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RESEARCH

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Theoretical analysis and technical application of mechanical intelligent manufacturing based on system digital-driven technology

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Abstract

With the accelerating process of global industrialization, the automated fabrication industry, as an important part of the industry, is also developing rapidly. Due to the low efficiency and high resource consumption of traditional manufacturing, it is more important to improve the production efficiency of conventional manufacturing and realize the resource-saving development mode. Due to the characteristics of system digital-driven technology, it can promote the intelligent development of the manufacturing industry. Therefore, the deep integration of system digital-driven technology and manufacturing is conducive to the intelligent promotion of manufacturing. Comparing the difference between the traditional manufacturing industry and the intelligent manufacturing industry, the application potential of system digitalization technology in the manufacturing field is analyzed. Based on the analysis of the theoretical basis of the system digital-driven technology and the application of the system digital technology in the main fields, the importance of the technology for the improvement of the accuracy index in the manufacturing process is emphatically analyzed. The maximum increase can be 5.3%, and the minimum increase can be 3.3%. It can be seen that the deep integration of digital-driven technology and manufacturing can not only improve the intelligent level of manufacturing, realize the intensive development of the industry, but also realize the data sharing of the entire industrial chain.

Keywords: System digital-driven technology, Artificial intelligence, Data sharing, Automated fabrication, Big data analytics

Introduction

Economic development is often built on the basis of the manufacturing industry. Now some traditional manufacturing enterprises still use relatively backward manufacturing and management technologies in the actual production management process. The relative lag of traditional manufacturing technology not only cannot help enterprises improve their product quality and production efficiency but also causes waste of various resources to a certain extent, and does not conform to the concept of sustainable development [1, 2]. In the context of rapid economic development, the transformation, upgrading, and high-quality development of the manufacturing industry must be based on digital means. Driving the rapid development of the manufacturing industry with big data and artificial intelligence technology has become the mainstream trend. Building a digitally driven intelligent manufacturing industry and promoting the information construction of the industry can ensure the intelligent improvement of the manufacturing industry and make continuous contributions to future development. Therefore, it is extremely necessary to adopt intelligent manufacturing technology in the manufacturing industry to change the current development status and characteristics. The application of digital-driven technology to promote the continuous development of the manufacturing industry has also become an inevitable requirement for the sustainable development of global industrialization.

Since the beginning of the twenty-first century, the global industrialization process has been accelerating, and all countries are facing the stage of continuous industrialization [3]. Digital artificial intelligence technology has become an accelerator for countries' industrialization strategies and plays a vital role. Digital artificial intelligence technology has been widely used in many disciplines and achieved fruitful results [4, 5]. The introduction of this technology has played a positive role in the development of various disciplines and has been deeply integrated with our daily lives. In the process of continuous advancement of globalization and industrialization, manufacturing is the core development field, and digitalization and intelligence are the core technologies [6, 7]. From the perspective of productivity, the application of digital technology and intelligent manufacturing technology in the manufacturing industry can effectively solve the problem of reducing labor resources while also effectively improving the production quality and efficiency of the manufacturing industry [8–10]. At the same time, digitalization and intelligent manufacturing require high-precision technical talents, which can also optimize the talent structure and continue to promote economic development [11].

At present, in the management process of the traditional manufacturing industry, on the one hand, a large amount of data has been accumulated due to the simple process of intelligence transformation and upgrading; on the other hand, the data standards are not unified, the data acquisition is difficult, and the data quality is poor [12, 13]. The data in the management process of the traditional manufacturing industry is mostly static and decentralized, which is cumbersome to rely on manual processing, and lacks the linkage mechanism between the overall processes. Therefore, the overall planning management is extremely difficult. In the management process, there are problems such as unclear business boundaries between the upper and lower levels, and unsmooth information flow, which are easy to create information islands [14]. The above phenomena easily lead to the failure to maximize the overall value of the enterprise and the failure to further improve the quality and efficiency.

Automated fabrication is a branch of the manufacturing industry, and it also faces the need to further deepen digital-driven technology. The development of the manufacturing industry is constantly improving, and the application of digitalization and intelligence in this field is becoming more and more extensive. The development of the manufacturing industry needs to combine modern scientific production technology, with the help of digital intelligence technology, to continuously drive the manufacturing industry towards the direction of "intelligent manufacturing." The technical means adopted by the manufacturing industry directly affect the quality of products [15]. The use of system digital-driven technology not only meets the needs of the times but also meets the needs of the market. Therefore, intelligent manufacturing based on system digital-driven technology can effectively promote the healthy development of the whole manufacturing industry based on improving the core competitiveness of enterprises.

To accelerate the development of intelligent manufacturing, China has published the intelligent manufacturing standard architecture, which lacks the support of information modeling and standards. To remedy this defect, China launched a special plan for intelligent manufacturing, focusing on digital information models and connectivity. Taking China's intelligent manufacturing system as an example, Fig. 1 shows the system architecture of China's intelligent manufacturing [16, 17].

In the manufacturing area, more and more enterprises take system digital-driven technology as an effective tool to improve intelligent manufacturing, gradually increase the investment in intelligent manufacturing, provide a financial guarantee for the application research of system digital-driven technology in manufacturing, further promote the deep integration of this technology and manufacturing, and accelerate the development of industrialization. In addition, the application of system digital-driven technology also promotes the overall management level of the manufacturing industry and the continuous improvement of business quality of practitioners to a certain extent, enhances the automation and intelligence level of mechanical equipment, provides a new concept and direction for enterprises, and improves the quality of intelligent manufacturing of machinery. Through the continuous improvement and application of system digital-driven technology and the comprehensive application of large data and neural network technology, the level of intelligent manufacturing will be significantly improved. Through the comprehensive and deep integration of traditional manufacturing and intelligent technology, the distance between us and the era of intelligent manufacturing will become smaller and smaller and the more benefits we will get from the era of artificial intelligence. Figure 2 shows the number of intelligent robots in major developed countries and developing countries respectively [18].

