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The application and development of digital twin in mulberry sericulture

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Abstract: The method of mulberry silkworm breeding has gradually evolved from manual empirical breeding to intelligent and factory farming as artificial intelligence technology has advanced. This paper discusses the current state of mulberry sericulture, as well as the basic concept, application prospect, industrial technology, and existing research results of digital twin technology for complex silkworm house environment monitoring system. The application and development of digital twinning technology in silkworms' culture can not only improve the efficiency and yield of silkworm's culture, but also provide technical support for industrial upgrading and development. Finally, this paper summarizes the digital twin technology system, key technology, technology application, and challenges for complex silkworm house environment monitoring system, and provide an outlook on the application of digital twin in mulberry sericulture.

1. Introduction

Silkworms culture has thousands of years of historical experience in China, and the development of mulberry silk weaving industry is one of the important driving forces of China's development. Clothing and other types of silk fabrics made of mulberry silk with Chinese cultural characteristics spread all over the world. Many countries know China because of silk fabrics[1], and China is also famous in the world.

Digital twin technology can map the real world to the virtual world and establish a mapping relationship corresponding to the real world in the virtual space, which provides a foundation for the application of digital twinning technology in the field of mulberry silkworm breeding. For example, digital twinning technology can be applied to display the feedback data of the sensor in the silkworm house on the created information platform. The traditional mulberry culture needs a lot of human resources in the environment management of the silkworm house. The sensor of the silkworm house needs to collect and adjust the data one by one. With the development of economy, mulberry silkworm breeding has gradually formed large-scale and industrial development, and the scale of silkworm house has been expanded, so the labor cost has been greatly increased. In view of this situation, the integration of mulberry culture and digital twin technology can greatly reduce

labor costs, improve breeding efficiency and promote the intelligent development of mulberry industry.

This paper firstly summarizes the status quo of traditional mulberry culture and mulberry culture industry, introduces digital twin technology, and summarizes the application and research status of digital twin technology in mulberry culture field.

2. Silkworms culture summarize

Silkworms culture has a long history in China, and records of planting mulberry and sericulture are rich in Chinese ancient literature. After a long period of development, mulberry culture technology gradually mature, and with the development and progress of agricultural science and technology and constantly update and improve. At present, people have been able to use modern science and technology to cultivate mulberry seedlings, seed production, sericulture and carry out large-scale, intensive and specialized sericulture. The integration of mulberry culture and modern science and technology has brought a technological revolution and innovation for China's sericulture industry.

2.1 Present situation of traditional silkworm rearing

As an ancient agricultural culture, traditional sericulture has a long history. In many areas, traditional sericulture is still the main way for local farmers to increase their incomes and is an important part of the local economy. However, with the development of social economy and the improvement of living standard, the traditional silkworm rearing is facing more and more challenges.

There are several problems in Chinese traditional agricultural sericulture model:

1) Small sericulture area, farmers planting mulberry sericulture enthusiasm is not high. According to statistics, in 2021, the total area of mulberry plantations in China was 796,700 hm2, and the planting amount was 17.24 million, of which the silkworm cocoon output in the east (Jiangsu, Zhejiang, Guangdong, Shandong and Hainan provinces) accounted for 12.64% in 2021. The silkworm cocoon production in the west (Guangxi, Sichuan, Chongqing, Yunnan, Shaanxi, Guizhou, Gansu and Xinjiang) will account for 80.89% in 2021. In sericulture production, especially in sericulture production, the problem of "more but not stronger" is more prominent.

2) The cost is high and the profit is small. The profit of farmers growing grain is much higher than that of planting mulberry and raising silkworm. It is estimated that the average income of grain and mulberry is 2000 yuan and 1500 yuan. Due to the low benefit of grain planting, mulberry rearing silkworms has obvious comparative advantages, farmers planting mulberry rearing silkworms income is much higher than planting grain.

3) Small scale and scattered, difficult to form scale management and industrialization development. Chinese sericulture has obvious regional characteristics and technical advantages, but it is still mainly operated by farmers on a small scale at present, and lacks effective organizational forms to effectively connect with large markets and form industrial division of labor. At present, in rural areas, especially in the main sericulture areas, it is still an industry with considerable development potential. Therefore, how to rely on the advantages of "three areas", achieve scale management, improve technical level and develop industrialization is one of the important issues to be solved to accelerate the development of Chinese sericulture.

