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1.论文: Digital Twin System Construction and Simulation Optimization for Collaborative Effectiveness of Industry-Education Integration

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Digital Twin System Construction and Simulation Optimization for Collaborative Effectiveness of Industry-Education Integration

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SUMMARY: *With the continuous development of social economy and artificial intelligence technology, it is difficult for the current collaborative effectiveness of industry-teaching integration in colleges and universities to meet the needs of society. To address this dilemma, the digital twin system in the context of the collaborative effectiveness of industry-teaching integration is explored. Based on the conceptual theory of digital twin system, this paper determines the functional module of digital twin system oriented to the collaborative effectiveness of industry-education fusion, obtains the research data through the web crawling program, and then constructs the resource recommendation module of industry-education fusion by using the LDA model and content recommendation algorithm. Under the role of development software and image processing algorithms, the design task of the practical training practical module is completed, followed by the use of improved LSTM network, back propagation Rprop algorithm for the design of student management early warning module, so as to complete all the design work of the system module. Finally, from the system function module, the system launched an experimental simulation analysis. After the simulation analysis, it can be seen that the prediction errors of red warning, orange warning, yellow warning, green warning are 0.0315, 0.0233, 0.0309, 0.0045, respectively, and the prediction errors are controlled within 0.05, which verifies the effectiveness of the warning module of student management in the digital twin system, in addition to proposing the corresponding optimization strategy. The research in this paper can improve students' practical ability and problem solving ability, aiming to promote the development of collaborative effectiveness of industry-teaching integration.*

KEYWORDS: *LDA model; content recommendation algorithm; LSTM network; synergistic effectiveness of industry-education integration; digital twin system*

1 Introduction

The integration of industry and education talent training model is the focus of attention of the education and industrial sectors [1]. The integration of industry and education is the main way to cultivate applied and practical talents, but from a practical point of view, some professional skills training is disconnected from the actual work, the data lack of authenticity, and the platform has a single function, which makes it difficult to meet the needs of enterprises for accounting talents [2, 3]. Currently, with the rapid development of 5G, Internet of Things, big data and other technologies, the construction of industry-teaching integration increasingly relies on the support of digital twin technology [4, 5]. Digital twin utilizes physical models,

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sensor update data, and operation history data to integrate multi-disciplinary, multi-physical quantity, multi-scale, and multi-probability simulation processes, and complete the mapping in the virtual space, so as to reflect the full life cycle process of the corresponding physical equipment [5-8]. Digital twin technology, with its ability to accurately simulate and monitor in real time, provides a brand new solution for the construction and operation of campus industry-education integration. Combining the data of the physical world with the virtual model, it realizes the multi-dimensional intelligent application of teaching, management, and service in the campus, in addition to prompting the enterprise work mode to continuously transform to intelligence and digitalization [9, 10]. Specifically, the digital twin system provides students with a highly simulated learning environment by simulating the real enterprise work scene, making it easier to realize the deep integration of industry and education, and cultivate professionals who are more in line with the market demand, thus promoting the collaborative development of education and industry [11, 12]. In this context, the research on digital twin system is of great significance.

There is a wealth of research on the integration of industry and education in academia, Yanan et al [13] take Chongqing Polytechnic University as an example, adding new courses such as Industrial Internet Technology and Industrial APP Development in classroom teaching, in addition to integrating enterprise cases into the teaching, which makes the students more clearly recognize the requirements of the industrial Internet field for application-oriented talents. Chen et al. [14] used linear regression and moderated effects model to examine the impact of industry-teaching integration on the quality of employment in higher vocational colleges and universities, and found that the degree of industry-teaching integration and the quality of employment have an inverted “U”-shaped relationship, and the factor that has a greater impact on the quality of employment is the practical teaching ability of teachers. Zhang, H et al [15] investigated the sustainability of agricultural machinery education in Chinese agricultural universities during the period of 2021-2023, in which the scores of indicators such as the cultivation of craftsmanship, the degree of integration of industry and education, and the degree of matching between the training programs and the social needs were low, for which an innovative model of integration of industry and education with the linkage of the government, universities, and enterprises was proposed. Rajalo et al [16] analyzed university-industry innovation collaborations, using an interdisciplinary approach with a multi-case study design to analyze university-industry collaborations, and found that the relevant prerequisites for industry-academia collaborations are the individual rather than the institution, and that it is the individual's level of motivation and absorptive capacity that determines the key aspects of the likelihood of success or failure of such collaborations.

