the amount of hazardous waste produced in the production of industrial enterprises has also increased substantially [1]. In 2020, the national hazardous solid waste generation amounted to 34.31 million tons, an increase of 116% year-on-year, the comprehensive utilization and safe disposal of hazardous solid waste reached 26.9 million tons, an increase of 81% year-on-year, and the comprehensive utilization and safe disposal rate reached 78%. Hazardous waste landfills, as a terminal facility for the safe disposal of hazardous waste, occupy an important position in the construction plan of hazardous waste disposal facilities [2]. Hazardous waste landfill is a land disposal measure. It consists of several waste disposal units and buildings. The main components of the landfill include waste pretreatment facilities, waste landfill facilities, and leachate collection and treatment facilities. Since hazardous waste landfills involve many types of hazardous wastes and complex components, they have certain impacts on air quality, groundwater, surface water, biological activities, and human health in the surrounding environment. Research in this field has attracted more and more attention from environmental protection departments and all walks of life.

A digital twin is a virtual body (mapping) of physical entities in the real world. It is a device or product, a production line, a process, a physical system, or an organization. The concept of digital twins is implemented by using "software" constructed with three-dimensional graphics to map objects in reality. This mapping is usually a multidimensional dynamic digital mapping. The digital twin is also a bridge between the real world and the digital virtual world [3].

Based on the development status of post-evaluation of environmental impact and various environmental characteristics of hazardous waste landfills, this article analyzes the advantages and disadvantages of various evaluation methods, selects appropriate evaluation methods, and constructs a comprehensive post-evaluation evaluation of hazardous waste landfills. From the perspective of the topic selection of this thesis, carrying out post-evaluation research into the environmental impact of hazardous waste landfills can test the effectiveness of the on-site implementation of the early-stage environmental impact assessment of hazardous waste landfills and the authenticity of relevant survey data, thereby promoting hazardous waste landfills. The quality of the environmental impact assessment work of the landfill has been continuously improved to realize the assessment of the whole process from construction to operation of the hazardous waste landfill and promote the standardization and systematization of the environmental impact assessment of the hazardous waste landfill. From the perspective of the content of this article, a comprehensive evaluation model for post-evaluation of environmental impact of hazardous waste landfills will be constructed. The method has certain reference significance and also provides theoretical support for the subsequent environmental impact assessment work of other hazardous waste landfills.

This article constructs a digital twin model framework of a hazardous waste landfill system related to landfill capacity. A visual virtual model of the hazardous waste landfill system was developed using 3D modeling technology, and the internal interaction mechanism of the digital twin model of the hazardous waste landfill system was studied. The virtual function blocks related to landfill capacity are designed, and the virtual function blocks with different functions are integrated into a virtual function block network. By constructing a reconfigurable digital twin model of the hazardous waste landfill system based on virtual function blocks, the control of task execution and the reconstruction of landfill capacity are realized. This article proposes an improved genetic annealing IGASA algorithm. The algorithm has strong solving ability and robust performance, which improves the accuracy of the algorithm. This article is oriented to the material network of hazardous waste landfills, comprehensively considers the distribution of transportation tasks and global path planning, adjusts the local path planning based on the time window method, and designs the intelligent material scheduling process. In view of the simple material path network of the intelligent terminal structure processing landfill, the optimal scheduling rules under various system states are obtained through simulation methods, and the rules are solidified based on SVM. Aiming at the large-scale material network, a dynamic priority method based on neuroevolution is proposed, which makes the material scheduling model adaptable and verifies the effectiveness of the method in a variety of situations.

2. Related Work

When discussing the importance of post-evaluation of environmental impacts, relevant scholars proposed that the implementation of environmental impact tracking evaluation and post-evaluation will improve the quality of the environmental impact assessment and encourage the operating unit to actively implement the specific environmental protection measures and emergency treatment methods in the original environmental impact assessment [4]. Moreover, the objective evaluation of the environmental impact of the project plays an important role.

When related scholars elaborated on the theory of post-evaluation of environmental impacts and analyzed specific cases, they pointed out that post-evaluation of environmental impacts is of great significance to the preconstruction preparation and implementation process of the project [5]. The content of the post-environmental impact assessment can reflect the environmental issues exposed during the operation and decision-making process of the project, and reflect the information to the environmental management department in a timely manner, so as to realize scientific decision-making and management of project construction and operation.

Relevant scholars put forward the graphic overlay method based on geographic information system based on the specific situation of the current postevaluation of the environmental impact of municipal facilities projects and selected relevant software as the research and development platform to conduct postevaluation of the environmental impact of municipal facility projects [6]. They have selected nine evaluation factors, such as air quality, water environment quality, acoustic environment, soil environment, ecological environment, etc., determined their weights, and used the data processing function and spatial analysis function of the geographic information system to produce the impact level map.

