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Predictive analysis of industrial engineering energy technology and international economic cooperation with KPCA-SVM

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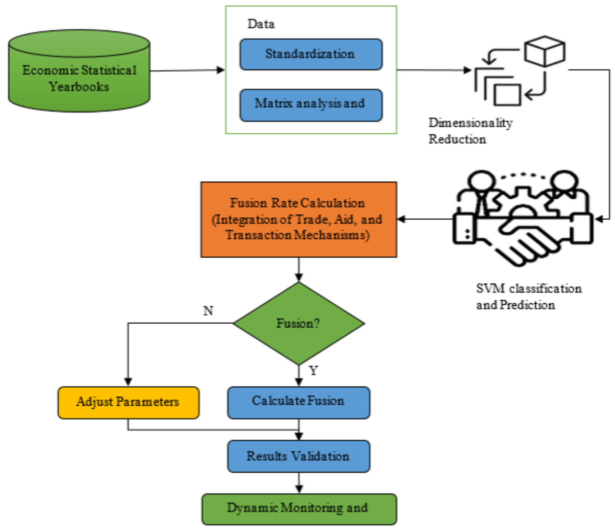
Graphical abstract



Abstract

The industrial engineering energy industry is in development and has broad development prospects. With international economic cooperation it can promote its development and structural optimization, so conducting relevant evaluations is particularly important. However, the current practical research on industrial engineering energy technology and international economic cooperation is not yet mature, and there is a lack of corresponding models and methods. Therefore, this article standardizes the data on industrial engineering energy technology development, analyzes it using the KPCA-SVM model, and finds the switching point with international economic cooperation practices. Firstly, matrix analysis is conducted on industrial engineering energy technology data and international economic cooperation practice evaluation data to identify the main trends and indicators of energy technology development using KPCA. Then, SVM models are used for classification prediction. Finally, the expected results of industrial engineering energy technology and international economic cooperation are predicted by adjusting the prediction parameters and classification parameters. And through simulation experiments, the verification results show that KPCA can recognize 90% of the characteristics in industrial engineering energy technology, SVM model can reduce 35% of redundant data, and KPCA-SVM model can improve the integration of energy technology and international economic cooperation, with an improvement rate of over 35%. So, the KPCA-SVM model can achieve massive data processing of industrial engineering energy technology, accurately predict international economic cooperation, and promote cooperation between the two.

Keywords: Industrial Engineering, International Economic cooperation, Support Vector Machine, Kernel Principal Component Analysis, Classification Prediction.

1. Introduction

In the current energy market, using original energy management methods to improve competitiveness is no longer the only means and approach. It is necessary to strengthen the correlation between energy technologies, optimize management structures, and change them in order to enhance their competitiveness in the energy market. Due to limited information acquisition capabilities[Mishra and Singh 2023; Shen *et al.* 2014), energy companies can only identify management directions based on external characteristics of energy technology, so it is necessary to predict and judge the future. The higher the level of prediction of technological development direction by energy enterprises in the market, the better the management effect of industrial engineering energy technology. International economic cooperation has gradually become a major tool for energy companies to enhance their management capabilities, which is crucial for the development of industrial engineering energy technology (Lin 2024; Filippov 2023). Therefore, various energy companies are weighting and practicing international economic cooperation. However, there are currently issues with outdated management methods and diverse management content in technology management and international economic cooperation, which limit global resource allocation and enhance the international competitiveness of energy enterprises[Shaulska *et al.* 2021; Meygoonpoury *et al.* 2024]. Industrial Engineering (IE) provides support for technological innovation by strengthening the management of human, material, and energy information, achieving optimization of energy capacity consumption and utilization efficiency. Although China plays an important role in global energy technology, it does not have an advantage in the depth of global international economic cooperation. Therefore, it is necessary to use artificial intelligence algorithms for prediction and classification, simplify and classify industrial engineering energy technology and international economic cooperation practice problems, predict their directions, and strive to explore a more suitable path for the development of industrial engineering energy technology in China. Specifically, the relationship between energy technology and economic cooperation mainly involves the integration of technology, mechanisms, and assistance [Liyuan *et al.* 2023; David *et al.* 2022]. The specific process is shown in **Figure 1**.

