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Research on Adaptive Intelligent Decision Algorithm in Industry 4.0 Digital Economy and Management Transformation Based on Clustering Algorithm

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Abstract: How to transform the business model of enterprises and make it more in line with the new requirements of industrial upgrading is an important part of the government's supply-side reform in the era of Industry 4.0. For the current research on the good management transformation of digital economy in the fourth Industrial revolution, linear function and four commonly used nonlinear function models are first selected to test the good management transformation of digital economy in different technologies, and the key success factors of the strategic transformation from traditional industry to Industry 4.0 business model are explored based on fuzzy hierarchical analysis. Logistic and Gompertz models were used to judge the life cycle stage of the hot technologies of the fourth Industrial revolution, and based on their development trend clustering, the hot technology groups of the fourth Industrial revolution were explored. Secondly, k-means clustering algorithm based on the optimal class center perturbation is proposed, and simulation experiments are carried out. A clustering algorithm based on k-means algorithm is designed, and the moving mode of k-means in the algorithm is changed, and a disturbance strategy is added to strengthen the adaptive intelligent decision-making ability of the algorithm. K-means clustering algorithm based on the optimal class center disturbance is proposed, and simulation experiments are conducted. At the same time, the values of step size factors in the algorithm are compared experimentally. Finally, it explores the function mechanism of digital economy, management transformation and management transformation in the operation of supply chain node enterprises. By analyzing the current situation and problems of digital operation of logistics and supply chain enterprises, it constructs the digital operation system of supply chain enterprises, and proposes the path of digital transformation and upgrading of supply chain enterprises, so as to promote the rapid development of supply chain node enterprises.

Keywords: adaptive intelligent decision making; clustering algorithm; digital economy; industry 4.0; management transformation

1 INTRODUCTION

At present, the fourth Industrial revolution has just emerged, and the relevant researches of domestic and foreign scholars on the fourth Industrial revolution are mostly based on expert judgment [1], and mainly remain in the stage of theoretical research or qualitative research. On the other hand, work on technology forecasting has often focused on technology forecasting for a single technology. This paper adopts a quantitative research method, takes scientific literature and patents as the data sources, selects the hot technologies in the current research of the fourth Industrial revolution through the bibliometric method, and uses mathematical models to simulate its development trend and make predictions. At the same time, based on the characteristics of the development of technology life cycle, the development stage of technology is analyzed. At the end of this study, we also cluster technologies based on technology life cycle characteristics, and try to divide technologies with the same growth trend into technology groups.

The transformation of digital economy and management is still far in line with the expectations of the outside world [2]. The boundary effect of traditional manufacturing industry restricts the circulation of various production factors between enterprises and enterprises and between enterprises in different industries. As an important foundation of the national real economy, traditional manufacturing enterprises cannot effectively play their full functions in the process of promoting the transformation and upgrading of Industry 4.0. Vigorously promoting the strategic transformation of the business model of manufacturing enterprises is to gradually eliminate the border effect, reduce the adverse impact of production factors, especially digital information resources, on the participation of manufacturing enterprises in the industrial division of labor 4.0, and make it a positive growth pole of national regional economic development.

Based on fuzzy analytic Hierarchy Process (FAHP), a triangular fuzzy number matrix for factor pair comparison is established, and the weights of key success factors obtained by AHP are sorted. Based on the trends in the hot technologies of the fourth Industrial Revolution, through cluster analysis, this paper attempts to explore technology groups with similar development trends in the fourth Industrial Revolution. Enterprises drive supply chain value through digital economy and management transformation. Using big data, cloud computing, and artificial intelligence to accurately capture user needs, drive enterprise R&D (Research and Development) and production, shift the focus of the supply chain from the core enterprise to the user, and make full use of data analysis to create new enterprise value. Use data analysis results to provide customers with quality services, improve customer satisfaction, and create customer data value. Through valuable feedback from customers, we can continuously optimize the supply chain and create the value of digital intelligent supply chain services.

2 RELATED WORK

Focusing on the impact of the new industrial revolution on social production and life, it believes that the transformation of this "digital revolution" has not improved the level of industrial organization and the decision-making power and autonomy of workers [3, 4], and work is more unstable, and technological innovation cannot replace jobs with lower skill levels. But given the two sides of the coin, the positive outcomes of Industry 4.0 for workers will depend on social conflicts and politics. It is proposed that the fourth Industrial Revolution will bring not only a simple improvement of efficiency or the construction of "holistic government" in the traditional sense [5], but also a great social practice adapting to the arrival of the fourth Industrial Revolution, which is likely to bring about revolutionary changes in the form of government. That is, from the "physical space" government form of industrialization to the "digital space" government form in the era of big data. This transformation of government forms is not only the law of the development of human society, a general law of social change promoted by technology [6], but also the unique social scenes in our country and endogenous forces of the change of government. Qualitative analysis of the development characteristics and trends of the fourth Industrial revolution and its development blueprint. The interactions between major inventions and innovation systems during the three historic industrial revolutions [7] are reviewed as a basis for understanding whether a new revolutionary era is now under way. For each individual industrial era, specific inventions, changes in national innovation systems, changes in the workplace and the organization of the workforce and the evolution of consumption patterns are considered, concluding with lessons about the spillover effects of innovation that underpinned the Industrial revolution and providing a contemporary perspective on the rate of technological change [8]. It also suggests that if the Fourth Industrial Revolution is to begin, changes will be needed to the organizational and institutional structures that support inventors and ensure the return on innovation for U.S. companies.