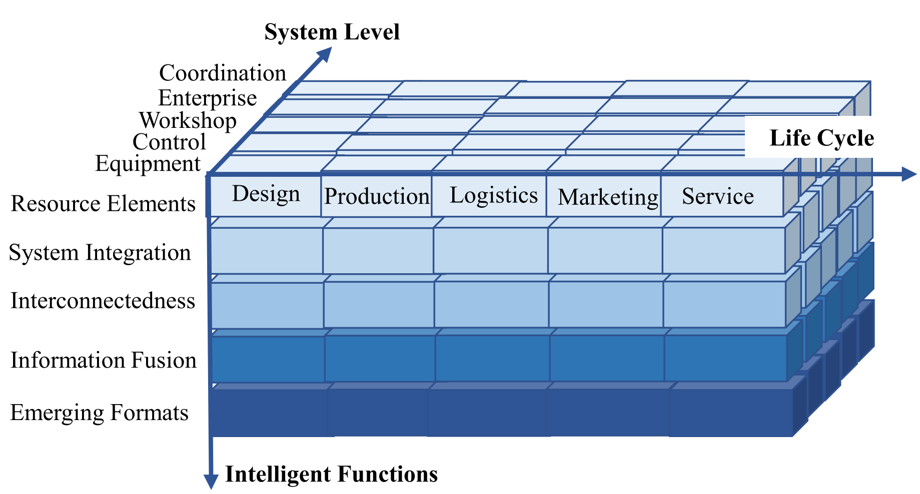
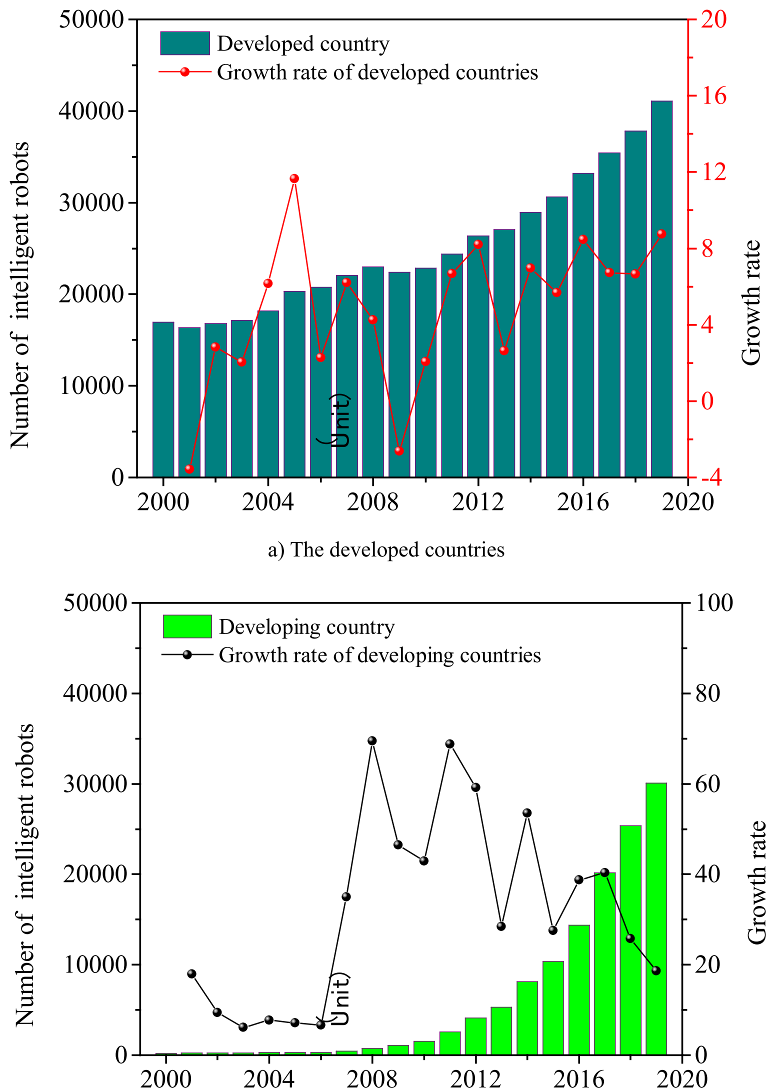


Fig. 1 Architecture diagram of China's intelligent manufacturing system



a) The developed countries

b) The developing countries

Fig. 2 Number of intelligent robots in countries with different economic development levels. **a** The developed countries. **b** The developing countries

It is obvious that the number of intelligent robots in developed countries is significantly higher than that in developing countries, but the growth rate in developing countries is relatively high. This also shows that developing countries need to further improve their current level of intelligence, shorten the gap with developed countries, and promote the comprehensive improvement of artificial intelligence applications.

Based on the above analysis, it is more important to give full play to the advantages of digital-driven technology in the manufacturing industry [19]. In the process of transformation of the digital-driven manufacturing industry, enterprises should make use of large-scale upgrading and transformation of systems and equipment to achieve the data-based full process management of core businesses such as design and fault detection in the manufacturing process and further expand the application scope of digital intelligent technology.