And with the progress of science and technology, in order to adapt to the development of the times, the mode of integration of industry and education also needs to be continuously innovated. Wang et al [17] explored the dilemmas faced by the development process of industry-teaching integration, they believe that the existence of barriers between enterprise technology secrets and educational propaganda is not conducive to knowledge sharing, and the enterprises' apathetic attitude towards students' practical training hinders the improvement of students' practical skills, and it is necessary to establish a positive digital ecosystem for the reform of industry-teaching integration. Zhang, H [18] summarized the content of the World Congress on the Development of Vocational and Technical Education held in 2024 on the aspects of industry-teaching integration, including the internal mechanism of industry-teaching integration to promote the development of vocational and higher education, the research progress of international cooperation in vocational education, and the development trend of industry-teaching integration in vocational education. He et al [19] designed and applied a cross-technology information management system based on digital

technology, which effectively solved the problem of the mismatch between the demand for talents in the industrial field and the educational field, and the system realized the assessment of educational quality through fuzzy algorithms, which had a positive impact on the teaching effect, the quality of teaching and the cultivation of professional competence. Lu et al. [20] studied the change direction of the industry-teaching integration mode in the era of artificial intelligence, and they constructed a three-dimensional framework of “technical skill mapping - collaboration mechanism innovation - actual scene reconstruction” to determine the practical application value of artificial intelligence technology, and then analyzed the education mechanism of school-enterprise cooperation through in-depth interviews. Then, through in-depth interviews, we analyzed the education mechanism of school-enterprise cooperation, and finally implemented the talent cultivation ecosystem and obtained a better performance of industry-teaching integration. Tang et al. [21] constructed a knowledge network of industry needs, adjusted the changes in industry needs in real time through a dynamic updating mechanism, and integrated the constructed knowledge map into the industry-teaching fusion curriculum system, which solved the problem of students’ inability to grasp the industry needs from the industry perspective. Wu et al. [22] explored the optimization of the faculty of vocational colleges and universities in Shandong Province oriented to the integration of industry and education, based on the human capital theory, the TPACK framework, and the AI-based learning model, and found that the current faculty was unbalanced in terms of structure and competence, and for this reason proposed an optimization strategy focusing on the incentive of the policy of integration of industry and education and the cultivation of AI competence to dramatically increase the proportion of dual-qualified faculty, enterprise participation and digital teaching coverage. Zhang, H [23] optimized the traditional “manual drawing-software operation” mode, that is, the introduction of case study teaching, project-driven teaching, three-dimensional modeling and virtual reality technology, combined with teacher training, school-enterprise cooperation and other measures, which greatly improved the students’ drawing ability and innovative thinking, and perfected the teaching system of integration of industry and education. System of Industry-Education Integration Teaching. Miao et al. [24], on the other hand, used the intelligent technology based on back-propagation neural network to construct a multimodal teaching quality assessment system to deal with problems such as mismatch of industry demand and outdated teaching content in talent cultivation, and the model has a better performance on teaching quality prediction, which promotes a deeper integration between industry and education.

At the same time, the digital twin technology has given a brand new research direction to the innovation of industry-education integration model. Na [25] actively responds to the national call for innovation in the mode of integration of industry and education, introduces digital technology into classroom teaching, builds an industry-teaching practical training platform by using digital twin technology, enriches the way of practice while optimizing the allocation of teaching resources, and studies in detail the specific implementation process by taking the professional course of equipment intelligent manufacturing as an example. Mohammad et al. [26] used digital twin technology for dynamic simulation of industry-education integration, and proposed a digital twin-based construction safety training framework with architecture and construction industry as the object of study, which combined with a virtual reality training environment to provide a professional training scenario for the students, and the framework realized the value of safety training in terms of effectiveness, cost-benefit analysis, monitoring of employees’ behavior, and safety education. Acker et al. [27] prescribed digital twins using technologies such as Unity and the Robotics Operating System in order to improve students’ understanding of K-12 industrial robotics in order to assist students in gaining a deeper understanding of industrialization and expertise in