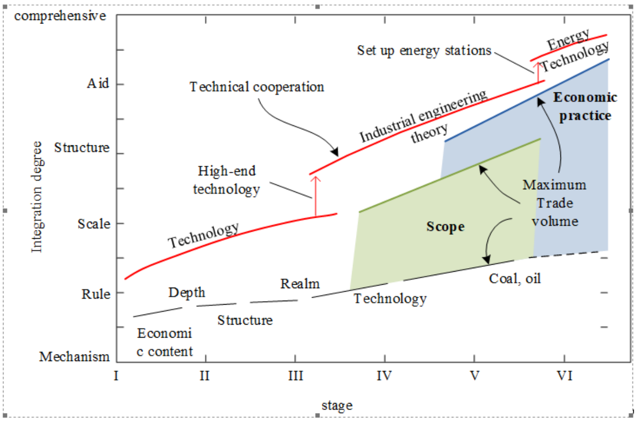


Figure 1. Relationship between Industrial Engineering Energy Technology and International Economic Cooperation Practice

The relationship between industrial engineering energy technology and international economic cooperation can be seen from the content of **Figure 1**. The cooperation between energy technology and the international economy is divided into different stages, and as the stages develop, the depth of integration between technology and economy gradually increases. In addition, the foundation of integration is the unity of economic scale, economic demand, and norms and systems, and it develops from economic theory to integration practice. So, there is a dynamic development between technology and international economic cooperation, and the process of change involves economic data, energy technology data, and other complex data, making it difficult to process. Qualitative analysis methods such as classification and binary analysis are mainly used in the research of industrial engineering energy technology (Yu *et al.* 2022; Urbano *et al.* 2021). However, this method can only point out the development direction, and there is insufficient expectation for the depth, integration points, and difficulty of integration. Quantitative analysis methods such as ant colony algorithm, bee colony algorithm, equation algorithm, etc. have complex computational processes and cannot achieve massive data. Therefore, some scholars have proposed a joint analysis method that combines qualitative algorithms with forward algorithms to comprehensively evaluate the actual situation of engineering energy, technology, and international economic cooperation and find the integration point of engineering energy technology and international economic cooperation, in order to achieve in-depth analysis of massive data and structure. Some scholars also believe that massive data is an important bottleneck for the average development of engineering energy technology. The complexity of data and its multidimensional nature still limit and affect the calculation results. How to perform targeted calculations on data information is a key issue that needs to be addressed. Some scholars also believe that setting parameters and weight ratios in the data to practice the combination of data can effectively remove the complexity of the data and achieve dimensionality reduction processing of multidimensional data. Many experts have researched this field and proposed comprehensive evaluation methods. Due to the multiple sources of technical data and complex indicator relationships in our country, and the excessive reliance on subjective judgment and the lack of objective and reasonable evaluation methods in the existing industrial engineering energy technology value evaluation process, a classification regression tree model based evaluation method for industrial engineering energy technology and international economic cooperation practice is proposed, and a system of evaluation indicators for industrial engineering energy technology and international economic cooperation practice is constructed. Key Principal Component Analysis (KPCA) can simplify parameter settings, eliminate irrelevant indicator data, and achieve industrial engineering energy technology features in practical simulation analysis. Support Vector Machine (SVM) uses direction vectors to trend the amplitude of binary classification data, reducing the scale of energy technology data and improving the efficiency of key indicator recognition. This system novelty lies in the uses of kernel principal component analysis with support vector machines mode for predicting international energy requirements as low carbon, environmental protection, including coal and oil consumption regionally across continents, such as Europe, Asia, and North America. It distinctly integrates KPCA-SVM to simplify complex datasets with critical indicators concerning inward economic globalization. This model puts expert interviews into consideration while ensuring energy technology indicators' rationality and effectiveness, while weeding away extraneous data adjustment parameters to quickly pinpoint practical fusion points. It also continuously enriches the database through entropy weight evaluation and gradient upgrading, thus providing a viable and scalable strategy in making decisions with regard to energy technologies and international economic cooperation.