Defining the basic concepts of Industry 4.0 [9] and its applicability in modern industry, the author believes that Industry 4.0 is a major component of the fourth Industrial Revolution, which changes around the development and changes of the manufacturing system [10]. An extensive background study has been conducted on the development of Industry 4.0. They also discuss the macro and micro perspectives of Industry 4.0 on sustainable manufacturing and provide the future scope of the field [11]. By summarizing the formation and evolution of technological economic paradigms in previous industrial revolutions, the connotation and characteristics of "Industry 4.0", the fourth Industrial revolution, are comprehensively analyzed [12]. On this basis, the law of the collaborative evolution of technological economic paradigm and management thought is deeply discussed, and then the essential changes in the theory and application practice of management thought in the era of Industry 4.0 are proposed, in order to provide support and reference for the innovation of management theory and the progress of management practice under the background of the new industrial revolution. It also provides power for China to leapfrog forward in the development wave of industry 4.0.

With the gradual rise of cluster analysis, the central idea of this algorithm is to abandon the traditional thinking mode of search [13], use the natural biological evolution process to simulate, and search the target space in a random way: artificial evolution, which has been successfully applied in cluster analysis. A new analog evolutionary algorithm, ant colony algorithm, is proposed. Its distributed, self-organizing characteristics make it successfully applied to many combinatorial optimization problems [14]. According to the behavior characteristics of fish swarm [15, 16], continuous research, simulation and simulation were carried out, and then combined with the model of animal autonomous body; a new bottom-up optimization mode artificial fish swarm algorithm was proposed for the first time [17]. This algorithm has some characteristics of swarm intelligent optimization algorithm, such as fast running speed, not falling into local extreme value, parallelism, simple operation and so on. In recent years, AFSA has been widely used in various combinatorial optimization problems such as data mining, numerical computation, signal processing and traffic fields. With the continuous research on cluster analysis and intelligent algorithms, by analyzing the advantages and disadvantages of K-means algorithm, a new hybrid clustering algorithm is obtained by combining AFSA with traditional K-means algorithm [18,19], and better clustering effect is achieved. The improved fish swarm algorithm with swallowing behavior is adopted and combined with FCM for classification, effectively overcoming the problem of FCM relying on initial value and easily falling into local extreme value [20]. Aiming at the urban vehicular navigation problem, AFSA is used to establish a theoretical model to seek the optimal solution of urban traffic roads, and a model of urban vehicular navigation system based on local separation AFSA is proposed [21]. It is proposed that AFSA is used to solve the path problem of the vehicle with return trip, which can reflect the individual performance function of artificial fish and the three classic behaviors of artificial fish: foraging, clustering and rear-end pursuit, all of which are applied to the path optimization problem [22]. The artificial fish swarm algorithm is combined with the nuclear fuzzy C-means algorithm, and has been successfully applied to wine quality classification [23]. A cluster analysis algorithm based on artificial fish swarm algorithm is proposed and successfully applied to regional economic analysis [24]. Aiming at some defects of artificial fish swarm algorithm, a number of optimization algorithms is proposed. For example, an artificial fish swarm algorithm based on adaptive T-distribution hybrid variation is proposed to solve the problem that AFSA arithmetic is easy to gather in non-global extremum points [25]. According to the problems such as slow search speed and inaccurate final solution of AFSA algorithm, an improved artificial fish swarm algorithm based on social learning mechanism was proposed [26].

From the perspective of the hierarchy of Industry 4.0 strategy, it is believed that Industry 4.0 strategy can be divided into three levels: vertical integration, whole-process application of network technology, Internet economy and full-dimensional integration of partners [27]. Vertical integration refers to the integration of production equipment, production system and business system through CPS system. The whole process of network technology application refers to the application of information technology and network technology to the whole life cycle process of product design, production, processing, operation, sales and after-sales. This requires full-dimensional integration of partners with the Internet economy, including major suppliers and technical solution suppliers of manufacturing enterprises, important customers of manufacturing enterprises and other third-party partners [28]. The strategy of Industry 4.0 is to use the information physical system to develop flexible manufacturing to a new height, and through the deep integration of information technology and communication technology to industrialization, the production mode of manufacturing enterprises will be transformed to socialization, visualization, lean and digitalization [29]. Industry 4.0 strategy not only emphasizes the intelligence of production results, but also emphasizes the intelligence of production and manufacturing process [30], and the realization path focuses more on improving the soft capability of manufacturing, especially emphasizing that the entire production process is changed from the previous automatic operation to the future intelligent operation. They also pointed out that the production process management of Industry 4.0 strategy should be more focused on the personalized needs of users, accelerate the personalized production mode and flexible manufacturing process, and make great progress in accelerating the transformation of intelligent production and manufacturing [31]. It can be seen that the digital economy provides a new idea for the development of supply chain enterprises in the new era and enables the transformation and upgrading of supply chain. This study focuses on using information technology and artificial intelligence to realize the digitalized supply chain operation model and promote the transformation and upgrading of logistics and supply chain enterprises.

3 RESEARCH STRATEGY OF ADAPTIVE INTELLIGENT DECISION MAKING FOR INDUSTRY 4.0 DIGITAL ECONOMY AND MANAGEMENT TRANSFORMATION