Methods

Basic theory of system digital-driven technology

The basic connotation of system digitalization

In the development process of artificial intelligence, early system digitalization is regarded as the basic application of information interaction, big data, and computer technology [20]. The main feature of this process is to convert complex data information into unified symbols or information by computer. The system digitalization is a digital signal based on digital technology, which is processed and analyzed by an artificial intelligence machine. With the gradual deepening of the application of big data and artificial intelligence technology, the scope of system digitalization technology has been gradually expanded, and its definition has gradually formed a diversified description [21, 22].

The common research classifications mainly include macro, meso, and micro levels to understand the connotation of digital technology. Based on the macro-level analysis, system digitalization is a series of activities carried out on the Internet platform driven by big data or artificial intelligence technology, which can promote the renewal and transformation of the social and economic environment and provide an important basis for macro-level analysis and decision-making. From the medium level, system digitalization refers to a big data resource library formed by integrating various elements of enterprises in the industry, such as human resources, material resources, technical resources, and management level, thus providing a shared digital platform for the sustainable development of the industry. From the perspective of current development, system digitalization is not only limited to traditional computer, artificial intelligence, and other digital industries but also includes new industries integrated with traditional industries driven by system digital technology. As a traditional basic industry, automated fabrication has become the most direct industry of system digital-driven technology.

The system digital-driven technology divides the elements in the source data system into different data sources for classification and analysis, collects the data source changes of different elements in production activities, centralizes them into a database, and collates and analyzes the data of each element and related factors among them. Through the analysis of the above big data, the relevant results will be stored on the big data platform of the system. The data in the platform will feedback and control the front-end production factors, ultimately realizing the optimal use of various resources, realizing intelligent control of activities, improving the intelligent level of the system, and thus promoting the continuous updating and iteration of production technology. Figure 3 is the schematic diagram of the system digital-driven technology process, giving the basic process of data collection, analysis, and feedback of the system digital-driven technology.

Main application fields of system digital-driven technology

As an intelligent and efficient tool, system digital-driven technology has been widely used in various fields of national economic activities. From the industrial level, it can be divided into the basic ability layer, the cognitive layer, and the field application enabling layer [23]. The basic layer is mainly composed of three basic elements of digital-driven technology, namely computing power, algorithm, and data. The technology layer is mainly based on the classification of digital technology research directions, mainly divided into perceptual technology and cognitive technology. The application layer

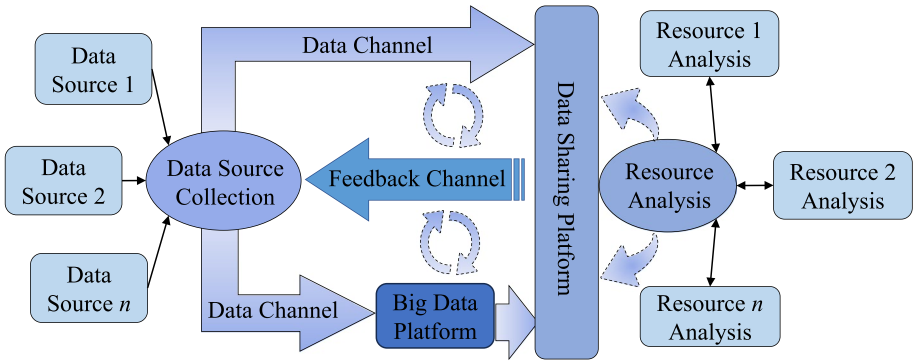


Fig. 3 Schematic diagram of system digital-driven technology process

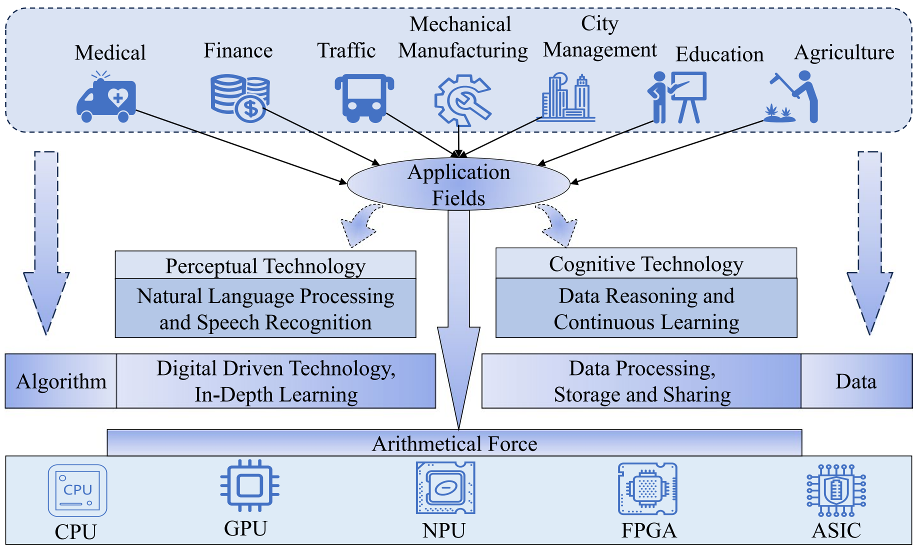


Fig. 4 Application level and field of system digital-driven technology

mainly refers to the implementation of intelligent scenarios [24]. Figure 4 shows the application distribution of system digital-driven technology in some main fields. In addition, this technology is also widely used in other fields.

The application layer of the system of digital-driven technology mainly involves medical and health, finance, transportation, urban intelligence, government affairs, education, agriculture, environmental protection, and other fields. More than 10% of Chinese enterprises combine artificial intelligence technology with their main businesses, promoting the improvement of the industry status and the continuous optimization of business benefits [25]. The application of system digital-driven technology in different fields not only improves the rapid development of related fields but also provides a technical basis for the standardized and intensive development of the industry. The rapid development of various fields has also accelerated the further promotion of system digital-driven technology, which forms a mutually reinforcing situation and provides sufficient development impetus for economic construction and industrial development.