conjunction with higher education. Sepasgozar et al [28] pioneered a variety of case study projects for innovative education and practical training, such as virtual tours, digital twin-based architectural education systems, and data visualization of immersive practical training environments, and the research is of practical relevance in the fields of architecture, mining, and urban planning. Filipescu et al [29] introduced a multifunctional robotic cell remote monitoring and control system centered on the Internet of Things and digital twin technology, which integrates the design concepts of Industry/Education 4.0 and Industry/Education 5.0 to create an intelligent, flexible, and extensible environment, which is better suited for industrial and educational fusion applications. Meng et al [30] proposed a virtual training platform based on digital twin technology for the problem of how to efficiently and safely conduct practical training in rail transportation, and verified the feasibility of the platform in improving teaching quality and cultivating students' practical and innovative abilities through teaching implementation. However, at present, the research on digital twin system related to the integration of industry and education is relatively small, lacking theoretical system support and practical application experience.

Based on the conceptual theory of digital twin system, this paper divides the digital twin system for the collaborative effectiveness of industry-teaching integration into three functional modules, which are industry-teaching integration resource recommendation module, practical training module, and student management early warning module. On the basis of data acquisition and preprocessing, LDA model and content recommendation algorithm are used to complete the design of the resource recommendation module for integration of education and industry. Next, under the joint action of development software, image processing algorithm, LSTM network, back propagation Rprop algorithm, the design of practical training module and student management warning module is finally completed. Finally, through the system function module simulation analysis, verify the application value of the system in this paper, and put forward the corresponding optimization strategy, in order to promote the development of industry-teaching integration collaborative effectiveness.

2 Construction of Digital Twin System under the Perspective of Industry-Education Integration

The construction of the digital twin system oriented to the synergistic efficacy of the integration of industry and education is not only the core link of the construction of industrial colleges in the context of the digital economy, but also an important manifestation of the integration of industry and education, and the digital twin technology provides a guarantee for the synergistic efficacy of the integration of industry and education. The system packages and processes real-time and real data of enterprises, classifies them through digital means, and displays them on the system to realize multi-party resource sharing. Through the construction of digital twin system oriented to the synergistic effectiveness of industry-education integration, it promotes the application of enterprise project construction and the innovation of talent cultivation mode in colleges and universities.

2.1 Digital Twin Concept and Reference Architecture

2.1.1 Concept of digital twin systems

Digital twin system is the process of digital representation of a specific target entity through data connectivity. In this case, the target entity, also known as physical entity, is the real world entity selected for digital mapping. The digital representation, also known as virtual entity, is

a digital mapping or digital mirror of the physical entity. The data connection is used to synchronize the update of the state of physical and virtual entities by employing accuracy and rate, and the concept of digital twin system is shown in Fig. 1. On the basis of data-driven, dynamic iteration and virtual-real interaction between physical entities, virtual entities, and service applications can be realized through connection interaction. Data-driven includes both activities such as data collection and data analysis, as well as activities such as data-based decision-making and execution, which ultimately form knowledge in iterative optimization. Dynamic iteration means that virtual entities receive data generated by physical entities in real time to complete iterative optimization, while physical entities receive feedback data from virtual entities in real time to complete assisted decision-making. Virtual interaction refers to the two-way mapping, real-time connection and dynamic interaction between physical entities and virtual entities to provide users with application services such as visualization, simulation, prediction and projection.