3.1 Industrial 4.0 Digital Economy and Management Transformation Hot Technology Strategy Framework

Digital economy and management transformation is the main driving force for the upgrading of logistics and supply chain in the 4.0 era of industry. Therefore, enterprises in the supply chain should be guided by the transformation of digital economy and management, jointly build a digital logistics and supply chain information platform, and effectively apply the transformation of digital economy and management to daily operations. And continue to develop innovative digital economy and management transformation to improve the efficiency of the supply chain. Cloud computing, big data, 5G information technology, artificial intelligence manufacturing and other digital economy and management transformation have brought new opportunities for the future digital upgrading of the supply chain. In order to make rational use of the digital economy and management transformation, the digital intelligent supply chain oriented by the digital economy and management transformation is upgraded. On the one hand, supply chain node enterprises should strengthen the digital construction of white infrastructure. Supply chain needs multi-party cooperation among suppliers, manufacturers, logistics distribution centers in the daily operation process. If one or two enterprises lag behind in digital infrastructure construction, the entire supply chain will not be able to achieve digital upgrading. Therefore, each node enterprise in the supply chain should be based on digital economy and management transformation. Jointly build a perfect digital logistics and supply chain information platform, realize real-time information sharing, and strengthen cooperation between enterprises. On the other hand, strengthen the reform and innovation of the supply chain white body, and use digital technology to optimize the supply chain structure. It mainly reflects the following points: First, the core enterprise manufacturers of the traditional supply chain build online sales platforms through the digital economy and management transformation, and change the structure of the supply chain while optimizing the sales channels; Second, the wide application of digital economy and management transformation shifts the focus of supply chain from the traditional core enterprises to consumers, integrates and optimizes information, services and resources in the supply chain, and uses digital economy and management transformation to promote the upgrading of customer-oriented supply transformation chain; The third is to upgrade and innovate the products and services of the supply chain through the digital economy and management transformation. All enterprises in the supply chain integrate and optimize information resources with the help of digital logistics and supply chain information platform, effectively enhance the core competitiveness of the supply chain, accurately capture consumer demand by using big data and cloud computing, and then develop innovative products and provide quality services to stimulate the purchase desire of potential consumers, creating more value of digital economy and management transformation. The technical strategy framework is shown in Fig. 1.

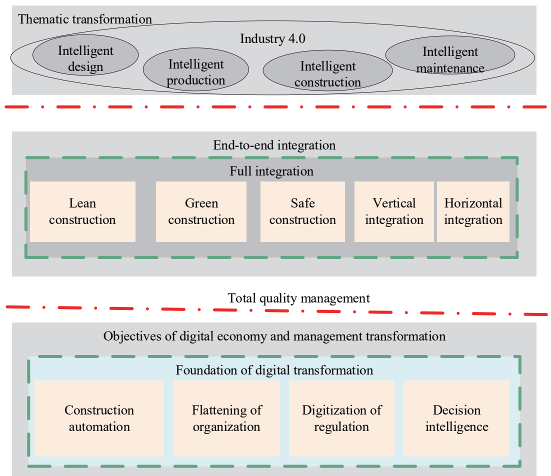


Figure 1 Industrial 4.0 digital economy and management transformation hot technology strategy framework

As shown in Fig. 1, in the age of industry 4.0 [32], digital technological innovation is the main driving force for manufacturing enterprises. For the entire supply chain, Industrial 4.0 on the basis of digital technological innovation management transformation, enterprises should also pay attention to collaborative innovation to increase the degree of mutual dependence and the risk resistance of the supply chain. The digital logistics and supply chain information platform are built through the Internet of Things, cloud computing, other technologies to achieve collaborative information management of node enterprises. Enterprises can make collaborative decisions according to the data of the information platform, respond to changing market demands, and provide personalized services to customers.

3.2 Research on Key Success Factors of Industry 4.0 Digital Economy and Management Transformation

Fuzzy analytic hierarchy Process (AHP) can be used to consider the problem from multiple angles according to the main characteristics and expected objectives of the problem studied, so that the problem can be considered in a more comprehensive way. The problem can be considered from different angles, and a hierarchical analysis can be carried out by combining considerations with each other, and a hierarchical model can be established to solve the problem, as shown in Fig. 2. In the age of Industry 4.0, a mature technological framework for the transformation of the digital economy includes themes, integrations and objectives, including intelligent design, production, construction and operation, integration including horizontal, vertical and end-to-end, and finally achieve the ultimate goals, such as total quality management, green construction and digital supervision.

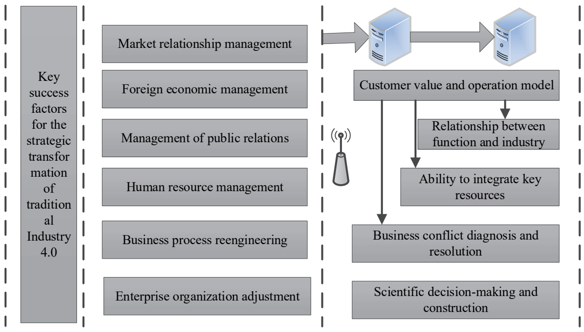


Figure 2 Framework of key success factors for strategic transformation of Industry 4.0 model

Step 1: Establish the hierarchy according to the fuzzy Delphi method

Based on the guiding order of ultimate goal, positive goal and item to be estimated, item j is screened out and a hierarchy is established according to the fuzzy Delphi method.

Step 2: Establish fuzzy pair comparison matrix

During the field survey and interview questionnaire, the respondent r evaluated the importance of any two items j and i among n items to be estimated in layer T + 1, calculated the ratio β of the two, and established the fuzzy pair comparison matrix:

$$T = [\beta_{i,j}], i, j = 1, 2..n \tag{1}$$

Step 3: Establish triangular fuzzy number

The intersection consensus of most interviewees is replaced by geometric mean, and the triangular fuzzy number is constructed by fuzzy Delphi method, a fuzzy algorithm, in order to sort out and analyze the fuzziness of m interviewees' views on the importance degree S of assessment items.

$$s_{ij} = (\beta_{ij}, \gamma_{ij}, \kappa_{ij}), i, j = 1, 2...n \tag{2}$$

Step 4: Construct a fuzzy positive inversion matrix, and the matrix elements are also triangular fuzzy numbers.

$$S = \left[s_{ij} \right] = \begin{bmatrix} s_{11}, s_{12} \dots s_{1i} \\ s_{21}, s_{22} \dots s_{2i} \\ \dots \\ s_{j1}, s_{j2} \dots s_{ji} \end{bmatrix}, j, i = 1, 2...n \tag{3}$$

Step 5: Calculate the fuzzy weight value of S:

$$T_j = S_j \otimes (S_1 ... \otimes S_n)^{-1} \tag{4}$$

Step 6: Deconstruction of fuzzification

Since the weights of each element and the items to be estimated are fuzzy values, it is necessary to deconstruct the fuzzy value to get a single value w of the fuzzy weight value.

$$\omega_j = \frac{T_{\beta j} + T_{\gamma j} + T_{\kappa j}}{3} \tag{5}$$

The fuzzy weight value and the normalized weight value of each level are calculated. First, the absolute weight value of Level 2 is obtained according to the weight of Level 1 and the relative weight of Level 2 in Level 1. Then, the absolute weight of key success factors at level 3 is obtained according to the relative weight of Level 3 elements in Level 2, and the absolute weight of key success factors at level 3 are further obtained and arranged in order of importance, as shown in Tab. 1 and Tab. 2.