When relevant scholars discussed the technical methods and work processes of post-evaluation of environmental impacts of construction projects, they discussed the specific implementation constraints of post-evaluation of environmental impacts [7]. It is proposed that the post-evaluation of environmental impact can adopt technical methods such as logical framework method, statistical forecasting method, and comparative analysis method [8]. The working procedures include evaluation commission, planning preparation, resource preparation, social survey and data collection, analysis and research, and report writing.

Relevant scholars apply geographic information systems to post-evaluate the environmental impact of transportation construction projects [9]. They advocate the use of hierarchical weighted map stacking when the post-evaluation of environmental impacts of transportation construction projects and the introduction of computer applications in the post-evaluation of environmental impacts. They use the computer to process the data in the post-environmental impact evaluation and analysis system.

The Greek scholar Christopoulos' research results show that the post-evaluation of environmental impacts can compare the results of environmental impact prediction with the actual evaluation results to verify the previous environmental impact predictions, gradually improve the level of environmental evaluation, and propose qualitative analysis and quantitative analysis [10]. The technical method of the analysis and combination was finally verified with the example of the Russian coal mine in the United States [11].

Relevant scholars took hazardous waste landfill as the research object, established a coupled model of groundwater flow and solute transport, and simulated and predicted the barrier effects of three control measures: leakage of the impervious layer, ground hardening, and drainage ditch and cut-off wall [12]. The researchers found through sampling and analysis of groundwater around a certain solid waste landfill that the surrounding groundwater was mainly polluted by ammonia nitrogen and volatile phenol [13]. Relevant scholars took a hazardous waste landfill in Changsha City as an example to simulate and predict the impact of the landfill leachate under different anti-seepage conditions and provide guidance for the planning and construction of the landfill [14]. The researchers used a hazardous waste landfill in Shanghai as an example and applied the health model recommended by the US Environmental Protection Agency to make a preliminary health risk assessment of groundwater pollution [15]. Relevant scholars took a hazardous waste landfill in Yunnan as an example to evaluate the environmental quality of groundwater in the study area and analyzed the sources of pollutants in conjunction with surrounding soil surveys [16].

Relevant scholars used a combination of qualitative and quantitative methods to carry out post-evaluation research into the environmental impact of the reservoir when conducting the post-evaluation of the environmental impact of the Fengjiashan Reservoir, expounding the relevant theories and technical methods of the post-evaluation of the environmental impact of the project [17]. On the basis of on-site investigation, the environmental impact of Fengjiashan Reservoir was analyzed qualitatively and quantitatively by using the method of comparison, and finally the beneficial and negative impacts of the reservoir were analyzed systematically [18–20].

3. Methods

3.1. Digital Twin Model Framework. The landfill data generated by the hazardous waste landfill system can be mapped to the virtual hazardous waste landfill system in real time, and the hazardous waste landfill system is controlled by real-time instructions from the information service platform during the processing. The physical data generated by the hazardous waste landfill system serves as the basis for driving the operation of the entire digital twin system. It is collected by RFID, smart meters, industrial cameras, and other sensors arranged in the landfill and transmitted and summarized to the information service platform through industrial bus, enterprise wireless network, etc.

The virtual hazardous waste landfill system not only includes the geometry, data, and physical models of landfill equipment and processed products, but also includes the rules, constraints, and behavior models within the system. The virtual hazardous waste landfill system is mainly used for the simulation, optimization, and iteration of landfill tasks. The monitoring, control, and prediction of the hazardous waste landfill system are realized through attribute mapping and information interaction with the hazardous waste landfill system.

The digital twin model of the hazardous waste landfill system related to landfill capacity is related to the physical data model of the landfill capacity of the hazardous waste landfill system, the digital description model of the landfill capacity of the hazardous waste landfill system, and the landfill capacity of the hazardous waste landfill system. The visual virtual model is iteratively interactive. Different models realize information fusion and interconnection through association mapping and communication interface. The model framework is shown in Figure 1.

In the physical space, the hazardous waste landfill system completes the processing of target tasks through the dynamic interaction between the production line level and the landfill unit level. In the process of processing, the various sensing devices installed in the landfill realize real-time collection of landfill data, but the massive, multisource, and heterogeneous characteristics of the landfill data make it difficult to directly convert the original data into knowledge. Therefore, through cleaning, classification, and sorting, the physical data related to landfill capacity are unified into the dimensions of landfill elements, technical parameters, processing process, and processing tasks. The physical data model of the landfill capacity of the hazardous waste landfill system is located at the bottom of the entire digital twin model and provides landfill data support for other models in the digital twin model, driving their dynamic operation.