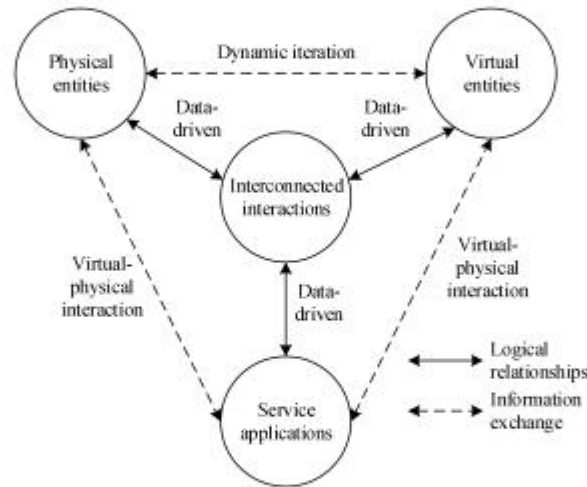


Figure 1: The concept of digital twin system

2.1.2 Reference Architecture for Digital Twin Systems

Digital twin system refers to the system based on data-driven to realize the dynamic iteration of the elements between the target entity and the digital entity, which consists of the target entity, the digital entity, the interactive data connection as well as the model, data, and interfaces involved in the process of the data connection, etc. The reference architecture of the digital twin system consists of three parts: industry-education fusion resources recommending module, practical training and combat module, and student management and early warning module. The digital twin system provides intelligent support for the collaborative effectiveness of industry-education integration by constructing an accurate digital mapping of physical entities in digital space in real time, and simulating, verifying, predicting, and controlling the whole life cycle process of physical entities based on real-time simulation and data analysis, and ultimately providing intelligent support for the collaborative effectiveness of industry-education integration.

2.2 Module for recommending resources for integration of education and industry

2.2.1 Data preparation

By analyzing the list of projects approved for the integration of industry and education released by the Higher Education Department, approximately 70,000 data items were crawled from 2014 to 2023, including "Company Name", "Project Type", "Project Name", "Undertaking school", and "Time". Then, based on each enterprise's name, the addresses of approximately 2,000 enterprises are crawled from the "Qichacha" platform. Finally, about 2,000 university addresses were crawled from "Baidu Baike" based on the names of the undertaking schools of each university, thereby obtaining the dataset of industry-education integration resources.

2.2.2 Data pre-processing

Data preprocessing is mainly to provide a data basis for the extraction of feature words of the title and the division of the subject interest theme of the project later. This subsection uses data standardization, word splitting, and deactivation word removal for data preprocessing to eliminate the interfering data in the data and make the research content of this paper more convincing.

2.2.3 Project Subject Interest Mining Based on LDA Modeling

(1) Text feature representation

When industry and academia reach cooperation on the project of industry-education integration, they first judge whether the resources of industry-education integration belong to their own fields according to the content of cooperation. Since the title is limited in length and highly summarizes the cooperation content, the project that reaches cooperation must involve the user's cooperation field, so in the theme recognition of the title, the participle result of the title can be directly used as the feature word.

TF-IDF is a commonly used method to classify text according to the importance of words in the text, and the basic principle is that if a word is relatively rare, but it occurs many times in the article, then this word can represent the characteristics of the article well. TF-IDF is divided into two parts TF and IDF. TF stands for word frequency, which indicates the number of occurrences of a word in an article, and needs to be normalized due to the length of the article. See equation (1):

$$\text{Term Frequency (TF)} = \frac{\text{The number of times a specific word appears in an article}}{\text{The total number of words in the article}} \quad (1)$$

IDF stands for Inverse Document Frequency, which indicates the frequency of occurrence of a word in all the texts, if the word occurs in most of the texts, the word does not represent the article features well, its importance should be low, and the value of IDF is low. The formula of IDF is shown in equation (2):

$$\text{Inverse Document Frequency (IDF)} = \log \left(\frac{\text{Total number of documents in the corpus}}{\text{Number of documents containing the term} + 1} \right) \quad (2)$$

The TF-IDF value is calculated in equation (3):

$$TF - IDF(x) = TF(x) * IDF(x) \quad (3)$$

(2) Topic Clustering

LDA topic clustering is the inverse process of article generation, which inputs articles and outputs article topics and topic words, i.e., according to a complete article to find its corresponding distribution of article-topics and topic-words, and then based on the distribution of article-topics to classify the set of articles into different topics, which also realizes the topic clustering. The goodness of the LDA topic model is usually evaluated by the degree of perplexity. Perplexity is an index that reflects the generalization ability of the model, the smaller the perplexity, the higher the prediction ability. The specific calculation formula is shown in equation (4):