Table 1 Ranking the importance degree of the second-level management elements

Goal hierarchy	Layer 1		Layer 2		Degree ranking
	Element type	Weight	Management variable	Absolute weight	
Industry 4.0 Key success factors for the transformation of digital economy and management	External factor	0.424	Market relationship management	0.136	2
			International division of labor and cooperation	0.064	7
			Management of public relations	0.076	6
			Industry collaborative management	0.148	5
	Internal factor	0.584	Human resource management	0.215	3
			Business process reengineering	0.230	4
			Enterprise organization adjustment	0.139	1

Table 2 Ranking the importance degree of the third-level influencing factors

Unassessed item	Absolute weight	Degree ranking	Unassessed item	Absolute weight	Degree ranking
Customer value proposition and operations	0.148	1	Labor mobility within the industry	0.046	9
Business personnel training and management	0.145	2	Ability to organize key resources	0.048	8
Service conflict diagnosis and resolution	0 .139	3	Relationship management with government and functional departments	0.034	10
Adjust the internal management system	0.096	5	By-law construction	0.032	11
Increase employee identification	0.098	4	Departmental coordination mechanism	0.026	12
Talent strategy management	0.067	7	Relationship management with industrial parks	0.034	10
Information communication and interaction with suppliers	0.078	6	Relationships with industry associations	0.018	13

3.3 Technology Cluster Based on Digital Economy and Management Transformation

The hot technologies of the fourth industrial revolution are classified according to the development stage of the technologies, and the development trend of these emerging technologies is observed in the current development process. Therefore, this paper uses the two parameter values of growth time and midpoint in the measured value of the technology life cycle for cluster analysis, and discusses the development trend of the technologies in groups. The purpose of cluster analysis is to find homogeneous groups and maximize the differences between groups. Unlike most parametric statistical techniques, cluster analysis does not explicitly provide solutions that are clearly acceptable or unacceptable. The systematic clustering method is chosen, and the systematic clustering has the characteristics of comprehensiveness objectivity.

Specifically, the information physics system applies to exponential functions, digital twins, blockchain, virtual reality, and deep computing are more suitable for third-order polynomial functions, and the Internet of Things, big data, cloud computing, additive manufacturing, unified architecture, machine learning, and augmented reality are more suitable for power functions. Logistic and Gompertz models were used to fit the data, and the fitting degree of the trend line was evaluated with the value of Logistic R2. The larger the value, the higher the fitting degree. Tab. 3 shows the best-fit trendlines and *R*-values for the selected techniques, respectively.

Table 3 Fitting results of Industry 4.0 revolution hot technology trend line

Technology	Logistic	Gompertz
Internet of Things	0.853	0.967
Cyber-physical systems	0.992	0.985
Big Data	0.996	0.986
Cloud computing	0.913	0.962
Additive manufacturing	0.997	0.994
OPC UA	0.953	0.986
Digital twin	0.987	0.997
Machine learning	0.978	0.943

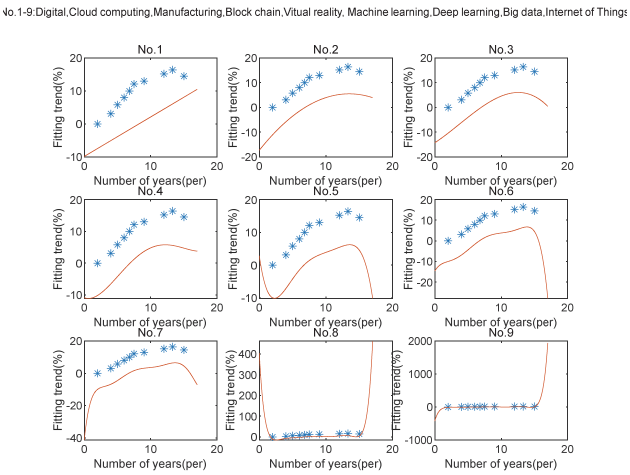


Figure 3 Best fitting curve of hot technologies of the fourth Industrial revolution

Fig. 3 shows the best fit curves for each of the selected techniques. Among them, Internet of Things, big data and deep learning have a higher upper limit of the growth curve, information physical systems, unified architecture, and digital twins have a relatively low upper limit, and the rest of the technologies are in between. Although the upper end of the growth curve is far apart, the technology growth trends are very close. The results also show that almost all technologies are in the growth period or transition from the introduction period to the growth period, and the technology maturity is low, and will continue to maintain a rapid growth trend in the next few years.

4 RESEARCH ON ADAPTIVE INTELLIGENT DECISION CLUSTERING ALGORITHM IN INDUSTRY 4.0

4.1 k-Means Clustering Algorithm Based on Optimal Class Center Perturbation

The clustering criterion function adopted is as follows:

$$K_v = \sum_{i=1}^{m} \sum_{c} d(Y_c Z_i) \tag{6}$$

Each k-means represents a solution to the clustering problem, and the k-means population represents the solution set of the clustering problem. The location of k-means represents the cluster center. The location of k-means determines its brightness value. The better the location, the greater the brightness, the worse the location, and the smaller the brightness. The quality of the location is measured by the clustering criterion function, the better the location, the smaller the value of the clustering criterion function; conversely, the worse the location, the greater the value of the clustering criterion function. The low brightness between k-means is attracted to move towards the high brightness k-means, and updates its position, eventually clustering into different classes.