Based on the landfill data in the physical data model and the semantic knowledge in the digital description model, a visualization virtual model of the landfill capacity of the hazardous waste landfill system is constructed in a virtual space. It uses three-dimensional modeling software such as Soilworks and Demo3D to model all the production

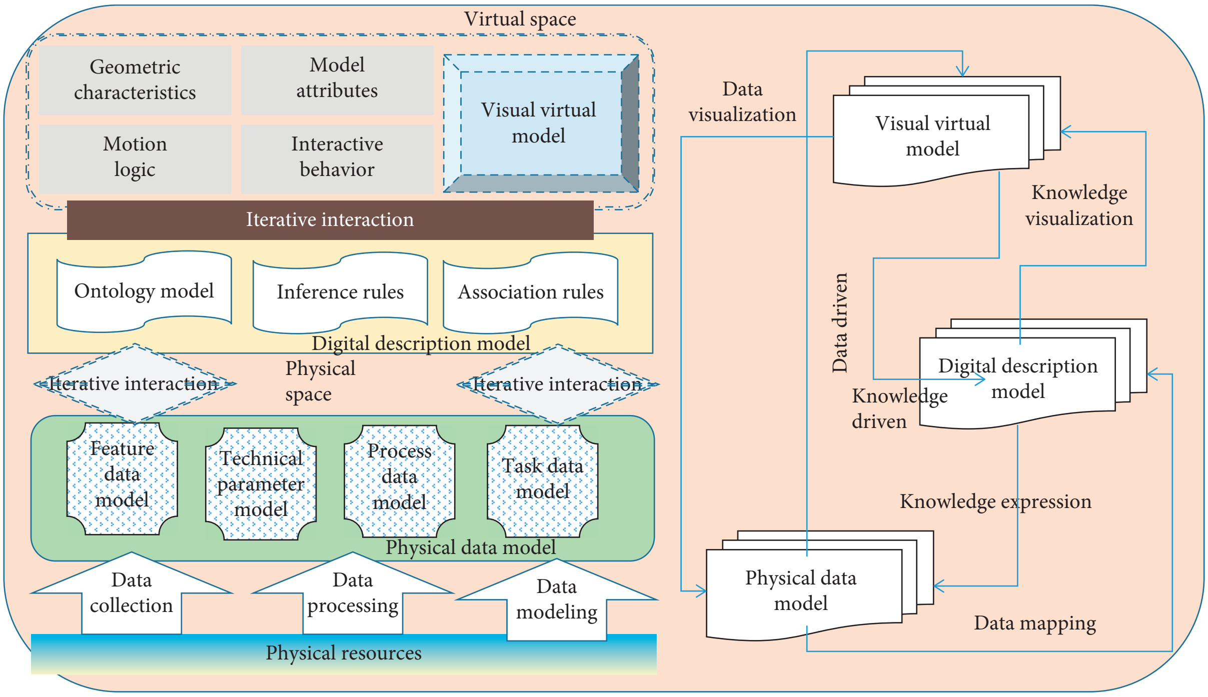

Figure 1: A digital twin model framework of hazardous waste landfill.

elements inside the hazardous waste landfill system in physical space from the aspects of geometric characteristics and physical properties, and uses the Jscript scripting language to equip industrial robots and conveyor belts. The motion logic and interaction behavior between different landfill units are encapsulated into the 3D model. The visual virtual model realizes data communication and mutual control with the hazardous waste landfill system through the PLC interface; realizes various functions such as task simulation, condition monitoring, task optimization, fault analysis, and prediction; and completes the knowledge evolution of the landfill capacity of the hazardous waste landfill system.

3.2. Physical Object-Oriented Virtual Model. The digital twin requires the complete, multiscale, high-fidelity characterization of the physical space in the virtual space, so that the virtual space and the digital space can interact and operate synchronously without barriers. The construction of the visualization virtual model of the hazardous waste landfill system related to the landfill capacity can realize the visualization of the production elements, production tasks, processing process, and landfill capacity of the hazardous waste landfill system in the physical space in the virtual space. The visual virtual model needs to describe the hazardous waste landfill system in the physical environment from multiple aspects. The virtual model controller is designed to control each submodel in the virtual landfill.

The visualized virtual model of the hazardous waste landfill system needs to replicate the real physical environment, establish a three-dimensional coordinate system in the virtual environment, and scale all physical objects in the physical environment into virtual three-dimensional models in equal proportions, and arrange these models according to the process layout of the physical space. The changes of equipment, materials, and workpieces related to the landfill capacity in the physical space can drive the corresponding elements in the virtual space to make corresponding changes in real time through the mapping of the physical environment to the virtual environment, thereby realizing the synchronization of the physical environment and the virtual environment. In addition, with the help of the virtualization and visualization of knowledge attributes related to the landfill capacity of the hazardous waste landfill system in the virtual environment, landfill operators can control the landfill capacity of the hazardous waste landfill system in the physical environment in real time, so as to control hazardous waste.

The operation of the visual virtual model of the hazardous waste landfill system needs to be driven by data related to landfill capacity. The interaction of intermediate data realizes the association between the physical data model, the digital description model, and the visual virtual model. In the process of interaction between physical data and virtual data, the hazardous waste landfill system based on digital twins can realize real-time synchronization and mutual control between physical objects and virtual models.