$$\text{Perplexity}(D) = \exp \left\{ - \frac{\sum_{d=1}^N \sum_{n=1}^M \log p(W_n)}{\sum_{d=1}^N N_d} \right\} \quad (4)$$

where D denotes the test set in the corpus, N denotes the number of articles in the prediction set, M denotes the number of words in each article in the prediction set, N_d tabulates the number of words in the article d , and $p(W_n)$ denotes the probability of the word W_n in the article. However, because the LDA topic model belongs to unsupervised clustering, relying on the perplexity degree alone to determine the number of topics, there still exists the phenomenon of inter-class crossover, for this reason, in this chapter, when carrying out LDA topic modeling, the clustering results will be visualized, and the optimal number of topics will be determined according to the perplexity degree and the visualization results.

Each industry-education integration cooperation project has a pair of partners, according to the LDA theme model output of the title theme category, the project subject interest theme mining results can be obtained.

2.2.4 Content recommendation methods

The content recommendation algorithm has inter-project subject independence, ensures that the personal preference of the project subject has nothing to do with others, and can effectively avoid the cold-start problem of the newly entering project subject. Taking the recommendation of colleges and universities to enterprises in the integration of education and industry resources as an example, the content-based recommendation method can be divided into three steps: establishment of enterprise interest topic model, establishment of college interest topic model and recommendation of integration of education and industry resources based on the similarity of enterprises and colleges and universities.

(1) Enterprise Interest Theme Model

Based on the construction of the theme model, the interest theme model of the enterprise is obtained. The topics of interest to the enterprise and the preference weights are expressed in the form of preference feature vectors. The representation form is shown in equation (5):

$$U_i^e = \{(b_{1i}, w_{1i}), (b_{2i}, w_{2i}), (b_{3i}, w_{3i}), \dots, (b_{ni}, w_{ni})\} \quad (5)$$

where $b_{ni} \in B$ denotes the item theme that the i th firm is interested in, i.e., the interest theme of the firm. $w_{ni} \in [0,1]$ denotes the preference weight of the i th enterprise under the topic of interest b_n . Where i is the number of enterprises and n is the number of program themes.

(2) College Interest Theme Model

Also based on the construction of theme model, the interest theme model of universities is obtained. The preference feature vector of colleges and universities is shown in equation (6):

$$U_j^u = \{(b_{1j}, w_{1j}), (b_{2j}, w_{2j}), (b_{3j}, w_{3j}), \dots, (b_{nj}, w_{nj})\} \quad (6)$$

where $b_{nj} \in B$ denotes the program theme of interest of the j th HEI, i.e., the theme of interest of the HEI. $w_{nj} \in [0,1]$ denotes the preference weight of the j th HEI under the topic of interest b_n . Where j is the number of colleges and universities.

(3) Recommendation of teaching resources for industry-teaching integration

The more the research topics of enterprises and universities are the same, the higher the preference weights of the same research topics are, and the higher the possibility of their recommendation. For this reason the similarity calculation formula is shown in Eq:

$$P(c, s) = \sum_b (w_{b,c} * w_{b,s}) \quad (7)$$

where $P(c, s)$ denotes the similarity between enterprises c and colleges s , $w_{b,c}$ denotes the preference weight of enterprises c under the topic of interest b , and $w_{b,s}$ denotes the preference weight of colleges s under the topic of interest b . The higher the similarity, the higher the likelihood of recommending the same topic of interest between the enterprise and the university.

2.3 Practical training modules

On the basis of the theory of digital twin technology, the construction of real with virtual, virtual to help the real, virtual and real combination of practical training modules, taking into account the theoretical explanations and practical operations, from the theoretical explanations and practical operations to improve the quality of the teaching of the integration of industry and education and the practical operation of the teaching effect at the same time, in order to enhance the integration of industry and education and the development of synergistic efficacy of the provision of new ideas.

2.3.1 Development of software

(1) Modeling software

Currently used modeling software: Autodesk, SolidWorks, Pro/Engineer, UnigraphicsNX

and so on.

(2) Rendering software

3ds Max software operates logically, has a friendly interface, has a wealth of tutorial resources and plug-in programs, provides excellent material editing, model rendering and optimization programs, and at the same time provides a wealth of data interfaces for other three-dimensional software, which provides strong technical support to enhance the fidelity and immersion of the virtual training room.