2. Mathematical description

2.1. KPCA simplification of industrial engineering energy technology data

Industrial engineering energy technology involves equipment, personnel, maintenance, and costs, and its development goals are structural optimization, cost reduction, and additional profit margins. Therefore, based on the income approach, the energy technology data is simplified by referring to the company's relevant financial data, and international economic cooperation practices are analyzed as virtual parameters.

Assumption 1: The data for industrial engineering energy technology is V, the simplified parameters is v, and their calculation is shown in formula (1).

$$v = L_i.S_i.\sum V_i \tag{1}$$

Among them, L_i represents the development environment of industrial engineering energy technology and S represents the simplification rate of industrial engineering energy technology (Wang *et al.* 2021). At the same time, the correlation between technology and economic cooperation is calculated as shown in equation (2)

$$l = G_i \to \frac{q_i}{T_i} \tag{2}$$

Among them, T represents the cost of energy technology in industrial engineering, and q represents the integration index with international economic cooperation, G_i is the entropy weight of technological development (Lin *et al.* 2024). The three parameters of industrial engineering energy technology cost, fusion index and entropy weight are analyzed in detail to find out the correlations l

2.2. SVM analysis of international economic cooperation practices

The practice of international economic cooperation includes factors of production, trade system, and international aid, which are expressed by t1, t2 and t3 respectively, and the practice of international economic cooperation is expressed as Equation (3):

$$R = \frac{\left(t_1 + \alpha t_2 + \beta t_3\right)}{k} \tag{3}$$

In equation (3), R represents the integration with international economic practice α and β and represents the degree of integration of production factors and trade mechanisms. Because there is also a dimension to the depth of integration, it is necessary to calculate the factors of production, trade mechanism and international aid, and the dimension is the measurement of the degree of energy technology and integration of industrial engineering, and it is a reflection of the influence of energy technology (Petridis *et al.* 2022; Halder *et al.* 2023). In the actual practice of cooperation, the fusion dimension is represented by I, and the increase or decrease of the fusion dimension the complexity of the data directly affects the scale of the data I_j, and the characteristics of the dataI_o, so the multi-entropy weight of the fusion dimension should be assigned, which is calculated as equation (4).

$$I = \sum AI_i + \sum B.I_j + \sum X.I_o + \Delta\lambda \tag{4}$$

In equation (4), A, B and X represent the entropy weight of the influence of international economic cooperation, $\Delta\lambda$ which is the error adjustment coefficient, and there is a certain relationship between the depth of fusion and the entropy weight, which can be transformed by the S-curve coefficient, so as to obtain the correlation degree between the calculated result and the entropy weight set (S) as shown in equation (5).

$$set\left(S\right) = \sqrt{\vec{I}_i \vec{I}_j \vec{I}_o} \tag{5}$$

Where, $\vec{I}_i, \vec{I}_j, \vec{I}_0$ represent the mapping directions of each dimension, respectively.

2.3. Evaluation of the results of the integration of industrial engineering energy technology and international economic cooperation practice

The practice of industrial engineering energy technology and international economic cooperation is a dynamic process, and the fusion results need to present dynamic fusion, so it is necessary to add dynamic functions to *f*(*V*) analyze the fusion results[15].

Hypothesis 2: the energy element of industrial engineering is N, the economic project suitable for cooperation is i, and the depth of cooperation is j, then the depth of fusion can be expressed as $N_{ij}\left(i, j = 1, 2, \ldots, Nature\right)$, the fusion structure is assigned, the degree of integration is calculated, and $lin\left(N_{ij}\right)$ the ranking is performed, then the evaluation of the fusion result F(V) can be expressed as equation (6).

$$F\left(V\right) = \sum_{i,j=1}^{n} N_{ij}.f\left(V\right) | \, lin\left(N_{ij}\right) + \Delta\lambda \tag{6}$$