In the medical field, the application of system digital-driven technology mainly refers to the use of artificial intelligence, neural networks, big data, and other technologies to upgrade the medical process to a new modern medical method. In this way, the patient can complete the diagnosis of the disease with the simplest medical process. In a broad sense, using the system digital medical system can realize the resource sharing of medical instruments and high-level experts, which transcends the distance limit in bit physical space. The hospital with a perfect health information database will be authoritative. At the same time, the establishment of the hospital health information system has greatly improved the systematization of diagnosis, treatment, education, and scientific research, making the hospital continuously improve its diagnosis and treatment level and competitiveness.

Under the background of system digital-driven technology, the digital transformation and development of finance are closely related to high-quality economic development. We should optimize the economic industrial structure, give full play to innovation advantages, increase the application of system digital-driven technology, strengthen information sharing among economic industries, jointly promote the digital transformation and development of the financial economy, and lay a solid foundation for higher quality economic development.

The intelligent transportation of digital driving technology is based on the channel network, energy network, digital transmission control network, and intelligent vehicle of physical space, and the traffic control network and transportation service network of system digital-driven technology are the core to form a travel service network and freight transportation service network with deep integration and high coordination of all links.

The application of digital-driven technology is an important technical basis in the process of intelligent city construction. With digital technology as the support and the digital industry as the leading project in urban development, a series of big data resource databases centered on digital services are formed. In the process of digital city management, it is necessary to improve and innovate the infrastructure and various functions in urban management through remote sensing mapping, computer network technology, biological simulation technology, and other corresponding technical measures.

Intelligent manufacturing is the inevitable choice for the future development of manufacturing enterprises, and intelligent manufacturing is the core of the industrial revolution in the new era. To better keep up with the pace of the times, manufacturing enterprises need to realize the digital management mode based on artificial intelligence in the manufacturing industry. It can be seen that to achieve a healthy and stable development of the manufacturing industry in the future, it is necessary to move towards the direction of intelligence. From traditional manufacturing to modern manufacturing driven by digital technology, many problems and difficulties will be encountered.

Development and present situation of intelligent manufacturing

Development of intelligent manufacturing

The manufacturing industry has a long history of development. Compared with other emerging enterprises, the theory and experience accumulated in the process of development are more abundant. Today, with the increasingly deep integration of artificial intelligence technology and daily life, science and technology are constantly developing and improving, and people's living standards are rapidly improving. Therefore, people have higher and higher requirements for all aspects of personalization. The management mode of the automated fabrication industry is still the traditional management mode commonly used by the current manufacturing enterprises. Under the background of continuous updating and development of system digital-driven technology, the competition among enterprises is more intense, while the intelligent construction of most manufacturing enterprises is still relatively backward. Therefore, we should pay enough attention to the construction of digitalization and informatization in manufacturing enterprises.

The system's digital-driven technology is an efficient means to improve the management mode of the manufacturing industry. The experience of information technology in developing countries is relatively short. Compared with developed countries, there are still some problems with professional technology. From the actual situation of the large- and medium-sized automated fabrication industry, most enterprises have started the digital management mode. However, it is still in the early stage of relatively slow development and cannot systematically apply this digital intelligent management mode. In addition, in most developing countries, the teaching of related majors is also undergoing reform, and the education sector has also increased its emphasis on the combined development of manufacturing and digital technology. However, due to the insufficient recognition of the relevant departments on the digital management of the manufacturing industry, the degree of emphasis still needs to be improved. It is necessary to further increase financial support and human support, supplement the shortcomings of the lack of talents, accelerate the information construction of the domestic manufacturing industry, rapidly promote the development of the manufacturing industry, and shorten the overall level of the digital construction of the manufacturing industry with the world's developed countries.

Based on the evolution process of industrial digitalization and the development path of the manufacturing industry, the development process of industrial digitalization is given in Fig. 5. At the end of the eighteenth century, the development of industry was mainly manual manufacturing [26]. The labor force was mainly human, with slow efficiency and relatively backward development. By the middle of the twentieth century, some mechanized production has begun. Although some machines have replaced manual labor in this production and the efficiency has been improved to a certain extent, at this time, the production is still in a relatively backward stage, and there is much room for improvement of production efficiency [27, 28]. By the 1970s, with the continuous improvement of business concepts and the deepening of global industrialization, the mechanical production of most enterprises had been further accelerated and realized. With the continuous increase in demand, simply relying on mechanized production has been unable to meet the comprehensive management needs of enterprises. Therefore, in the field of automated fabrication, more and more enterprises have begun to pay attention to the introduction of artificial intelligence and big data technology, thus forming the application of system digital-driven technology in this field. This phenomenon has become more obvious since entering the twenty-first century. The popularization and application of system digital-driven technology have promoted the transformation from "manufacturing" to "intelligent manufacturing," provided more advantageous technical

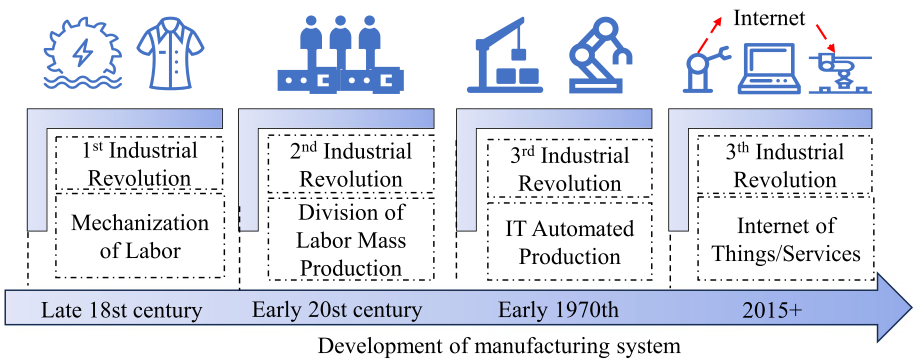


Fig. 5 The evolution of industrial digitalization

means for the development of the industry promoted the production of the industry to be more efficient, resources to be more intensive, and management to be more elaborate.