The fusion of the physical model and the virtual model refers to the physical data model of the landfill capacity of the hazardous waste landfill system in the physical space, the digital description model of the landfill capacity of the hazardous waste landfill system in the virtual space, and the visualization of the hazardous waste landfill system related to the landfill capacity. The construction of a multidimensional model of the landfill capacity of an industrial hazardous waste landfill system needs to be characterized from multiple dimensions of physical objects, knowledge semantics, and virtual information. It not only describes the underlying landfill resources, processing flow, and task scheduling in physical space, but also describes the knowledge concept, reasoning rules, model behavior, and simulation process of landfill capability in virtual space. At the same time, the relationship and interaction mechanism between the multidimensional models of the landfill capacity of the hazardous waste landfill system are established to realize the virtualization and visualization of the landfill capacity of the hazardous waste landfill system.

3.3. *Virtual Function Block Network Construction.*

The virtual function block logically corresponds to the landfill unit in the hazardous waste landfill system, and its structure is shown in Figure 2. The input events of virtual function blocks include execution event flow and reconstruction event flow. The execution event flow and execution data flow are coupled to reconstruct the event flow and reconstruction. Data flow and knowledge data flow are coupled. In the virtual function block, on the basis of the original execution control table, a reconstruction control table for reconstruction control is added. Accordingly, the internal algorithm of the function block is divided into an execution algorithm and a reconstruction algorithm. In this way, the virtual function block can perform task execution control and landfill capacity reconstruction in parallel. The execution event flow and execution algorithm are controlled and scheduled by the execution control table, and the reconstruction event flow and reconstruction algorithm are controlled by the reconstruction control table.

When a new processing task arrives, the execution event flow of the virtual function block is the current processing task of the hazardous waste landfill unit, and the execution data flow is task data, equipment data, and process data. The execution event flow and execution data flow drive the operation of the virtual function block, and under the scheduling of the execution control table, the adaptive algorithm is selected for execution, so as to realize the control of the task processing process. When conditions such as changes in the requirements of processing tasks occur, the information will be input into the virtual function block in the form of reconstruction event flow and reconstruction data flow. The current landfill capacity is diagnosed. When the landfill capacity is insufficient, an appropriate reconstruction algorithm is selected to execute through the reconstruction control table, landfill resources are reallocated, and processing tasks are replanned, so that the landfill capacity of the landfill unit can meet the requirements of the processing tasks again, while changing the state in the reconstruction control table.

In the virtual function block network, different virtual function blocks are closely connected according to the process layout of the hazardous waste landfill system in the physical space. The output events and output data of one virtual function block can be used as input events and input data of another virtual function block. As a bridge between the virtual function block network and the hazardous waste landfill system in the physical space for information exchange and communication control, the service interface virtual function block can be divided into two types: subscribe virtual function block and publish virtual function block. The subscribe virtual function block is used to receive input data and input events from the physical space, and the publish virtual function block is used to send the output data and output events of the function block network to the hazardous waste landfill system in the physical space. From the outside, the virtual function block network still has the structural characteristics of the virtual function block, and also has the input/output event interface and the input/output data interface. Different from the virtual function block, the virtual function block network deals with higher level events and data and realizes the task control of the entire hazardous waste landfill system and the dynamic reconstruction of the landfill capacity.

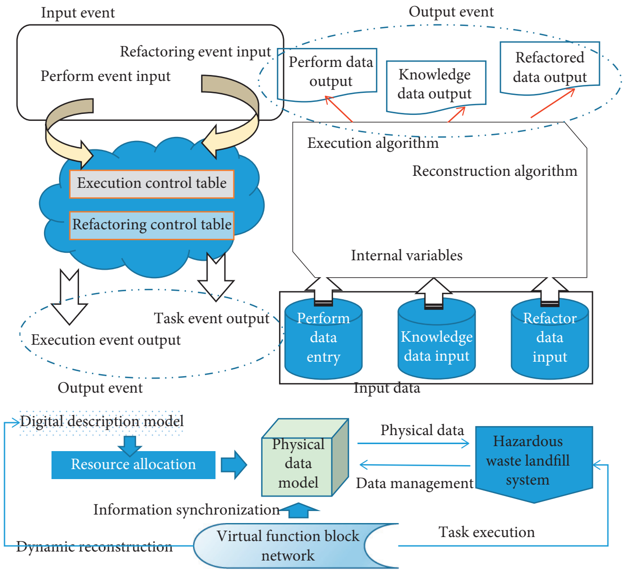

Figure 2: Virtual functional blocks related to landfill capacity.