Among them $\left(i, j = 1, 2, \ldots, Nature\right)$. In the process of integration, it is necessary to integrate the results of production factors, trade mechanisms, and aid conditions, so it is necessary to realize the intersection of data such as production factors, trade mechanisms, and aid conditions, and construct a set of evaluation results, as shown in equation (7).

$$tri\left[F\left(V\right)\right] = \begin{bmatrix} N_{11} & f\left(V_{11}\right) & lin\left(N_{11}\right) \\ \vdots & \vdots & \vdots \\ N_{ij} & f\left(V_{ij}\right) & lin\left(N_{ij}\right) \end{bmatrix} . \begin{bmatrix} \alpha_i \\ \beta_i \\ \lambda_i \end{bmatrix} \tag{7}$$

Among them, the $tri\left[F\left(V\right)\right]$ result of the fusion is represented $\begin{bmatrix} \alpha_i \\ \beta_i \\ \lambda_i \end{bmatrix}$ as the degree of fusion matrix, and the logical relationship of the matrix is compared to realize the overall fusion between the data.

2.4. 2.4 Practical constraints of cooperation based on the KPCA-SVM model

The cooperative practice needs to be realized under the constraints to avoid the false results of the fusion results, so the KPCA-SVM model constraint analysis should be carried out. Hypothesis 3: The constraints of the main factors of KPCA analysis of industrial engineering technology are CIi, and the constraints of SVM to judge the trend of international economic cooperation are RIi, then the constraints are shown in equation (8).

$$Z_i = \frac{(CI_{max} - CI_i)}{(RI_i - RI_{min})} \quad (8)$$

In equation (8), it CI_{max} represents the highest level of energy technology development in industrial engineering and RI_{min} is the minimum standard for the practice of international economic cooperation, and each standard must meet certain constraint dimensions, which are represented by **Table 1**.

Table 1. KPCA-SVM Model Constraint Table

dimension	I_i	I_j	I_o
standard	<100	<5	<1

As shown in **Table 1**, if yes $I_i < 100$, the highest level of development of energy technology is 100%; If so $I_{j>5}$, the complexity level of the data is level 5, and the SVM model performs binary classification calculations. KCA calculation $I_o \approx I$, indicating that the calculated eigenvalue is 1. The fusion matrix can be processed to SVM vector machine, which can predict the positive and negative directions of economic cooperation practice, which is convenient for the later development classification and fusion strategy formulation. At the same time, vector analysis can also clarify the weight value of international economic cooperation practice, which is convenient for weight adjustment in the later stage. In order to ensure the rationality of the constraints and the rationality of the practical results of economic cooperation, it is necessary to dynamically constrain the calculation process, introduce the mapping change function, and adjust the number of calculations, so as to avoid excessive solution of the calculation results and waste of calculation time due to too many calculations.

Hypothesis 4: The fusion constraint function of industrial engineering energy technology and international economic cooperation practice is O_{ij} O_{ij}, then the calculation of the fusion process of the KPCA-SVM model is shown in equation (9).

$$\sum_{i,j=1}^{set(s)} O_{ij} = \frac{F(V) \to f(v) \mid R}{l} + \Delta\lambda \quad (9)$$

According to the classification method in SVM, the influencing factors and indicators are calculated by classification, and the classification results are summarized to construct a classification set, which is calculated as shown in equation (10).

$$set\left(\sum_{i,j=1}^{set(s)} O_{ij}\right) = x, y \quad (10)$$

Among them, x and ythe binary classification results are stored separately, and the calculation results are mainly used for qualitative judgment, which is based on the constraints of energy technology and international economic cooperation. According to equation (9), the proportion of each grade to the influencing factors is calculated, and the weight fuzzy matrix of the customer’s evaluation is integrated. According to the KPCA model, the energy technology limit for industrial engineering is between 1 and 100.

3. Actual case analysis

3.1. Information

In this paper, we take the public data from 2020~2022 (economic statistical yearbooks, economic cooperation projects, and industrial engineering energy technology development information) as the research object, and collect a total of 1232 pieces of information data, with 5 data attributes (aid, trade mechanism, trade exchange, transaction system integration, and transaction form), and the correlation between the data is shown in **Table 2**.