Current situation and dilemma of automated fabrication development

Automated fabrication, as an important branch of the industrial base, plays an important role in promoting economic and social development. As it belongs to technology and labor-intensive industries, it has also become an important source of power for technological innovation. For our country, the automated fabrication industry has become the largest manufacturing country in the world from the beginning, and we also deeply appreciate the dividends that the manufacturing industry brings to us. From the reform and opening up to the present stage, the manufacturing industry in China's coastal areas has begun to rise rapidly, especially in the Yangtze River Delta and the Pearl River Delta, which have become important clusters of manufacturing industry due to their inherent geographical advantages and the continuous liberalization of national policies.

Automated fabrication often involves the design and production of important mechanical parts, and the precision of processing is relatively high. Conventional manual and lathe technology can no longer meet the requirements of production, so it is easy to have a low pass rate and waste resources during production and manufacturing. At the same time, it ignores the accumulation and analysis of system production data and cannot provide data support for the later expansion of production.

Especially at the design stage, traditional design processes appear weak in the field of modern manufacturing with higher precision. In the field of modern mechanical design, more complex and huge data analysis is required before the design to meet the process requirements. At this point, if we still rely on the traditional design process, not only the production efficiency be reduced but also the product fineness will be difficult to meet the requirements. However, with the involvement of AI technology, system digital-driven technology is introduced in the process of machine design and manufacturing, which can carry out fine machining according to the requirements of the machine. Through the analysis and study of the depth of historical experience data, the more suitable production target data is determined according to the assembled parts, and the matrix programming is carried out through historical experience value and design requirement value so that the objective problem can be solved automatically.

In addition, the processing and assembly of parts are relatively complex in the machinery industry, and there are many parts working procedures for the machine. The whole process must be carried out in strict accordance with the standard and logical sequence. Errors or numerical errors will lead to interruption of the whole manufacturing process, damage to instruments and equipment, cause economic losses, and even endanger the life and safety of personnel. These conditions will not only increase production costs but also reduce production efficiency. However, with the help of system digital-driven technology, the production line can greatly reduce human resources, not only reduce the value deviation of parts caused by human factors, improve the efficiency of manufacturing, but also effectively guarantee the safety factor of personnel. Part of automated fabrication is relatively dangerous. To reduce the harm to people caused by automated fabrication, in enterprises with system digital-driven technology, artificial intelligence technology can be used instead of traditional manpower for pipeline production. At this time, when there is a failure in the design and production process, artificial intelligence technology can immediately warn of the failure and specify the location, which not only reduces the production cost but also improves the safety factor.

Based on the above analysis, the main problems facing automated fabrication at present are to ensure the safety of workers; improve the design and production precision of spare parts; achieve fast diagnosis and repair of faults in the system production process; achieve economic, efficient, and maximum storage of relevant data in the whole process management process to form a data sharing platform; and improve the process technology of automated fabrication through in-depth analysis of data sharing platform. Then, realize the whole industrial chain "Intelligent transformation of manufacturing."

Principle of application of system digitization technology in manufacturing

Application status of system digital-driven technology and manufacturing

With the continuous development and progress of science and technology, the application of intelligent automated fabrication in the field of intelligent manufacturing is expanding and deepening. Through intelligent manufacturing, the role of manufacturing is maximized. Through digital-driven technology, a large number of automatic analyses and calculations of data are carried out, and the deep accumulation and learning of big data are continuously carried out. Intelligent communication technology is used to collect data in the production process and combined with cloud computing to realize the big data sharing of the whole manufacturing. From the current application of intelligent manufacturing in manufacturing, it can be found that its application modes are diverse. The main advantage is that the economic cost is reduced through intelligent application, and the quality and accuracy of production are improved. In terms of industrial manufacturing, China has launched Made in China 2025, which shows that China attaches great importance to the development of the manufacturing industry. At the same time, intelligent manufacturing combined with system digital-driven technology to promote the sustainable development of its industry is also an important strategy and strategy in its development process.

The maturity of industrial automation has also promoted the further development of intelligent manufacturing and has become an important way to achieve intelligent manufacturing. Intelligent manufacturing based on system digital-driven technology makes more use of large-scale data, networks, artificial intelligence, and other new technologies. With the continuous development of digital information technology, the Fourth Industrial Revolution leading intelligent systems around the world has changed. The integration of German Industry 4.0, American Industrial Network, Made in China 2025, and other new information technologies and manufacturing thinking into the production model has led to significant changes in the industrial form, which is also the future planning of intelligent manufacturing in major countries around the world based on the current application of intelligence in manufacturing.

At present, the big data analysis and application of intelligent manufacturing based on the system digital-driven technology are mainly based on the network, which constructs the mobile data into a data network construction in different forms from the data of the manufacturing industry and products. Through the collection and analysis of big data, we can use a large amount of data to analyze and complete the design and manufacturing of products. The core of the application of digital-driven technology is to adopt a new generation of information communication technology and sensor technology to realize the design and manufacturing of mechanical equipment. In the current intelligent manufacturing process, related equipment is combined with cloud computing through the Internet, and digital manufacturing-related technologies are combined in the entire industrial manufacturing to realize the automation of information flow.