3.4. *Construction of a Reconfigurable Digital Twin Model Based on Virtual Function Blocks.*

In the hazardous waste landfill system, the multilevel landfill capacity is encapsulated to provide landfill services as a whole through mechanisms such as hierarchical association, task decomposition, real-time interaction, and dynamic coordination between the landfill unit level and the production line level. The physical data model is a unified description and modeling of landfill equipment and landfill resources in the hazardous waste landfill system. The digital description model uses digital form to describe the multilevel landfill capacity through the mining and analysis of physical data and stores the semantic knowledge related to the landfill capacity in the knowledge base with the help of ontology tools. The visual virtual model integrates the physical data of the physical data model and the knowledge information of the digital description model and realizes the sublimation of knowledge information while dynamically replicating the hazardous waste landfill system in the virtual space. The data transmission and information interaction between these three types of models constitute a multidimensional model of the hazardous waste landfill system related to landfill capacity. The multidimensional model dynamically interacts with the virtual function block network in the virtual space through data interaction, task interaction, and knowledge interaction.

In the task execution stage, after receiving the task order and resource allocation plan, the visualization virtual model is based on the high-fidelity and full-element characterization of the hazardous waste landfill system in the physical space. After many iterations in the model, the task processing schedule is worked out. The task processing arrangement will be input to the virtual function block network in the form of event stream. The virtual function block network is driven by the input task from the visual virtual model and the input data from the physical data model, relying on the internal execution control table to control the processing process of the task. After the task processing is completed, the landfill resource database and task plan database will be updated. When the next batch of task orders comes, it can be matched with the historical data and historical schemes stored in the database, so as to quickly respond to task requirements and improve production efficiency.

Based on the physical data model, the ontology theory and mining algorithm are used to extract and mine knowledge attributes and association rules related to landfill capabilities at different levels and construct a digital description model in the virtual space, filled with data and physical data model. The knowledge attributes describing the model are correlated and updated in real time. By visually modeling the geometry, physics, and rules of physical entities, a virtual model in a virtual space can be constructed. At the same time, the model motion logic, model interaction mechanism, and human-computer interaction mechanism are embedded into the virtual model, so that the virtual model can reproduce the information and state of the physical entity and realize the interaction and synchronization between the physical space and the virtual space. The state data from the physical entities, the simulation data of the virtual model, the reconstruction data of the virtual function block network, the virtual-real fusion data, and the semantic knowledge constitute the twin database. With the support of the twin database, the model attributes in the virtual space can be synchronized with the landfill data of the physical entity to ensure the accuracy of the model. The entity of the physical space can receive the control data from the virtual space, so as to realize the control and scheduling of the physical entity.

3.5. Optimization Based on Improved Genetic Annealing Algorithm.

Genetic algorithm is an intelligent search algorithm based on natural selection and genetic inheritance. It draws on the biological evolution principle of "survival of the fittest" and uses phenomena such as reproduction and mutation in the process of simulating biological evolution to automatically adjust the search process to achieve efficient global search.

When using the genetic algorithm to solve the processing path optimization problem, each "chromosome" (individual) represents the code of each feasible solution (feasible solution) in the problem, and several chromosomes form a group (all possible solution spaces). The effect of the solution is evaluated by the fitness function, the fitness value is calculated and given, and then the population evolution is realized through selection, crossover, and mutation operations. The selection operation is used to generate offspring individuals, which fully embodies the natural law of "survival of the fittest." The "excellent" individuals are used to continue producing offspring and the "bad" individuals can be directly eliminated. Crossover operation is the key operation of GA. It acts on the population. It is the same as the mutation operation. The crossover operation changes some genes in the chromosome according to the predetermined probability. After crossover and mutation operations, a new generation with better performance than the previous generation is generated. As a result, the population gradually evolves towards the approximate optimal solution. Therefore, the GA algorithm can be regarded as a process of gradual evolution of a group composed of a certain number of solutions.

Genetic algorithm has the concept of population, can process multiple individuals at the same time, has high parallelism, high calculation accuracy, relatively small calculation time, and strong global search ability. GA still has some shortcomings. When solving optimization problems, genetic algorithms have weak local optimization capabilities and often converge to local extreme points, resulting in nonoptimal solutions.

SA is a heuristic random intelligent optimization algorithm, derived from the principle of solid annealing. SA is based on the similarities between the thermal balance problem between particles and the combinatorial optimization problem during the annealing process of solid materials to achieve the goal expectation of finding the global optimal or approximate optimal solution. SA is a probability-based algorithm. The Brownian motion between particles will increase significantly when the solid matter is heated up, and it will quickly become disordered as the temperature rises. When the temperature of the object rises to a sufficiently high level, the solid matter will change. At this time, the annealing and cooling operation is carried out, and the movement between the particles gradually weakens, and gradually becomes orderly as the temperature decreases, until the equilibrium state at this temperature is achieved. When the temperature drops to the lowest temperature (generally referred to as normal temperature), the internal energy of the particles is the smallest and the particles reach a stable state.

The primitive feature can be expressed as follows:

$$D = \begin{bmatrix} d_1 & 1 & \cdots & 1 \\ 0 & d_2 & \cdots & 0 \\ 1 & 1 & \ddots & 1 \\ 0 & 0 & \cdots & d_n \end{bmatrix}, \quad (1)$$

where n represents the primitive type, D represents the set of all primitive types in this processing, for each element d_i $(0 < i < n)$ in the D set, it represents the specific processing information of the ith type of primitive.

$$E(x) = \prod_{i=0}^{nN-1} \left[(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2 + (z_i - z_{i-1})^2 \right]^{1/2}, \tag{2}$$

where $n * N$ is the number of all primitives, and x_i, y_i, and z_i, respectively, represent the direction coordinates of the three coordinate axes.