Table 2. Proportions and correlations of data by different years.

Time	aid	Trade mechanisms	Trade exchanges	Integration of trading systems	Form of transaction
2020	25.11	25.02	32.24	9.72	7.91
2021	23.65	26.82	30.31	8.2	11.02
2022	19.36	22.32	39.66	6.32	12.34
F	0.033	0.025	0.028	0.036	0.011

Table 3. Objective conditions for case implementation

parameter	Specific configurations
operating system	Windows
CPU type	AMD
CPU operating frequency/GHz	3.0
memory	32GB
programming language	Java

As can be seen from the contents of **Table 2**, the proportion of aid is relatively small, the proportion of institutional integration and transaction form is the lowest and the second lowest, respectively, and the correlation between the data is small. This can be illustrated. The information collected in this article is highly independent. In addition, objective hardware and software are required as a guarantee for case analysis, as shown in **Table 3**.

According to **Table 3**, the hardware and software requirements for the case study analysis are as follows. The system runs on a Windows operating system on an AMD CPU with clock speed 3.0 GHz, which provides sufficient computational power for the case study operations. Large datasets are processed efficiently in a memory capacity of 32GB. The programming language used for model implementation and data analysis is Java.

3.2. Validation of the KPCA-SVM model

Due to the large amount of data collected from the data, the KPCA-SVM model can simplify the information complexity of the data and improve the accuracy of fusion at the theoretical level, so the test function is used to test the model to verify its rationality and extreme value change rate.

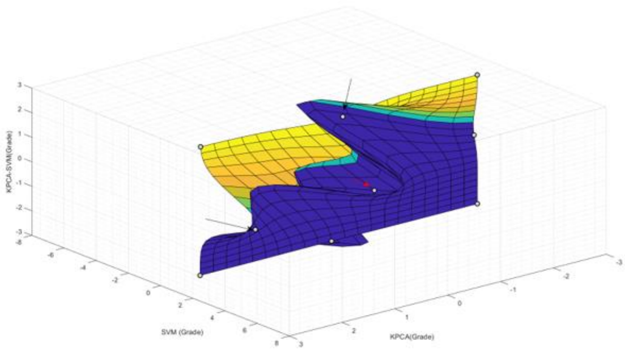


Figure 2. Existence of extreme values of the KPCA-SVM model

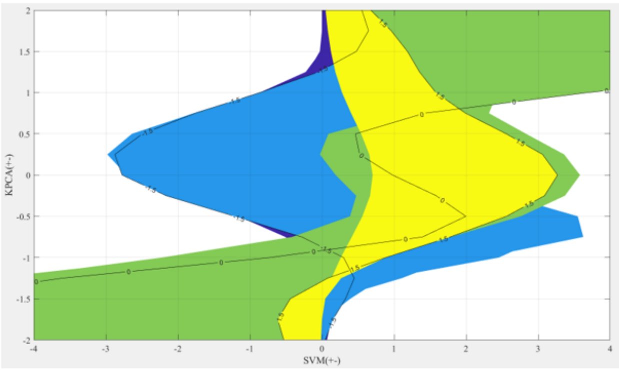


Figure 3. Rationality of the KPCA-SVM model

The data analysis results in **Figure 2**. show that the model constructed in this paper has a maximum value and a minimum value in it, and the maximum value is in the main peak region, indicating that the extreme value has a strong rationality. Although some of the eigenvalues are distributed at the edges, they are not the main extrema in this paper, which indicates that the extrema calculated in this paper are highly distinguishable and can be obtained by calculation. It can be seen that the extreme value of the model constructed in this paper is highly possible.

In order to further verify the validity of the model, it is necessary to judge its rationality, and the results are shown in **Figure 3**. In addition, the rationality analysis of the model constructed in this paper shows that the concentration of SVM and KPCA models is low, presents a discrete multi-region, and covers the whole region, which indicates that the construction of the model in this paper is reasonable, basically meets the needs of later analysis, and can be analyzed and judged.