Step 1: Set the algorithm parameters: the number of clusters C, the number of k-means, the maximum attraction, the light intensity absorption coefficient, the step factor, and the maximum number of iterations;

Step 2: Initialize the k-means location (randomly select NY in the data set as the initial k-means location, calculate the distance between each sample point and each cluster center, and then divide the sample point into the class where the cluster center is nearest to it;

Step 3: Calculate the brightness of k-means according to the initial clustering results of Step 2, find out and record the brightness, position and clustering results of the brightest k-means;

Step 4: Compare the brightness of k-means, the clustering criterion function value is small, and the position is better;

Step 5: After the k-means position update is completed, cluster again, update the brightness of k-means, find out and record the brightness, position and clustering results of the brightest k-means;

Step 6: Stop the algorithm when the maximum number of iterations is reached, otherwise go to step 3;

Step 7: Output the result.

The k-means clustering algorithm flow chart of adaptive weight increment for Industrial 4.0 digital economy and management transformation is shown in Fig. 4.

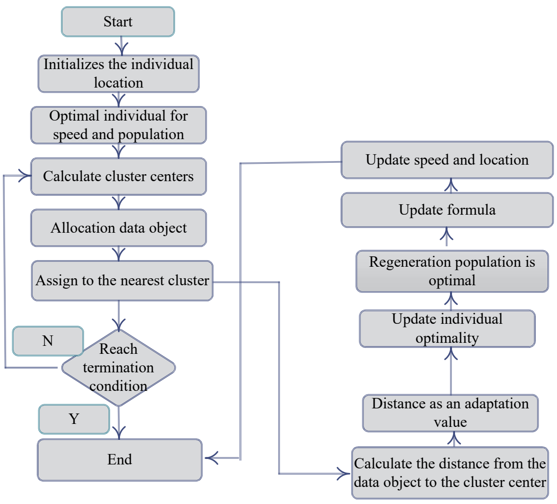


Figure 4 Flowchart of adaptive weight increment k-means clustering algorithm

In order to increase the randomness of the algorithm and make particles have better searching ability, this paper sets the fixed and constant adaptive weight constant in the k-means clustering algorithm as a gradually increasing variable. The specific operations are as follows: set the maximum number of iterations of the algorithm as M, the current number of iterations as t, and the maximum value of the adaptive weight as $W_{\max}$ If the minimum value of the adaptive weight is $W_{\min}$, the adaptive weight learned from the optimal particle in each iteration is set to:

$$w = W_{\min} + \lambda * \frac{W_{\max} - W_{\min}}{m} \tag{7}$$

In order to have an intuitive and profound understanding of the solving performance of k-means clustering algorithm, the performance of the self-adaptive weight increasing k-means clustering algorithm proposed in this paper is tested to verify the feasibility and effectiveness of the improved algorithm.

Sphere function:

$$l = \sum_{i=1}^{m} w * K_v * x_i^2 \tag{8}$$

Schwefel function:

$$f = \sum_{i=1}^{m} x_i^2 + \prod_{i=1}^{n} x_i^2 \tag{9}$$

The population size is set to 500; the upper limit of iteration times of the algorithm is set to 500. The dimension of the solution space is set to 200 dimensions. The impact factor is set to 1.0 and 1.2; The inertia constant in the traditional k-means clustering algorithm is set to 0.8, and in the improved k-means clustering algorithm proposed in other papers [13] and this paper, the maximum adaptive weight is set to 0.85, and the minimum adaptive weight is set to 0.5. The three test functions used in the experiment were tested independently for 100 times, and the results obtained for solving Sphere function are shown in Tab. 4, and the results for solving Schwefel function are shown in Tab. 5.

Table 4 Comparison of results of k-means clustering algorithm solving Sphere function

Execution result	Improved algorithms in other papers [13]	An improved algorithm is proposed in this paper	Traditional clustering algorithm
Optimal value	$4.449583528e^{-07}$	$2.521363044e^{-07}$	$2.29158185e^{-06}$
Worst value	$4.013676328e^{-05}$	$3.182685176e^{-06}$	$6.17114579e^{-05}$
Mean value	$1.052731562e^{-05}$	$1.338868919e^{-06}$	$2.04080562e^{-05}$

Table 5 Comparison of the results of solving Schwefel function by k-means clustering algorithm

Execution result	Improved algorithms in other papers [13]	An improved algorithm is proposed in this paper	Traditional clustering algorithm
Optimal value	0.007562844	0.0011224742	0.0036532338
Worst value	0 .279076292	0.1091697671	0.2642660184
Mean value	0.0289973794	0.1265128174	0.0360626336

4.2 Digital Technology-Oriented Industry 4.0 Adaptive Intelligent Decision Algorithm Upgrade

In the era of Industry 4.0, digital technological innovation is the main driving force for manufacturing enterprises. For the entire supply chain, on the basis of digital technological innovation, enterprises should also pay attention to collaborative innovation to increase the degree of mutual dependence and the risk resistance of the supply chain. The digital logistics and supply chain information platform is built through the Internet of Things, cloud computing, other technologies to achieve collaborative information management of node enterprises. Enterprises can make collaborative decisions according to the data of the information platform, respond to changing market demands, and provide personalized services to customers.

In order to use digital technology to realize collaborative oriented digital innovation, first of all, enterprises should build an information platform of the whole supply chain on the basis of white body information technology construction. Secondly, the establishment of supply chain integration collaborative innovation operation mode, upstream and downstream enterprises to integrate resources, clear the responsibility of the white body at the same time to actively assist upstream and downstream enterprises to carry out business, to achieve collaborative innovation between enterprises. Finally, with the help of the government or intermediary agencies to provide security, provide policy support for the supply chain innovation coordination between enterprises, adjust the industrial layout according to the policy to seize the development direction of collaborative innovation.