Traditional sericulture is an important part of Chinese sericulture industry, which is the crystallization of the long-term hard work of Chinese working people, and has made great contributions to social and economic development. However, due to its own limitations, the traditional silkworm rearing technology in some areas can no longer adapt to the current social

development, so it is necessary to introduce and popularize new technology to perfect and improve.

2.2 Present situation of culture Silkworms industry

Nowadays, Silkworms industry still has an important position in agricultural economy production. At the same time, mulberry culture and mulberry silk weaving industry also play an important role in social development and construction. Mulberry culture keeps the historical charm while keeping up with the pace of The Times[2].

Sericulture industry plays a very important role in the adjustment of agricultural structure, increasing farmers' income, increasing employment of agricultural labor force and promoting the development of rural economy.

In China, Silkworms industry is an export-oriented industry, and the domestic market is relatively small. Silk commodities made from silk production are mainly exported, mainly to the European Union and the United States[3]. The Silkworms market relies on the international market for export and is susceptible to the fluctuations of the international market. Therefore, Silkworms culture industry not only needs to face pressure from within the industry, but also needs to deal with competition from outside the industry.

At present, China's sericulture industry is still facing the challenge of digital transformation, which is mainly reflected in the shortcomings of data collection, silkworm seed quality, sericulture management system, information communication and so on. Most of the data acquisition equipment is handheld, lack of effective management, technology and equipment need to be further improved; Silkworm seed procurement from different sources leads to mixed varieties and uneven quality, so it is necessary to improve the sericulture management system and the function of digital service platform. Most sericulture areas have not been connected with optical fiber, information transmission can only rely on mobile terminals, each sericulture is an independent island of information, sericulture information is still in the initial stage. Digital sericulture must use broadband network, but at present most of the silkworm areas have no broadband network, and in the process of digital sericulture needs a lot of calculation, data transmission and processing, so it needs a large number of servers and other hardware equipment and maintenance personnel for maintenance. On the whole, sericulture industry is facing severe challenges.

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3. Digital twin technology

Digital twinning is a new technology mode of constructing physical entity with digital technology. It is the crossover integration of digital technology and Industry 4.0. Its basic principle is: the physical system and process in the real world, through digital equipment such as sensors, virtual simulation mapping to the computer three-dimensional space, so as to carry out dynamic simulation of the real system. Digital twin technology can drive better product production, optimize operational processes, reduce costs and improve customer experience. The concept of "digital twinning" was first proposed in the United States. This definition defines the basic prototype of digital twinning technology[4].

At present, countries around the world are committed to integrating digital twin into product design, product manufacturing, medical analysis, engineering construction, urban management and

other fields. Microsoft sees Azure Digital Twins as an IoT platform to empower digital models in the environment, including buildings, factories, energy networks, and even entire cities. The digital twin technology of SAP in Germany is based on its Leonardo platform[5], which realizes real-time engineering research and development by creating complete digital products. Siemens seamlessly integrates the real world and the virtual world through digital twin, digital design, simulation and verification of products, and integration of electrical and electronic systems. Japan's NTT company put forward the "digital twin Computing Plan" in 2019[6]. In February 2021, Tokyo, Japan, unveiled the "Tokyo Metropolitan 3D Visualization Demonstration Project"[7], which made use of digital twin technology to produce 3D urban models of West Shjuku region and Shibuya ·Roppongi region, and conducted simulation experiments with these models to verify the effects of infrastructure construction on population flow, disaster prevention and reduction. Compared with the United States and Germany, digital twin research and attention in China is relatively late. China's digital twinning started from Professor Tao Fei of Beihang University, who introduced the concept of digital twinning in Computer Integrated Manufacturing System[8].