3.3. The integration rate of energy technology and international economic cooperation practices

The integration rate of practice is the ultimate goal of the development of energy technology in industrial engineering, and it is also the result of the implementation of the KPCA-SVM model, so it is necessary to carry out dynamic analysis, and the analysis results are shown in **Figure 4**.

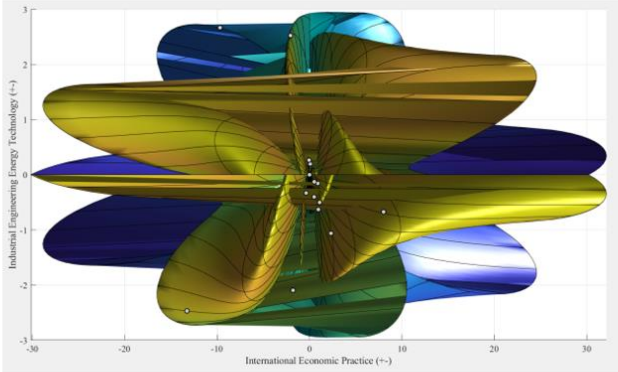


Figure 4. The integration rate of energy technology and international economic cooperation practices

From the data in **Figure 4**, it can be seen that the fusion rate of the two is good, and the color is symmetrical on the central axis, indicating that the fusion trend of the two is consistent and there is a positive correlation. In addition, in terms of fusion angles, the two are symmetrical in the form of left, right, and center, which further indicates that the fusion angle meets the requirements. On the whole, the fusion result diagram is symmetrical, and the color and central axis are symmetrical, indicating that the results are good. The analysis of the practice of industrial engineering energy technology and international economic cooperation shows that the KPCA-SVM model proposed in this paper can realize the effective integration of industrial engineering energy technology and international economic cooperation.

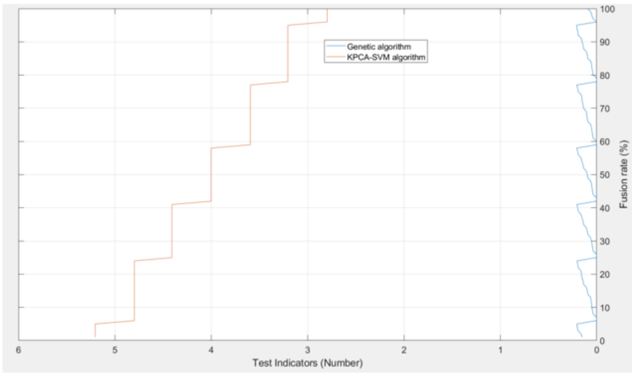


Figure 5. Comparison of fusion rates of different methods

Figure 5 shows the comparative analysis of the method proposed in this paper with the genetic algorithm, it is found that the proposed method's fusion rate is good, mainly reflected in the fusion of multiple indicators. Although the integration rate of genetic algorithm for the practice of international economic cooperation has reached 90%, the number of fusion indicators is small, and the reason for this is that the KPCA-SVM model fuses entropy weight evaluation and binary classification data simplification, so that the effective data has been kept at about 80%, and the entropy weight evaluation can effectively reduce redundant data, reduce the error rate of analysis results, and is more practical. Therefore, the KPCA-SVM model can improve the integration rate of industrial engineering energy technology and international economic cooperation practice, which has high practical value.

3.4. Expectations for the practice of international economic cooperation

In this paper, the binary classification method of the SVM method is repeated to predict the results, so as to improve the possibility of economic cooperation practice, and the expected result is a comprehensive reaction of entropy weight, binary classification and parameter optimization, which is also the advantage of the KPCA-SVM model. At the same time, it is still compared with the genetic algorithm, and the comparison results are shown in **Table 3**.