Combined with the above analysis, Fig. 6 shows the flow chart of intelligent manufacturing based on the system's digital-driven technology. Each sub-data center conducts data analysis and processing and transmits relevant data to the data-sharing platform of the main data center. At the same time, each sub-data center can receive data instructions from the main data center, thus realizing intelligent management of the whole process.

Integration of system digital-driven technology and intelligent manufacturing

The introduction of system digital-driven technology has brought higher working efficiency to manufacturing and promoted the development of the manufacturing

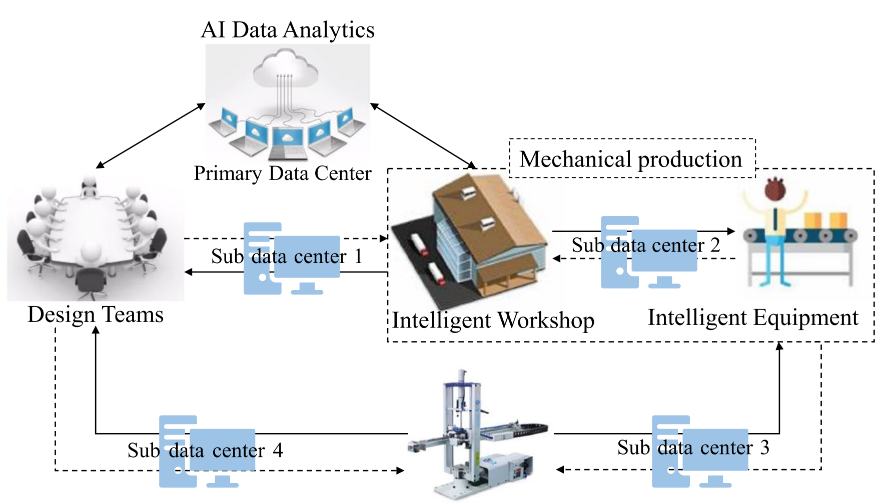


Fig. 6 Flow chart of intelligent manufacturing based on system digital-driven technology

industry towards industrial automation. At present, digital technology has played an important role in all aspects of manufacturing. From the front-end design, material analysis, and selection, to the optimization and improvement of the manufacturing process in the medium term, to the final product inspection in the later stage, and even to the market sales, all have become a part of the overall link of intelligent manufacturing. Each part of the data sharing through digital technology has become an organic part of intelligent manufacturing. After the introduction of system digital-driven technology, it has played a more significant role, especially in the design stage, fault diagnosis stage, and information processing stage.

Integration of system digital-driven technology and mechanical design The design link is the most important part of intelligent manufacturing. The application of digital technology in mechanical design can meet the accuracy requirements of designers for different products or equipment. Through the analysis and optimization of big data, the design efficiency is improved, while the labor cost is reduced. In the design process, the production mode of mechanical systems can be innovated by integrating artificial intelligence technology to achieve a more diversified development of design. In the design stage, attention should be paid to the construction of the automation level of machinery to reduce the impact of subjective design factors. Through the introduction of digital technology, the mechanical design phase can achieve long-term continuous work and can store information at different design stages and read and deeply learn the information, which is conducive to the promotion and improvement of the overall design. At this stage, the system digital-driven technology has been applied to mechanical engineering such as aircraft manufacturing, ship manufacturing, and automobile manufacturing, and its mechanical equipment parts design has been innovated, breaking the thinking limitations of traditional mechanical design and making mechanical design more flexible.

Integration of system digital-driven technology and manufacturing fault diagnosis In the process of automated fabrication, the staff needs to demonstrate the data generated during the operation of machinery, and the traditional demonstration method needs to invest a lot of human and material resources. However, the introduction of system digital-driven technology in the demonstration link can achieve efficient processing and classification of relevant data and effectively improve such problems. In addition, the application of digital technology in the demonstration process can ensure the accuracy of the demonstration work. Through in-depth analysis of digital technology, the automatic detection function of mechanical faults can be realized, and the detection results can be verified by reverse inference, which improves the accuracy of detection. Therefore, through the system digital-driven technology, the fault diagnosis of mechanical devices can be realized, and the production efficiency of mechanical use can be improved.

Integration of system digital-driven technology and data processing In the traditional manufacturing process, the data processing tool has greater limitations, which affect the quality of manufacturing and cannot meet the requirements of high-precision data processing in manufacturing. Therefore, in order to effectively solve the problem of accuracy and efficiency of data processing in the manufacturing process, the application of digital-driven technology has become a way based on advantages in the data processing process. In the actual application process, digital technology can comprehensively monitor the problems in the data transmission process, monitor the stability of the information system operation, and improve the reliability of massive data input and output. At present, by adding system digital-driven technology to data processing, we can not only achieve the expected data processing goals but also improve the automation practice ability of manufacturing, which is of great significance to promote the specialization and intelligence of manufacturing.