The digital operation of the supply chain upgrades the pull of customer demand on the entire supply chain. On the one hand, by tracking consumer behavior in real time through big data, enterprises can accurately and comprehensively grasp the demand motivation of consumers, and use intelligent and white dynamic tools to convert the captured demand motivation into actual demand. The use of big data computing to recommend suitable products to consumers, this accurate and personalized recommendation effectively improves the transaction rate of goods, while saving consumers' time to buy, providing consumers with quality services, and stimulating the vitality of the entire supply chain. On the other hand, through data analysis of consumers' behavior after purchase, enterprises can better understand consumers' deep-seated needs and future expectations of products, and upgrade and innovate products on this basis. Therefore, the digital upgrade of the supply chain should pay attention to consumer-oriented, and make full use of digital technology to tap customer needs.

Keyword co-word analysis is mainly to generate co-citation matrix through statistical analysis of the frequency of high-frequency keywords appearing in the same article. Through co-word analysis, we can show the hot spots in this field. Fig. 5 shows the keyword co-occurrence map of digital transformation research from 2006 to 2021, and 130 high-frequency keywords are obtained. The size of nodes and text in the figure is proportional to the frequency of keyword occurrence.

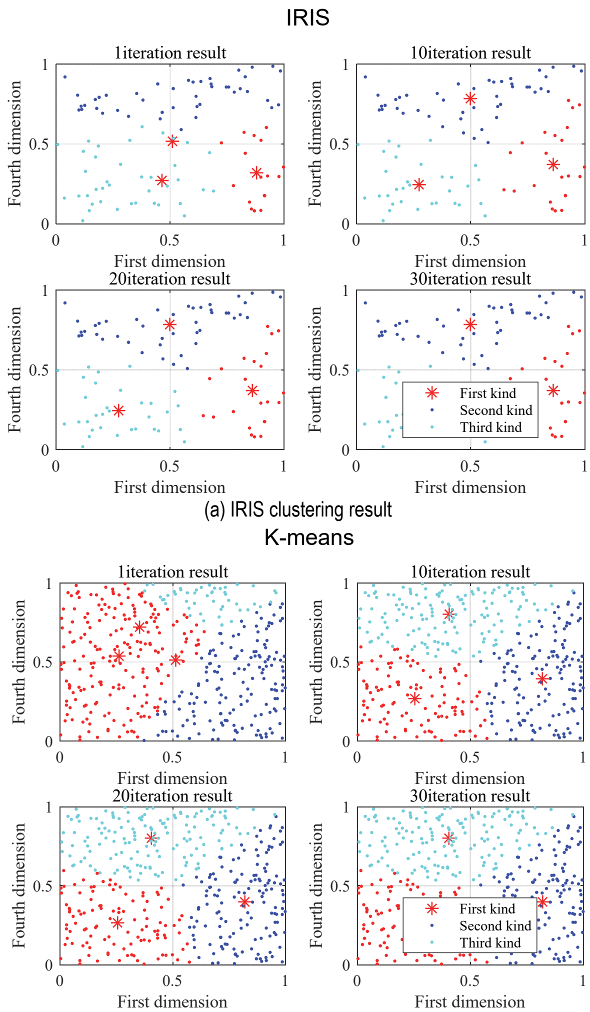
Figure 5 Keyword co-occurrence map

The results of digital transformation have a certain breadth, mainly involving the organizational level, the economic and the social level. Among them, the impact on the organizational level includes agile organizational structures, customer-centric business models, virtual business processes, improving operational efficiency, and building digital ecosystems. A longitudinal case study explores how organizational members respond to a dual organizational model aimed at accelerating digital innovation and proposes a hybrid organizational model of separation and integration. The economic impact includes improving organizational performance, improving new forms of value, and improving industry performance. For example, companies can use digital technologies to improve business processes, enhance collaboration with external groups, improve service quality, reduce costs, thereby improving corporate performance and creating new forms of value. The implications for society include security and privacy.

5 SIMULATION VERIFICATION

In order to verify the feasibility of the k-means clustering algorithm proposed in this paper for Industrial 4.0 digital economy and management transformation with adaptive intelligent decision weight increment in cluster analysis, test data sets are introduced to test the algorithm proposed in this paper. The data set used for the experimental data in this paper is as follows: the data set contains 150 data objects, each of which is recorded in the form of 5.1,3.5, 1.4,0.2, Iris-setosa; 7.0, 3.2, 4.7, 1.4, Iris-versicolor; 6.3, 3.3, 6.0, 2.5, Iris-virginica: The first dimension data represents the first-level factors of the Industrial 4.0 digital economy, the second dimension data represents the second-level factors of the Industrial 4.0 digital economy, and the third dimension data represents the external factors of the Industrial 4.0 digital economy. The last one-dimensional data is deleted during the clustering test, and this one-dimensional data saves the correct clustering results, that is, the classification of the three internal factors of the industry 4.0 digital economy.

In the case of the increasing weight of adaptive intelligent decisions in the Industrial 4.0 digital economy and management transformation, the experiment also compares the optimal results of 200 data clusters executed independently with the correct clustering results based on the k-means clustering algorithm. Fig. 6 is a two-dimensional plane comparison graph generated by selecting the first and fourth dimensional coordinates of data objects in the data set as horizontal and longitudinal coordinates.



(a) IRIS clustering result

(b) Intelligent decision weight increment k-means clustering result

Figure 6 Comparison of results of k-means clustering IRIS clustering with adaptive intelligent decision weight increment

As can be seen from the comparison of k-means clustering results with increasing weights of adaptive intelligent decision for Industrial 4.0 digital economy and management transformation in Fig. 6, the k-means clustering algorithm achieves ideal results in solving IRIS clustering.