As can be seen from **Table 4**, the model proposed in this paper can effectively predict the practice of industrial engineering energy technology and international economic cooperation, and the expected results are greater than 90, which is higher than that of genetic algorithm. Among them, the expected results of technical and economic value do not have advantages, mainly because the index is a public index that can be obtained by a simple evaluation method, so it is not the focus of this paper. The technical multiplier is a summary of historical data and an amplification of the expected results, so it is crucial, and the expected results in this article are better. Due to the rapid development of industrial engineering energy technology, the scale of evaluation data is large, so genetic algorithms are prone to redundant data, which reduces their expected results. In terms of the analysis of the depth coefficient of fusion, the calculation results of the algorithm in this paper are good, mainly because this index is an important index and the main aspect of the integration of international economic cooperation practice, and the calculation advantage of this index is very obvious. On the whole, the expected results of the KPCA-SVM model are better than those of the previous algorithms. However, the expected results are a dynamic calculation process, so they should be judged continuously.

Table 4. Comparison of the expected results of the KPCA-SVM model

Expected metrics	KPCA-SVM model	Genetic algorithms
Techno-economic value	91.25	93.87
Industrial Engineering Energy Technology Multiplier	24.97	17.89%
Fusion depth coefficient	85.937	77.823
The practice coefficient of international economic cooperation	96.13	87.09

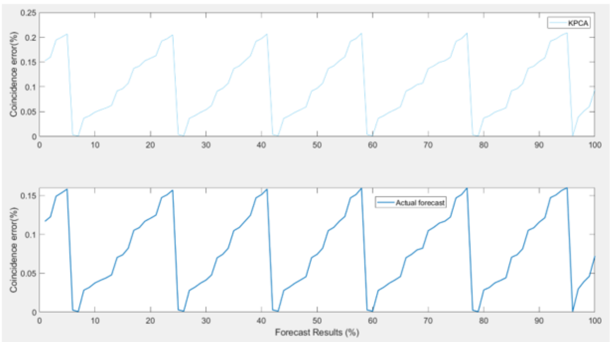


Figure 6. Comparison of the algorithm in this paper with the actual test results

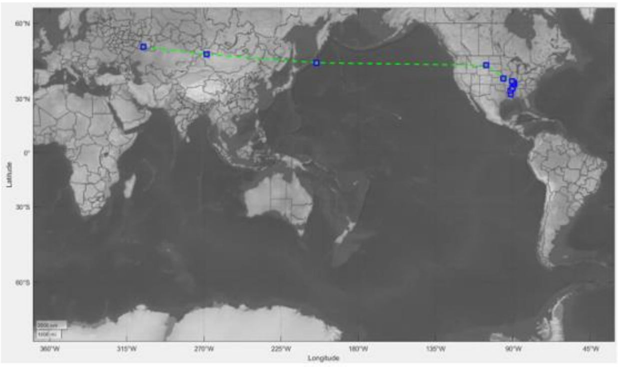


Figure 7. Schematic diagram of the practice points of international economic cooperation

From the data in **Figure 6**, it can be seen that the method proposed in this paper is almost consistent with the actual test results, but the adjustment rate in the test in this paper is relatively high, about 0.1.

As can be seen from **Figure 7**, the practice points of international economic cooperation are based on European and American countries, and international energy economic cooperation is mainly carried out by European and American countries, mainly because European and American countries master more industrial engineering energy technologies.

3.5. Reasonableness of the results of economic cooperation practice

A single calculation does not represent the effectiveness of the algorithm in this paper, so it is necessary to perform multiple iterative calculations to verify the reasonableness of the calculation results in this paper.

Compared with the genetic algorithm, the practical depth analysis of the KPCA-SVM model in **Figure 8** shows that the KPAC-SVM model is used for analysis, and the rationality of the evaluation gradually improves with the increase of the number of experiments, mainly by using entropy weight, classification and other methods to process international economic cooperation data. An appropriately increasing the weight parameters can obtain a more reasonable evaluation result, and a higher prediction value can be obtained. After the classification and entropy weight processing of the model proposed in this paper, the rationality of the results is relatively ideal, and the calculation error result is represented by **Figure 8**.