4. Application of digital twin in Silkworms culture

At present, digital twinning is widely used, including mulberry silkworm industry. The application of digital twinning technology in mulberry culture mainly combines virtual model with real data, and realizes real-time monitoring and control of mulberry culture through modeling in the real world. The equipment used in mulberry culture mainly includes sensors, Internet of things equipment and so on. The application of digital twinning technology in mulberry culture can not only improve the production efficiency and quality level, reduce the cost, but also effectively improve the culture environment and conditions, and improve the economic benefits of mulberry. Intelligent temperature and humidity sensors and video monitoring equipment are installed in the silkworm house to monitor whether the environmental factors in the silkworm house are normal. Through monitoring equipment and intelligent sensors, the collected data information is transmitted to the central server in real time, and finally the three-dimensional visualization and dynamic simulation model is generated and pushed to the user for review and analysis, which solves the problem of difficult personnel management in the process of silkworm rearing, and greatly improves the efficiency and quality of silkworm rearing.

With the development of technology, human beings have entered the information and digital age. Digital twin technology enables the public to have a deeper understanding of people, things and objects in the physical world. The application of digital twin technology in agriculture has provided people with a deeper understanding of the processes, decisions and data in the agricultural production process. At present, the digital twinning technology can improve the understanding and grasp of all the elements in the production process of mulberry silkworm culture by digital, visualization, intelligent management, and at the same time, the use of computer simulation technology to analyze and simulate the entire production process of mulberry silkworm culture. Through digital and visual presentation, it can provide scientific decision-making and guidance basis for mulberry culture managers. The main research contents of the application of digital twinning in mulberry culture are divided into four aspects: silkworm house environment monitoring, virtual mulberry silkworm modeling, silkworm growth simulation and digital visualization and interaction.

4.1 Environmental monitoring of silkworm house

In the traditional silkworm house, the environment of silkworm rearing is bad and difficult to control. Such as indoor air humidity is too large, poor ventilation, light is too strong, insufficient

light, humidity in the silkworm room will cause the occurrence of silkworm disease. If we want to control these unfavorable factors, we need to monitor and manage the environment of silkworm house in real time, so as to achieve better rearing effect. The digital twinning technology was used to monitor the environment of the silkworm house in real time, and the environment conditions in the silkworm house were adjusted timely through the intelligent data analysis of the system.

The functions of digital twinning system applied to silkworm house environmental monitoring are as follows:

1) Data acquisition: Collect sensor data using the Internet of Things technology, upload it to the cloud server, and then judge the temperature and humidity changes in the silkworm house through real-time monitoring, analysis and processing;

2) Warning and control: real-time temperature, humidity and alarm information in the silkworm house can be directly viewed in the monitoring center, and remote control of temperature and humidity in the silkworm house can also be achieved through mobile phone App.

3) Cloud platform and statistical report: all monitoring data are counted and analyzed through the cloud platform, and the analysis results are sent to the user's mobile phone through the App. After data collection and processing, the temperature and humidity changes of each room can be viewed every day;

4) Linkage control: linkage control can be carried out on the equipment in the silkworm house when abnormal conditions occur. For example, when the indoor humidity is too high, turn on the dehumidifier to reduce the humidity. When the indoor temperature is too high, turn on the exhaust fan to lower the temperature. In the case of unattended, remote control can be achieved through mobile App.

Through the integration of various data, a set of environmental monitoring system suitable for the growth and development of silkworm pupa can be generated. In terms of environmental monitoring system research, Tencent applied real-time digital twinning technology to map the whole process of ecological environmental monitoring in reality to the digital twinning world in a key project initiated by Beijing Ecological Environment Monitoring Center[9]. The system can quickly build 3D visualization models to achieve remote, highly realistic and immersive energy control. At the same time, it can conduct intelligent analysis on monitoring images, automatically identify equipment defects and environmental anomalies, and comprehensively improve the production efficiency and safety level of energy enterprises.