The k-means clustering algorithm and its comparison algorithm for adaptive intelligent decision weights of Industry 4.0 digital economy and management transformation are shown in Fig. 7 as the convergence curve of fitness change with evaluation times on typical test cases T-INS-1, T-INS-6, T-INS-8 and T-INS-9. For brevity, convergence graphs for the various algorithms on several other test examples have been omitted. For ease of observation, the natural logarithm of the number of evaluations is taken on the horizontal coordinate in Fig. 7.

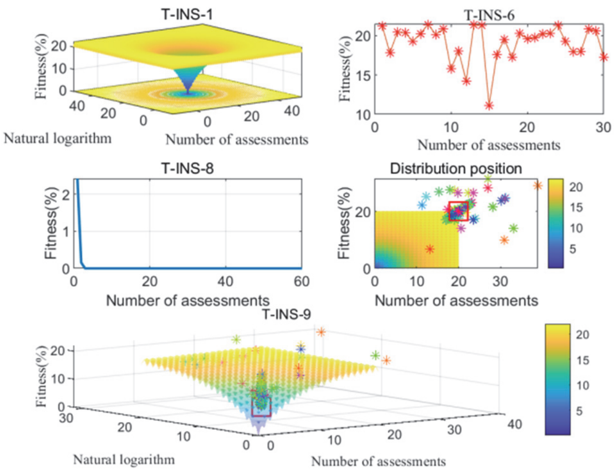


Figure 7 Convergence curves of the comparison algorithm on test instances T-INS-1, T-INS-6, T-INS-8 and T-INS-9

From the observation of Fig. 7, we can see that in small-scale test cases, the convergence speed of k-means clustering for Industrial 4.0 digital economy and management transformation adaptive intelligent decision weights is similar to other algorithms, and the solution quality is slightly superior. However, the performance of k-means clustering algorithm based on adaptive intelligent decision weights is significantly better than other algorithms in large scale test cases and larger scale test cases. As can be seen from the comparison of subgraphs in Fig. 7, as the scale of the problem increases, the superiority of k-means clustering algorithm for adaptive intelligent decision weights becomes more and more obvious. Through the analysis of Fig. 7, the following conclusions can be drawn:

(1) In general, k-means clustering algorithm for Industrial 4.0 digital economy and management transformation has better solving speed and quality than other algorithms;

(2) The solving effectiveness and efficiency of k-means clustering of adaptive intelligent decision weights for Industrial 4.0 digital economy and management transformation become more and more obvious with the increase of solving scale;

(3) The performance of general intelligent optimization algorithms decreases rapidly with the increase of problem scale, but the k-means clustering algorithm with adaptive intelligent decision weights can still maintain good solving characteristics. This phenomenon shows that multi-strategy parallel search technology is one of the effective ways to overcome the problem that the performance of a single intelligent optimization algorithm decreases with the increase of the case size.

In order to verify the feasibility, effectiveness and convergence of k-means clustering algorithm based on adaptive intelligent decision weights for industrial 4.0 digital economy and management transformation, the clustering algorithm based on adaptive intelligent decision weights of k-means clustering algorithm is compared with FA algorithm, k-means algorithm and PST algorithm. Fig. 8, Fig. 9 and Fig. 10 respectively show the convergence curves of the four clustering methods on the data set. It can be seen from Fig. 8 that the clustering algorithm of k-means clustering algorithm based on adaptive intelligent decision weights converges quickly and stably, and the clustering criterion function value solved is significantly better than that of FA and PST (Pure Stream Transfer) clustering methods.

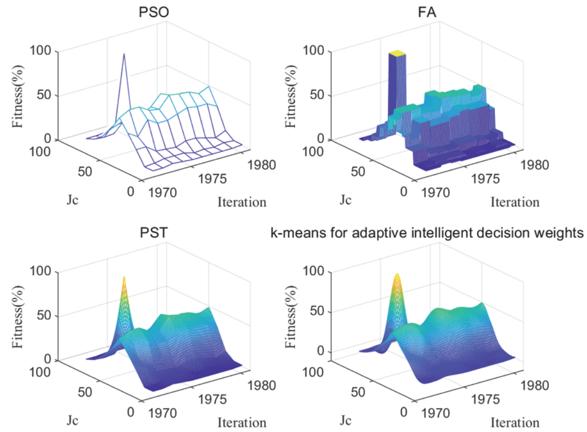


Figure 8 Clustering convergence curve

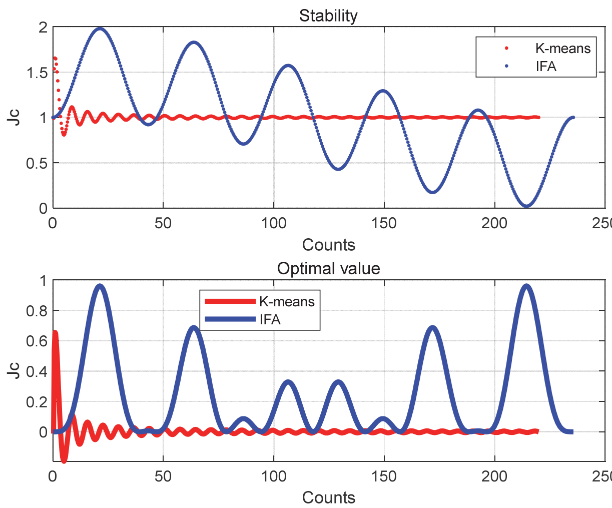


Figure 9 Comparison of optimal values of k-means clustering algorithm and k-means clustering criterion function for adaptive intelligent decision weights

Therefore, the optimal values of the two are further compared in Fig. 9, and the program is run 200 times.

As can be seen from Fig. 9, the k-means clustering algorithm is sensitive to the initial clustering center, resulting in poor stability, and the obtained optimal value fluctuates significantly. The k-means algorithm based on adaptive intelligent decision weights is relatively stable. The optimal value obtained is superior to k-means clustering algorithm.