Results and discussion

Application analysis of system digital-driven technology

In the process of intelligent manufacturing, based on the application of digital-driven technology, holonic manufacturing components are combined with job-shop scheduling control host in the multiagent integration framework to complete the system construction. In this system, scheduling optimization decisions are subject to two main constraints: resource capacity constraints and process constraints, which can be described by Eqs. (1) and (2):

$$\sum_{ij} \vartheta_{ijtk} \leq M_{tk}\ (t = 1,2,3,\cdots,T; k = 1,2,3,\cdots) \tag{1}$$

$$c_{ij} + TR_{ijs} \leq b_{is}\ (i = 1,2,3,\cdots,N-1; j = 0,1,2,3,\cdots N_i - 1) \tag{2}$$

In addition, the average processing time $\bar{F}$ for the optimization target in the system can be expressed by Eq. (3) as follows:

$$\bar{F} = \frac{\sum_{i=0}^{N-1}(C_i - b_{i0})}{N} \tag{3}$$

To further describe the reliability of the system's delay time completion, Eq. (4) defines the average delay time:

$$\bar{T} = \frac{\sum_{i=0}^{N-1}(max(0, C_i - D_i))}{N} \tag{4}$$

Based on the above theoretical analysis, for the whole process control system of manufacturing, the deployment of identification nodes must follow the artificial intelligence technology. In this system, by comparing the difference between the initial distance between adjacent control nodes and the actual distance, it can be seen that the constraint of this technology is on the whole process control system of manufacturing [29, 30]. When the relationship between holonic manufacturing elements and job-shop scheduling control remains unchanged, the value of this indicator parameter always meets [1, e]. The node identification definition based on artificial intelligence technology can be expressed as Eqs. (5) and (6) [31]:

$$Q = \delta\sqrt{\frac{\sum_{r=1}^{+\infty}(u_2 - u_1)^2}{W}} \tag{5}$$

$$W = \gamma \times \left| -(\frac{\dot{y}}{D})^2 \right| \tag{6}$$

where r represents the coding coefficient of manufacturing information based on digital technology. Assuming that u_1 and u_2 represent different component manufacturing scale values, the inequality condition $u_1 \neq u_2$ is always true because the control system only assigns scales to manufacturing components without repeating the notes.

The coding principle followed by agent instruction is the program interaction principle executed in Holonic manufacturing elements. As for agent instructions, the operation of interactive instructions of execution program can be mainly divided into loading and unloading. Holonic manufacturing components are the only execution background of both instructions. The loading and unloading procedures are defined by Eqs. (7), (8), and (9), respectively [32]:

$$A_1 = \frac{\int_{s=1}^{+\infty} \left[Q \times (f_s - \bar{f}_s)^2 \right] ds}{\beta \times \widehat{k}} \tag{7}$$

$$A_2 = \frac{(f_s - \bar{f}_s)^2 / (\beta \times |\Delta H|_{max})}{Q^2} \tag{8}$$

$$\bar{f}_s = \frac{\sum_{i=1}^{s} f_i}{S} \tag{9}$$

Based on the logical relationship between the physical quantities, the control information feedback result can be expressed as Eq. (10) by combining Eqs. (7) and (8):

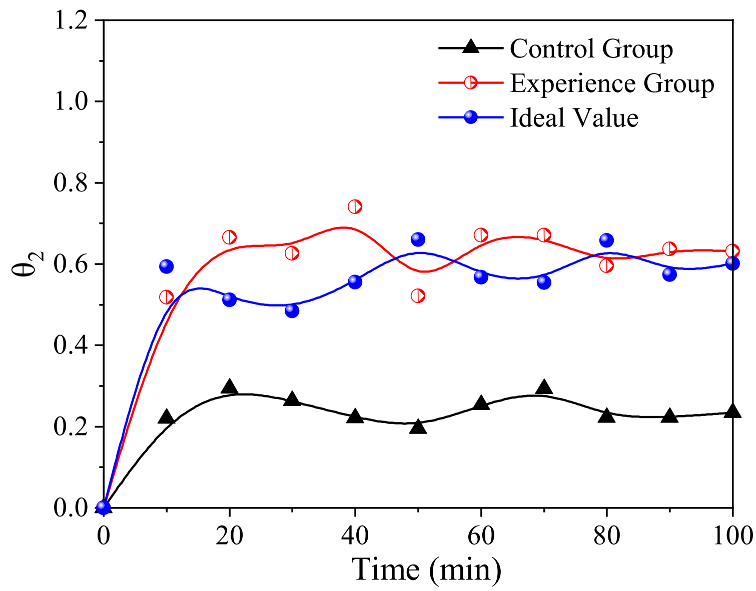
$$C = \left[\sum_{m=1}^{+\infty} (|A_1|^2 - |A_2|^2) \right] \times k_\varepsilon \tag{10}$$

The manufacturing accuracy index of mechanical components can reflect the precise control ability of the technology on manufacturing behavior. The higher the precision index is, the stronger the precision control ability of the system digital-driven technology on the whole process of manufacturing behavior is. The manufacturing accuracy index expression of mechanical elements is shown in Eq. (11) [32]:

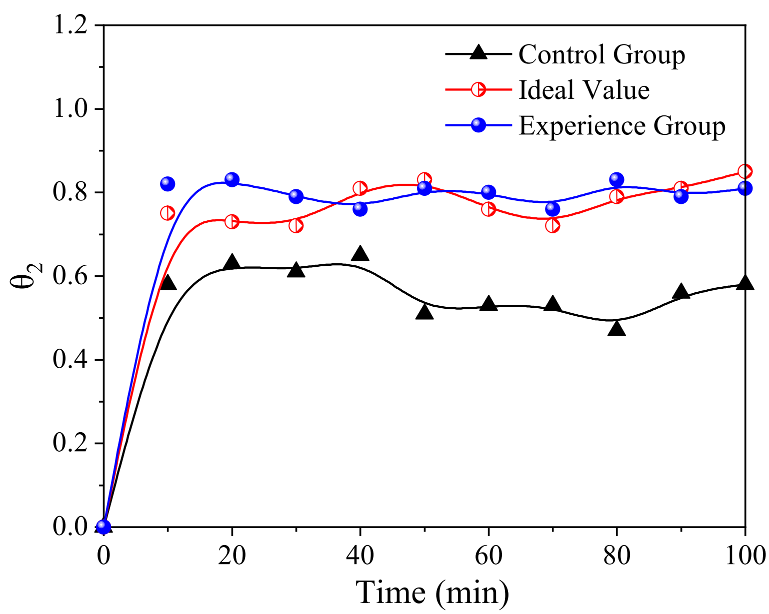
$$\mu = \frac{\theta_1 \times \theta_2}{C \times |\Delta T|} \times 100\% \tag{11}$$

where ΔT represents the length of time the control system executes and θ_1,θ_2 represents the manufacturing coefficient of different mechanical elements.