4.2 Virtual mulberry silkworm modeling

As virtual reality technology becomes increasingly mature and enters a wide range of application fields, passive and inanimate static virtual environment can no longer meet the actual needs of real world simulation, and it is urgent to construct computer-synthesized virtual organisms in it[10]. Virtual mulberry silkworm modeling is based on three-dimensional laser scanning and three-dimensional laser point cloud data, using computer graphics and digital technology, three-dimensional modeling software for three-dimensional digital processing, acquisition of mulberry silkworm surface morphology, texture, shape and other spatial feature data, construction of digital twins and rendering. Through the analysis of morphological characteristics and characteristic parameters of mulberry in different growth stages, the accurate modeling of mulberry in different growth stages was realized. In the virtual mulberry silkworm modeling, the application of digital twin technology is mainly the digital reproduction of the growth process of mulberry silkworm. Through real-time monitoring of the environmental parameters in the growth process of mulberry silkworm, the construction of digital twin, digital modeling of the virtual mulberry silkworm through the digital model in the digital twin, the use of three-dimensional simulation software to

complete the simulation of virtual mulberry silkworm. In practical applications, the mulberry growth process can be monitored and data collected in real time, the data can be transmitted to the digital twin for digital reproduction, and then it can be simulated by building a model, and real-time interaction can be carried out by monitoring and data acquisition. For example, real-time monitoring of mulberry can be conducted according to data such as light, air humidity and soil temperature during the growth of mulberry leaves, and the virtual mulberry model can be modified and adjusted according to its growth status and data changes, so as to ensure the accuracy and effectiveness of mulberry modeling and provide reference and basis for the cultivation and cultivation of mulberry. Virtual mulberry silkworm modeling can also visually display silkworm (pupa) in different growth stages, and classify the models according to the characteristics of different growth stages. By comparing and analyzing the collected point cloud data with the model, the characteristic parameters of silkworm (pupa) in each growth stage can be obtained, which can prevent silkworm diseases in advance and give early warning to its growth state.

4.3 Silkworms growth simulation

silkworms growth simulation is based on physiological mechanism, combined with mulberry leaves, climate and other environmental factors required by mulberry growth, through digital simulation of mulberry growth conditions. With the deepening cognition of the physiological state process of mulberry silkworm, as well as the development of virtual reality and Internet of Things technology, biological simulation based on digital simulation develops rapidly[11] and is gradually widely used in the growth of mulberry silkworm. silkworms growth simulation refers to the use of computer simulation and simulation technology to simulate the growth process of mulberry from hatching to pupae, so as to achieve the analysis of the growth law of mulberry and optimize the breed aquatics program. Generally speaking, growth simulation needs to consider the following aspects:

1) Simulation accuracy: It requires high-precision calculation and data to simulate the growth process of mulberry silkworm, including multiple factors such as environmental temperature, humidity and nutrient level. Therefore, accurate data analysis and reliable algorithms are very critical.

2) Model construction: A complete simulation of mulberry growth requires the establishment of an accurate model, including the equations and models representing the physiological and biochemical processes at each stage of mulberry growth. At the same time, the model should be designed with comprehensive consideration of the actual breeding environment and the differences between different varieties of mulberry.

3) Visualization: The simulation results must be presented in a visual form, so that users can intuitively understand the experimental data and optimize or improve the breeding plan by observing the model results.

4) Interactive: Mulberry growth simulation needs to develop a friendly user interface to facilitate users to control and feedback the simulation process. At the same time, the user can also modify the input variables to change the experimental conditions, so as to realize the analysis and adjustment of the model.

In short, silkworms growth simulation is an important technical means to simulate and analyze the growth process of mulberry, which is of great significance to improve the breeding and production level of mulberry. In the process of establishing the model, various factors need to be taken into account to control the physiology and behavior of mulberry silkworm growth as accurately as possible.

4.4 Digital visualization and interaction

Digital visualization is a very important tool that can present complex things and systems in a visual way. Visualization includes Geographic Information System (GIS), 3D visualization and Building Information Modeling (BIM). In digital visualization, interaction is a very important link. For different data types, different users, according to the need for reasonable interaction. For example, the analysis and processing of silkworm big data, after processing the silkworm house environmental monitoring, virtual modeling and silkworms growth data, the visualization, finally analysis and processing. But the two cannot replace each other, digital visualization is just a form of interaction, interaction is more important than digital visualization. But the two cannot replace each other, digital visualization is just a form of interaction, interaction is more important than digital visualization.