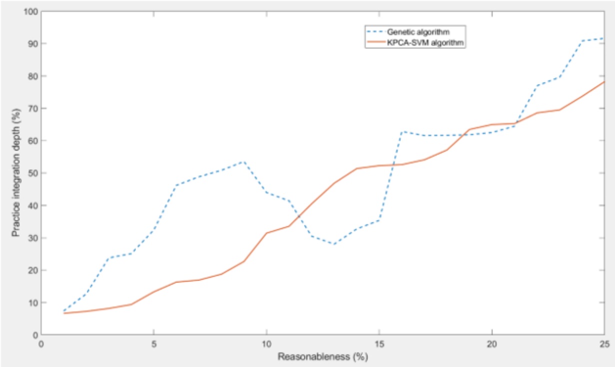


Figure 8. In-depth comparison of the cooperative practices of different algorithms

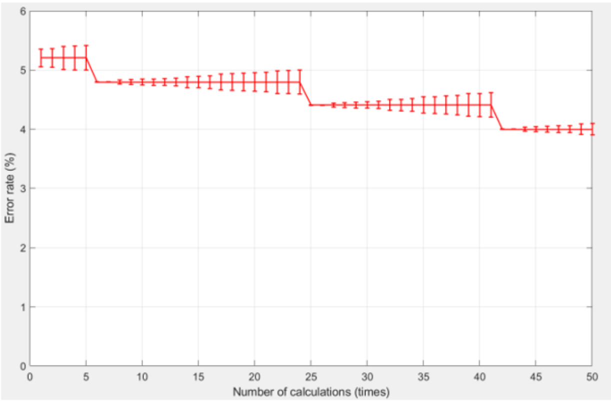


Figure 9. Changes in the error of international economic cooperation practices

The analysis of **Figure 9** shows that the error of the qualified practice analysis results using the model proposed in this paper is reasonable, changing from small to large, and the change shows an iterative trend, mainly because the KPCA-SVN model uses classification, vector and other methods for data processing, and the estimation error gradually increases with the increase of the number of experiments. However, with the intervention of the entropy weight parameter, the calculation error of the practical results is constantly decreasing. Although the error shows a phased change, the rationality of the overall calculation is effective and can still meet the actual practical analysis requirements.

4. Conclusion

At present, the importance of industrial engineering energy technology has become more and more prominent, and it is necessary to intensify its development. and international economic cooperation has become a problem that needs to be dealt with at present. Since industrial engineering energy technology is still developing, it is necessary to clarify the practice of industrial engineering energy technology and international economic cooperation. In evaluating industrial engineering energy technology and international economic cooperation practice, selecting an evaluation model suitable for China's national conditions is necessary. Therefore, this paper comprehensively evaluates the practice of industrial engineering energy technology and international economic cooperation, improves the KPCA-SVM model, integrates entropy weight, binary classification and other analysis methods, realizes the simplification of industrial engineering energy technology data, and improves the accuracy and rationality of the analysis of international economic cooperation practice, so that it is at the level of more than 90%. At the same time, compared with the genetic algorithm, it is found that the model proposed in this paper is more effective due to the traditional methods in the past. The error analysis and prediction analysis of the proposed model in this paper are relatively good, and the influencing factors such as aid, trade mechanism and trade scale are considered to enhance the applicability of the calculation results of industrial engineering, energy technology and international economic cooperation practice, which can meet the needs of international economic cooperation practice. To extend the research in future will include enhancing the dataset by adding new variables and areas to allow for thorough investigation of international economic cooperation and energy technology integration. In addition, the KPCA-SVM model will be improved ny integrated with advanced model to increase its scalability and adaptability to real-world applications. Impacts of emerging technologies and their implementation in the model will be further investigated to enhance prediction. Further pursuit of real-time data analysis and continuous model validation will also be done to guarantee practical use in dynamic contexts.

Project funding

Research on the Digital Transformation and Development of Anhui Provincial Supply and Marketing Cooperatives Oriented towards Rural Revitalization (2023AH051508). Research on the Innovation of Precise Supply Mechanism for Compulsory Education under the New Situation of Population Structure (2024AH053242).

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