The Metropolis criterion actually defines the acceptance or acceptance probability of a state (solution): when the current solution, that is, the energy $C(j)$ is lower than the energy $C(i)$ at the previous moment, the current solution is chosen to be the new solution instead of the previous one. On the contrary, when the current energy is higher than the energy at the previous moment, the new solution is not completely abandoned, but the new solution is accepted with a certain probability. Through the application of this random factor, SA can escape the limitation of local optimal solution and obtain (approximately) global optimal solution.

$$P_{i\longrightarrow j} = \begin{cases} -1 & C(i) < C(j) \\ e^{C(i)-C(j)}/T & C(i) \geq C(j) \end{cases}. \tag{3}$$

Since *SA* is an optimization for a single individual, its “climbing” ability is relatively good, and it escapes the limitation of local solutions, but its grasp of the entire solution space is insufficient, resulting in poor global grasp ability. The slower speed results in longer running time. GA is a group algorithm with high parallelism, short running time, better control of the overall situation, but low local optimization ability. Therefore, this section first improves GA, and then combines the improved GA algorithm with SA to form a new algorithm—improved genetic annealing algorithm (IGASA).

In order to avoid the problem of poor solution ability of the algorithm due to improper setting of the initial temperature, the following method is used to set the initial temperature:

$$T_0 = \left|0.5E_{\text{Smean}} - E_{S\,\text{min}}\right|, \tag{4}$$

where E_{Smean} and E_{Smin} represent the average and minimum values of the solutions in the initial population, respectively.

$f(x)$ is used to evaluate the pros and cons of each chromosome in the population. Generally, the larger the value of $f(x)$, the better the individual. The optimization objective function of CNC machine tool processing path optimization is the least cost, that is, the shortest stroke. Therefore, the inverse stroke is used to express the fitness function, and the fitness of individual k is as follows:

$$f(k) = E(k)^{-1} \bullet E_{S\,\text{min}}. \tag{5}$$

Select chromosomes by integrating optimal retention and duplication, namely, elite retention and improved roulette: first the chromosome with the largest *f(x)* value is retained and copied it to the next-generation population, and use improved roulette for the remaining choosing. Taking the square value of *f(x)* as the roulette selection object, the probability and cumulative probability of the individual being selected are calculated as follows:

$$\begin{aligned} P(x_i) &= f^2(x_i) \bullet \prod_{j=0}^{N-1} f^{-2}(x_i) \\ q_i &= \prod_{k=0}^{i-1} \left[P(x_k) \bullet P(x_{k+1})\right]. \end{aligned} \tag{6}$$

By taking the square of fitness as the object of roulette, the traditional roulette selection is improved, and the cumulative probability of individuals with high fitness is increased, thereby increasing the convergence speed of the algorithm.

4. Results and Analysis

4.1. Intelligent Material Scheduling. When the production plan, process information, etc. are completely determined and undisturbed, material scheduling can theoretically achieve global precision scheduling. However, real systems are often complex and dynamic, and material scheduling often uses simple and easy heuristic scheduling methods. Material scheduling can be divided into multiple stages. Each module generates feeding and receiving requests to the AGV system (AGVS). When the AGV reaches the material docking point, the AGVS needs to be assigned to the idle AGV. During the operation of the landfill, the AGV selects a better driving path (local path planning) according to the location of the next task to be executed and other AGV states.

The total task set contains w tasks, and the computing speed of the computer is generally 112 times/s, so the relationship between the running time of the traversal search and the number of tasks is shown in Figure 3. It can be seen from Figure 3 that the time of the traversal search is less than 3.5 s, which has a certain real-time performance.

4.2. Combination Rule Simulation Based on Improved Genetic Annealing Algorithm. Due to the limitation of the landfill space, the AGV paths for the actual material transportation of the intelligent terminal structural parts processing landfills are all one-way single-channel tracks, and the transportation path network is very simple. When the assignment of the AGV's receiving and feeding tasks is completed, the path planning can be determined accordingly. When the AGV may collide and interfere, it only needs to use simple traffic management methods to avoid the collision.