1) Three-dimensional visual design

Visualization technology began to appear and develop in the late 1980s, it is a kind of computer data processing and image display technology combined for practical application of information technology. 3D visualization technology based on computer technology is mostly reflected in the form of software, which is currently mainly divided into modeling software, platform software and application software. The key of 3D visualization is modeling. Platform software is mostly based on models to realize basic operations such as roaming, observation, analysis and decision making. The application software is mainly developed to satisfy the application of 3D visualization technology in a certain aspect, such as digital campus, digital community, 3D urban landscape simulation, etc.[12,13].

The visual design process in silkworms culture can be simply divided into three parts: front end, processing and back end[14]. The original data extracted from a variety of silkworm culture data sources are converted into visual graphics that are easy to perceive and receive information, and the deep-seated high-value information contained in the original data is visually displayed, as shown in Figure 1.

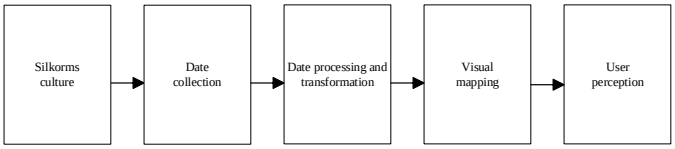

Figure 1: Visualize the transformation process

Among them, data acquisition directly determines the format, dimension, size, resolution, accuracy and other important properties of data, and to a large extent determines the quality of visualization results. Data processing and transformation is to convert less structured or unstructured original data into highly structured metadata tables. The conversion process includes data noise removal, data cleaning and feature extraction. Visual mapping is the core of the whole visualization process, which maps the value, spatial position and relationship between different position data of mulberry silkworm breeding data to different visual channels. In user perception, the biggest difference between data visualization and other data analysis and processing methods is the user, who uses data visualization results to feel the difference of data and extract information, knowledge and inspiration.

2) Twin interaction design

In the world of silkworms culture digital twinning, all physical entities are digitized, modeled and interoperable. Interaction design is the core of the interaction between farmers and digital twins. It is necessary to study the interaction design of mulberry silkworm breeding twins from the perspective of farmers. Digital twin interaction design needs to pay attention to the physical objects in the physical world and the virtual world at the same time, so as to achieve the consistency of the

physical objects and the virtual objects in the information expression, interaction mode and logical relationship, and achieve the perfect integration of the real world and the virtual world.

Twin interaction design is to match the interactive interface by calling the program language and according to the relationship between the computer to construct three-dimensional animation in the virtual environment. It calls complex computer background running programs, including application functions and commands, to carry out the interaction process quickly and intuitively, and realize the interaction between the subject and the scene in the virtual situation[15].

The following points must be paid attention to in the interactive design of mulberry silkworm breeding twinning: First, the information requirements of real and virtual environments of mulberry silkworm breeding under different types and scenarios should be understood, and the corresponding interaction modes should be selected according to their requirements. Secondly, it is necessary to analyze the characteristics and forms of data information transmission, as well as possible problems in the process of data information transmission. Thirdly, it is necessary to analyze the types of perceived information under the corresponding scenes according to different rearing scenarios of silkworm age, and select the appropriate information content and mode. Finally, the safety performance and risk level required for the interaction between virtual world and real breeding should be considered to ensure the safe growth of mulberry worms.

5. Conclusions

With the continuous development of intelligent agriculture industry, mulberry silkworm breeding is gradually changing from traditional sericulture mode to modern technology sericulture mode. In this process, there are still many difficulties to be overcome, which not only requires sufficient manpower and material resources but also needs advanced science and technology. Through the analysis of this paper, it can be seen that the application prospect of digital twin technology in the sericulture industry is very broad. Digital transformation and intelligent upgrading can be carried out in each link of the sericulture industry chain by using digital twin technology, which greatly improves the production efficiency. The application and development of digital twinning technology in silkworms culture can not only improve the efficiency and yield of silkworms culture, but also provide technical support for industrial upgrading and development. With the continuous update and iteration of digital twin technology, it will be further applied to silkworms culture industry and bring more innovative methods and technologies. At the same time, digital twin technology will be more applied to other agricultural industries, bringing greater benefits to agricultural production.

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