(3) Virtual Reality Software

Virtools is a kind of development of virtual reality system - tool software, developers through the intuitive graphical development interface, as long as the required module dragged to the object can be produced complex interactive behavior, not only to meet the development needs of program designers, and even do not know the program development of the art staff can be used freely, and the two can be reasonably divided into two, can effectively shorten the development link, improve the development efficiency, Virtools is a kind of development of virtual reality system - tool software, developers through the intuitive graphical development interface, as long as the module drag to the object can be produced complex interactive behavior. Virtools is characterized by its ease of use and wide range of applications.

2.3.2 Image processing algorithms

In the practical training module, often encountered object movement, rotation, machining chip display, parts of the cutting and machine tool model of the relative relationship between the components and other issues, by virtue of Virtools itself can solve some of the problems, but in order to achieve the desired results, the need for geometric transformation, particle system, collision detection and shadow drawing and other key algorithms to optimize. The optimization and implementation of these image processing algorithms will be introduced next.

(1) Geometric Transformation Algorithm

Translation transformation refers to moving an object from its current position to a new position without changing its direction and size. Suppose the translations in the X , Y , and Z directions are T_x , T_y , and T_z , respectively. Then there are:

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ T_x & T_y & T_z & 1 \end{bmatrix} \quad (8)$$

Therefore, the new coordinates of a point (X, Y, Z) after translation are:

$$\begin{cases} X' = X + T_x \\ Y' = Y + T_y \\ Z' = Z + T_z \end{cases} \quad (9)$$

Proportional scaling transformations are those that change the size of an object by a certain proportion. Assuming that the scaling factors S_x , S_y , and S_z correspond to the (X, Y, Z) coordinate axes respectively, the transformation matrix is:

..

$$\begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (10)$$

Therefore, the new coordinates of a point (X, Y, Z) after scaling are:

$$\begin{cases} X' = XS_x \\ Y' = YS_y \\ Z' = ZS_z \end{cases} \quad (11)$$

A rotational transformation is a form of geometric transformation that rotates elements of an object around the $X/Y/Z$ axis. Suppose that the rotation of the α angle around the X axis gives a matrix of R_x and the rotation of the β angle around the Y axis gives a matrix of R_y . Rotate the θ angle around the Z axis for a transformation matrix of R_z , respectively. i.e:

$$R_z = \begin{bmatrix} \cos \theta & \sin \theta & 0 & 0 \\ -\sin \theta & \cos \theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad R_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos \alpha & \sin \alpha & 0 \\ 0 & -\sin \alpha & \cos \alpha & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (12)$$

$$R_y = \begin{bmatrix} \cos \beta & 0 & -\sin \beta & 0 \\ 0 & 1 & 0 & 0 \\ \sin \beta & 0 & \cos \beta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (13)$$

(2) Particle system algorithm

Particle system is an indispensable part of almost every virtual engine, which is mainly used to solve the problem of generating and displaying on the computer a large number of large substances composed of a large number of tiny substances moving according to certain rules. Particle systems are considered to be the most successful algorithm for generating graphical simulations of irregular objects to date. The basic conception of the method is that a large number of particles with simple shapes and tiny sizes are taken as the basic elements, and then they are gathered together so as to form a system of fuzzy objects with irregular shapes and closed objects, which is the particle system.

It can be seen that each of the above steps is a process computational model, so it can be combined with all the models depicting the motion and characteristics of the object, e.g., partial differential equations can be used to describe the motion and transformation of particles. For the control of particle shapes, features and motions, some simple stochastic processes can be used to realize the stochasticity of the particle system. As for the parameters of each particle should be chosen randomly within a pre-determined range, and then its variation range is determined according to the given maximum variance and average expected value, the operational equation can be expressed as:

$$Parameter = MeanParameter + Rand() * VarParameter \quad (14)$$

where: Parameter denotes any required random parameter. MeanParameter is the mean value of the parameter. Rand() is the uniform random function in $[-1, 1]$. VarParameter is the variance of the parameter.