The actual material transportation system often adopts heuristic task allocation rules, and needs to allocate as many tasks as possible at a time when the constraint conditions of the abovementioned task allocation strategy model are satisfied. However, when the state of the system changes, a

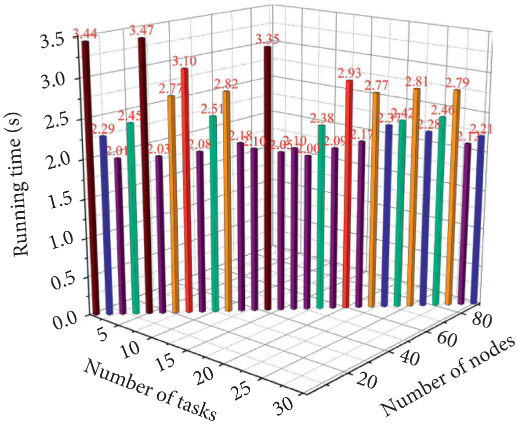

Figure 3: The relationship between the running time of the ergodic algorithm and the number of tasks.

single scheduling rule does not perform well in some cases. Based on the digital twin landfill model, the system location per unit time is used as the evaluation performance index, and the four parameters of AGV number, process tact, processing time fluctuation coefficient, and production line failure rate, are used as the description of the system state, and different scheduling rules are simulated. We statistically analyze the system performance indicators and obtain the optimal scheduling rules under various system states, as shown in Figure 4.

For how to select scheduling rules based on the state of the system, machine learning provides a new solution. Machine learning is mainly used to solve the problem of classification and prediction. The main idea is to establish the relationship between the system state and the type of scheduling rules, and in actual use, the corresponding rules according to the state of the system and the learned model output are selected.

In this article, the improved genetic annealing algorithm is used to construct the mapping relationship between the system state and the scheduling rules, and 2000 sample data are obtained through simulation operation. The improved genetic annealing algorithm test data prediction accuracy rate is shown in Figure 5.

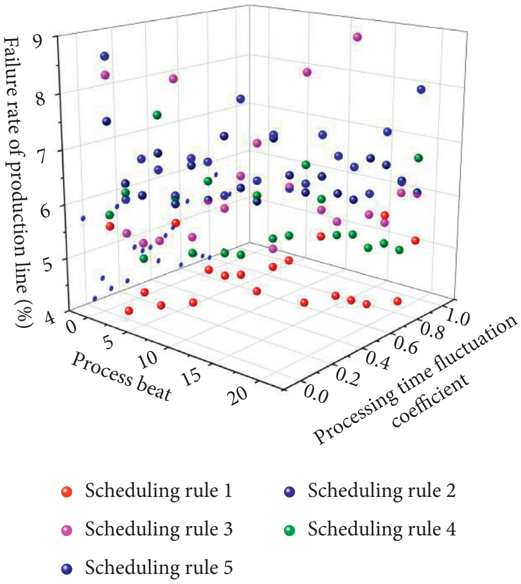

Figure 4: Optimal scheduling rules in each system state.

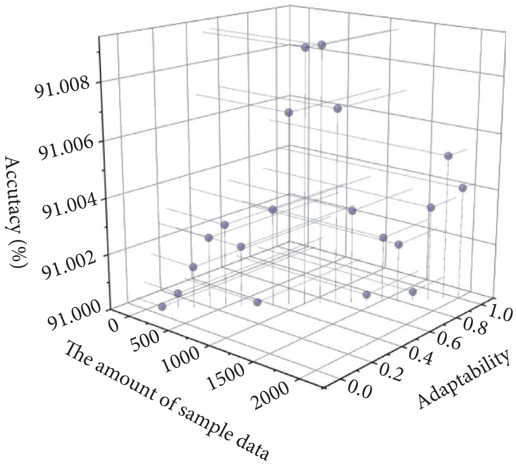

Figure 5: Improved genetic annealing algorithm test data prediction accuracy.

4.3. Dynamic Priority Simulation Based on Neuroevolution.

The dynamic strategy method based on simulation and SVM needs to consider various system states in advance, and then the actual data or simulation data are calculated and trained to obtain the scheduling planning selection model. However, the scale and state of the actual production system are complex and diverse, and the boundary of the system state is not completely predictable. When the organizational structure of the production system is adjusted and changed, it is necessary to re-statistics and repeat model training. For landfill material scheduling under different scales and system states, the priority evaluation V of its task set should also be dynamic.

The main idea of how to solve the optimal V in various situations is to express the priority evaluation function V through a neural network. The input of the neural network is each single-rule indicator and the real-time state of the system, and the output is the priority of the task set.

The solution of the optimal V in each situation is transformed into the optimization problem of its neural network parameters. The general neural network parameter optimization process is based on sample data, using the gradient descent method, according to which the optimal direction is pointed out, and iterating continuously in this direction is updated. In this article, we need to solve the learning problem of a strategy. Direct label data cannot be obtained, only simulation performance indicators under different strategies can be obtained. As a branch of reinforcement learning, neuroevolution has developed rapidly in recent years. It provides another important method for solving the optimization of neural network parameters. It applies evolutionary ideas to parameter optimization and can take advantage of the characteristics of parallel

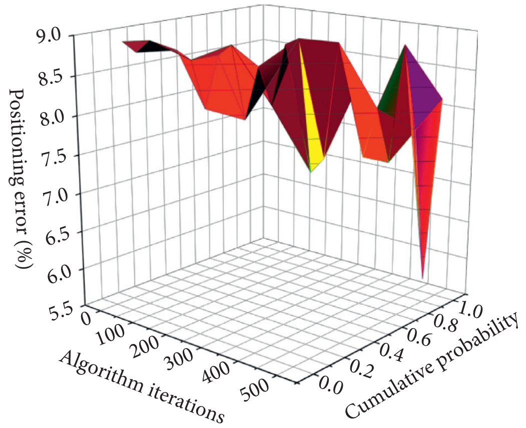

Figure 6: Accurate positioning error of material location in hazardous waste landfill.