Through the analysis of the experimental results, it can be seen that during the entire experimental process, the indicators θ_1 and θ_2 show a fluctuating state, leading to the fluctuating trend of the calculation results of the manufacturing accuracy μ indicators of mechanical components. Based on the analysis of the calculation results, Fig. 7 shows the comparison of the experimental group, the control group, and the ideal value.



a) Experimental value of index of θ_1



b) Experimental value of index of θ_2

Fig. 7 The experimental results of indicators θ_1 and θ_2 in the experimental group and the control group. **a** Experimental value of index of θ_1. **b** Experimental value of index of θ_2

By calculating the difference between the accuracy indicators of the experimental group and the control group at different times, Fig. 8 shows the values of the manufacturing accuracy indicators. It can be seen from the figure that when the time is 30 min, the calculated results of the indicators in the experimental group reach the maximum value of 6.7%, which is 5.1% higher than the 1.6% of the control group at this time; when the time is 90 min, the difference between the experimental group and the control group is the minimum value of 3.3%.

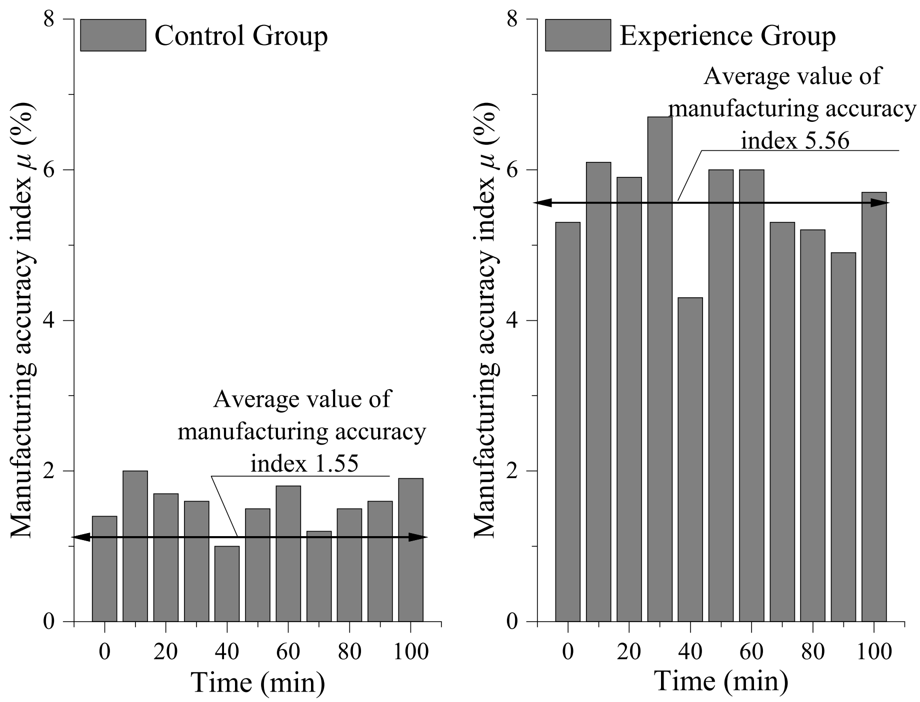


Fig. 8 The values of the manufacturing accuracy indicators

Conclusions

The popularization and application of system digital-driven technology in the field of manufacturing are of great significance for the intelligent improvement of manufacturing. This technology is deeply integrated with the whole process of manufacturing, which not only improves production efficiency but also saves a lot of human resources and material resources and promotes the continuous improvement of the intelligent level of the industry. Based on the above analysis, the following main conclusions can be drawn:

1) The application of system digital-driven technology in the field of manufacturing can effectively solve the problems of front-end design and digital detection while reducing the input of manpower and material resources.
2) In the manufacturing process, the system's digital-driven technology can be used to analyze and integrate a large amount of data, form a shared database, and realize the whole process management of the industrial chain data information through the whole process of deep integration.
3) Through the analysis of the proposed system of digital-driven technology, the manufacturing accuracy index in the manufacturing process can be improved by 5.1% at most and 3.3% at least.

Abbreviations

MMI Machinery manufacturing industry

Symbols

μ Manufacturing accuracy index
θ_1,θ_2 Coefficients in the manufacturing accuracy formula
ΔT Duration of time the control system executes
Q Node identification definition

W	Weight in node identification formula
A_1,A_2	Agent instructions in automated fabrication
fs	Function defining loading and unloading in automated fabrication
C	Control information feedback result
F	Average processing time in system
T	Average delay time
ij	Subscript indicating position in matrices
tk	Subscript indicating time period
β	Scaling parameter
ϵ	Parameter used in control feedback

Greek symbols

γ	Multiplier in weight calculation
δ	Differential or small change in variables

Subscripts

i, j	Indexing variables
s	General subscript used in formulas

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Authors' contributions
GL created and presented the published work, specifically writing the initial draft, and formulated overarching research goals and aims and oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team and also project administration. YQ created models (methodology) and developed software and also verificated, whether as a part of the activity or separate, the overall reproducibility of results and other research outputs. MW applicated statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data and also reviews language.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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