(3) Collision detection algorithm

The various 3D models constructed in the practical training real-world module are independent of each other, in order to avoid objects crossing in motion, so that the scene characters are more complete, but also need to use collision detection technology. Collision detection algorithms are usually divided into two categories: spatial decomposition method and hierarchical enclosing box method, the latter is very suitable for collision detection in complex environments, which is more widely used.

Commonly used hierarchical enclosing box shown in Figure 2, compared with the AABB tree, the biggest feature of the OBB tree is the arbitrariness of its direction, because it only needs to contain the object and the direction of the hexahedron relative to the coordinate axis arbitrary. The OBB in 3D space can be expressed using the midpoint F , the half-length edges $R1/R2/R3$, and the mutually perpendicular unit vectors $Z1/Z2/Z3$ with a total of seven parameters. The expression is given below:

$$R = \{F + a R1 Z + b R2 Z + c R3 Z \mid a, b, c \in [-1, 1]\} \quad (15)$$

The algorithm utilizes the first and second order statistical properties of the object's vertex coordinates, and the enclosing box hierarchy is based on:

$$\mu = \frac{1}{3n} \sum_{i=0}^n (p' + q' + r') \quad (16)$$

$$c_{jk} = \frac{1}{3n} \sum_{i=0}^n (\bar{p}'_j \bar{p}'_k + \bar{q}'_j \bar{q}'_k + \bar{r}'_j \bar{r}'_k) \quad 1 \leq j, k \leq 3 \quad (17)$$

where: n the number of triangles that make up the model, $\bar{p}' = p' - \mu$, $\bar{q}' = q' - \mu$, and $\bar{r}' = r' - \mu$ is a 3×1 vector. $p' = (p'_1, p'_2, p'_3)^T$ and C_{jk} are 3×3 covariance matrices. μ : mean value. C : covariance $\bar{p}$. The three vertices of the i th triangle are (p', q', r') .

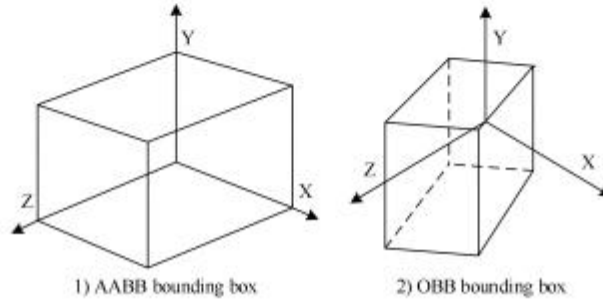


Figure 2: Commonly used hierarchical bounding boxes

(4) Shading Rendering Algorithm

Mask calculation is divided into three directions of calculation - plane normal, center point and plane X , Y direction. The formula for calculating the mask plane normal is as follows:

$$N_{mask} = \frac{\sum_{i=1}^{N_s} (V_i - V_{light})}{N_s} = \frac{\sum_{i=1}^{N_s} V_i}{N_s} - V_{light} = O_p - V_{light} \quad (18)$$

where N_{mask} represents the normal vector of the masking plane, V_i is the coordinate of the i th node of the scene, N_s is the number of nodes, O_p represents the geometric center coordinate of the scene, and V_{light} represents the coordinate of the point light source.

Project the scene onto the masking plane to obtain the masking polygon, and finally generate the masking polygon by the following transformation matrix (T_matrix). i.e:

$$V_{mask} = M_{ObjectLocalToWorld} * M_{WorldToMask} * V_{ObjectLocal} \quad (19)$$

where: V_{mask} are the coordinates of the projected nodes on the mask plane, $M_{WorldToMask}$ is the transformation matrix from the system coordinate system to the mask coordinate system, $V_{ObjectLocal}$ is the value of the local coordinates of an arbitrary node on the scene, $M_{ObjectLocalToWorld}$ is the transformation matrix from the object coordinate system to the system coordinate system.