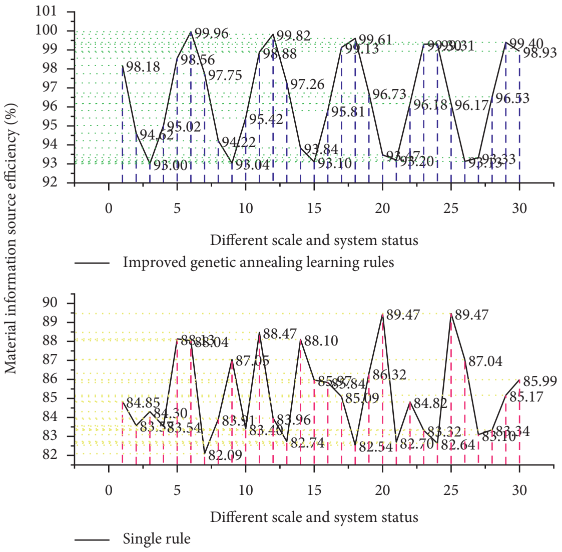

Figure 7: Comparison of single-rule and improved genetic annealing learning rule in multiple situations.

computing. In the case of a larger order of magnitude, it performs better than traditional reinforcement learning methods.

The neural network model constructed in this article contains a three-layer structure. The input layer is the evaluation index of five conventional scheduling rules, the output layer is the priority of a task set, and the middle hidden layer contains three neurons. The activation parameter selects the sigmoid function and uses evolution. The algorithm optimizes and solves 9 neural network parameters. Based on the digital twin landfill model, it simulates the production process of materials under various scales and states and obtains statistics of the overall position of the system per unit time as a measure of individual fitness.

Under the system state, where the number of AGVs is 1, the average processing time of production modules is 115 s, the time standard deviation coefficient is 14%, the module failure rate is 22%, and the material scheduling is carried out. Figure 6 shows the accurate positioning error of the material position in the hazardous waste landfill.

The optimization of the priority evaluation function was carried out for the production system under 30 different situations, and compared with the optimal average production capacity of single-rule scheduling. The results are shown in Figure 7. It can be seen that the material information source efficiency corresponding to the improved genetic annealing learning rule is greater than or equal to the material information source efficiency of a single rule.

5. Conclusion

Aiming at the problems of insufficient interaction and difficulty of integration between the physical space and the information space of the hazardous waste landfill system, a digital twin model framework of the hazardous waste landfill system related to the landfill capacity is proposed. We developed a visual virtual model of the hazardous waste landfill system and analyzed the interaction mechanism between the multidimensional models in the digital twin model of the hazardous waste landfill system. The virtual function blocks related to landfill capacity are designed, and the virtual function blocks with different functions are integrated into a virtual function block network. Based on the reconfigurable characteristics of virtual function blocks, the dynamic reconfiguration of the landfill capacity of the hazardous waste landfill system is realized, and the problem of reduced production efficiency caused by changes in production factors during the production process is solved. The improved genetic annealing IGASA algorithm is studied, which improves the accuracy of the algorithm. Considering task allocation and global path planning issues, we build an intelligent landfill material scheduling model. On this basis, for simple material network, this article designs a combined rule scheduling method based on simulation and improved genetic annealing algorithm. For complex material networks, we propose a dynamic priority method based on neuroevolution, so that the material scheduling process can be adapted to production material systems of different scales and states, and the effectiveness of the method is verified through examples. Digital twins can reduce the dependence on the hardware environment in the research process of physical entities. Therefore, in addition to applying the virtual and real synchronization technology characteristics of the digital twin to visualize real-time monitoring of the landfill unit, the offline simulation technology characteristics of the digital twin can also be used to perform offline simulation of the landfill unit. Although this article focuses on constructing a fault tree and anomaly diagnosis expert knowledge system around the equipment in the digital twin landfill unit, it only explores the application of the digital twin from the landfill unit abnormal diagnosis, and it is necessary to further expand the management and control of the digital twin in the landfill unit in the later period. At the same time, the application of data science and simulation technology in this article is not sufficient, and further considerations need to be given to the application scenarios and matching degree of data science and simulation technology in landfill unit management and control.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Acknowledgments

This work was supported by the Project of The Basic Research Program of Wenzhou Municipal Bureau of Science and Technology in 2021: Design and Application of Digital Twins System in Hazardous Waste Landfill (Grant no. S20210018).

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