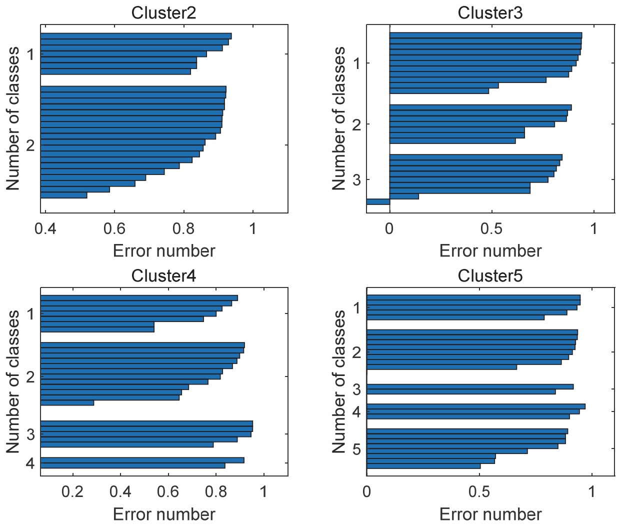


Figure 10 Sample distribution of data set after clustering based on adaptive intelligent decision weight k-means

As can be seen from Fig. 10, after the improvement, the Industrial 4.0 digital economy and management transformation in each category of adaptive intelligent decision rights reunion class, the number of errors is significantly reduced, the clustering effect is better than before the improvement.

The preparation stage of questionnaire survey refers to the preparation work to be done before the maturity assessment of the enterprise, including organizing the establishment of the 4.0 maturity assessment team, screening the team members suitable for assessment, determining the leadership of the team members to arrange the specific division of labor, and ensuring that each team member participating in the assessment has memorized the relevant knowledge of the model, such as evaluation standards and evaluation methods. The evaluation team established by the manufacturing enterprise is the key to the evaluation of the maturity of the enterprise industry 4.0, which is the premise of whether the measurement results are scientific and accurate. Therefore, it is suggested that the evaluation team members should be composed of senior managers of the enterprise and have a meeting to uniformly deploy the learning evaluation process before the implementation of the evaluation.

In order to ensure the comprehensive and accurate evaluation results, in addition to the senior leaders of the enterprise, the evaluation team should also select 1-2 staff members from the main departments of the enterprise, such as the backbone staff of the research and development department, the production department and the marketing department. It is also possible to invite several experts in the manufacturing industry from major universities or scientific research institutions to understand the elements of Industry 4.0 capability assessment for manufacturing enterprises. Experts accompany the evaluation, provide construction opinions and suggestions, and ensure the objectivity of the evaluation results. The main application subjects of the maturity model for manufacturing enterprises can be manufacturing enterprises, competent departments of manufacturing enterprises, suppliers of production and technical solutions of manufacturing enterprises and third-party institutions, and the main uses are statistical analysis, diagnostic evaluation and improvement. The clustering algorithm based on adaptive intelligent decision weights analyzes the evaluation results as shown in Fig. 11.

After reading a large number of relevant materials and literature related to the manufacturing industry, the evaluation factors that affect the 4.0 capability of the manufacturing industry are sorted out and screened. In order to ensure the scientific, rational and objective evaluation factors, experts and managers are invited to score the set factors, and the corresponding weights are calculated using mathematical methods, so as to ensure the objectivity and authenticity of the research results to the greatest extent.

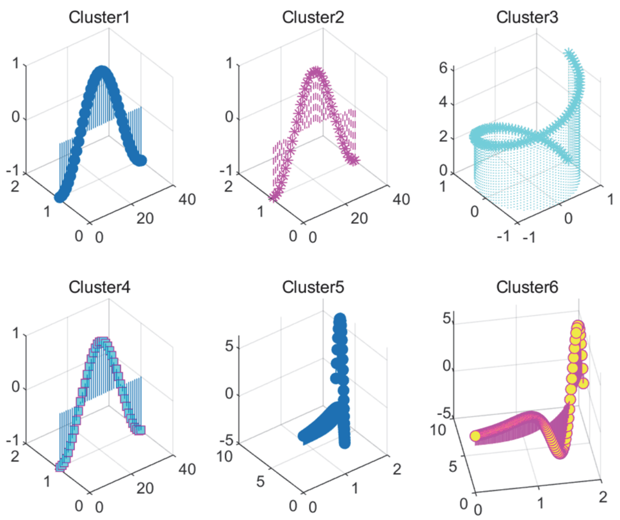


Figure 11 Adaptive weighted K-means clustering in three-dimensional space

6 CONCLUSION

Industry 4.0 is dominated by intelligent manufacturing, which will have a great impact on the strategic transformation of the business model of the enterprise, and the degree of impact is different, and the influencing factors of the strategic transformation of the business model of the enterprise are also very different. Therefore, it is necessary to analyze the key success factors of its business model transformation from the perspectives of different customers, market environment, industry background, public relations, regional and industrial economic background. The opinions of marketing personnel and enterprise management experts are interviewed by questionnaires, and the data obtained are sorted and analyzed by fuzzy analytic hierarchy process. This is a comprehensive method based on actual cases and combining two fuzzy trigonometric algorithms, which is suitable for judging the importance of influencing factors in a short period of time and obtaining the real core of the problem. The clustering algorithm of adaptive intelligent decision making for industrial 4.0 digital economy and management transformation proposed in this paper is feasible and effective. It is a cluster analysis method with higher efficiency and better stability, and has achieved good application effect in personalized practice, and also provides useful reference for the subsequent further research. In the construction of the evaluation index system of technological innovation capability of equipment manufacturing industry under the background of Industry 4.0, the influencing factors considered are quite limited and need to be further improved. The next step will be improved and applied to practice.

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