2.3.3 Establishment of training scenarios

This system is based on a school CNC machining training workshop as a prototype, involving CNC lathes, CNC milling machines, machining centers and other equipment, as well as virtual machining, learning materials display, etc., the virtual scene is more complex and a large number of virtual scenarios, so this project adopts a modular scenario design ideas, to break down the complex scenarios into a number of relatively independent sub-scenes, such as: CNC lathe virtual scenarios, virtual scenes of machining centers, workshop peripheral scenes, virtual machining scenes and so on. , workshop peripheral scene, virtual machining scene and so on. Before modeling, we must fully understand the appearance, size and internal structure of the real equipment, map the real machine tool and collect relevant data as the basis for virtual modeling. Then use the modeling software to build the model of the components, and then assemble the components and make appropriate optimization, and at the same time make the model material texture, and finally render the model. The training scenario avoids the safety accidents and equipment damage caused by the operation in the real environment, provides students with a vivid and realistic environment for the integration of industry and education, and at the same time enriches the practical teaching of CNC machining, which improves the collaborative efficiency of the integration of industry and education.

2.4 Early warning module for student management

Student management is the foothold of the construction and development of colleges and universities, which determines whether a school can realize sustainable development, and student management early warning work is the top-level design to realize the synergistic efficacy of the integration of industry and education. By building the early warning module of student management, we can grasp the learning status of students in time, deepen the integration of industry and education, school-enterprise cooperation, strictly implement the early warning and withdrawal mechanism, reduce the specialties in time, focus on the advantageous resources to create high-level talents, and enhance the synergistic effectiveness of the integration of industry and education.

2.4.1 Classification of Early Warning Levels

According to the actual situation of the integration of industry and education student management early warning level is divided into four levels: red warning, orange warning, yellow warning, green warning. Through the student management early warning neural network prediction, we will predict the probability of employment is lower than 50% of the students included in the red warning object, will predict the probability of employment is low between 50% and 60% of the students included in the orange warning object, will predict the probability of employment in 60% to 80% of the students included in the yellow warning object, for the prediction of the probability of employment is higher than 80% of the students included in the green warning object.

2.4.2 Improving LSTM networks

After the multi-dimensional normal distribution feature extraction of all the student data matrices, each matrix is divided into singular class and standard class, for each class of student data matrices through two networks, for the different types of data, the data rows with high dependence on timing such as one-card consumption records, etc. will be input into the LSTM network based on the adaptive excitation function for training, and for the data rows with low dependence on timing such as student Theoretical scores, practical scores, etc. are input into the MLP network based on the elastic back propagation algorithm for training, and the output obtained from each network is fitted with a linear probability so as to realize the cascade of the network, and ultimately the employment probability is obtained. That is:

$$f(x) = \frac{1}{u} \frac{e^x - e^{-x}}{e^x + e^{-x}} + \frac{1}{v} \max(0, x), u + v = 1 \quad (20)$$

The original tanh incentive function into an adaptive incentive function Relu+tanh weighted average function, for each gate of LSTM incoming data using the form of incentives, so that through the LSTM on the student card consumption related information for training, warning classification of each student, for each student targeted to generate a personal analysis report. If the warning is a high-risk warning, it will receive the corresponding warning information and cascade the warning information with the artificial neural network in 3 to predict the probability of the student's employment.

Calculation of the parameters of the adaptive excitation function: the input layer is a matrix of size $j_1 * n$, where $j_1 < m$, j_1 is the number of rows extracted from the total data matrix K , where $j_1 = 7$, through repeated iterative calculations and optimal approximation to obtain the adaptive excitation function. That is:

$$z = \frac{1}{v} \text{relu}\left(w \frac{x'}{t-1}\right) + \frac{1}{u} \tanh\left(w \frac{x'}{t-1}\right) \quad (21)$$

The weighting coefficients $v = 0.637$ and $u = 0.363$ are best trained.

2.4.3 Iterative Training Based on Backpropagation Rprop Algorithm

The advantage of choosing the elastic backpropagation algorithm model is that the gradient of the error function only has an impact on the direction of the change of the weights in the process of model training, the value of each change of the weights is equal to the corresponding learning rate of the weights, and the gradient of the change of the error function is only due to the direction of that the weights are updated, and does not affect the intensity of the update of the weights. When the gradient of the error function is positive, it is appropriate to reduce the value of the corresponding lower weight. If the gradient of the error function is negative, it is appropriate to increase the corresponding weights to make the error function close to the minimum value, as shown in the following formula:

$$\begin{aligned} \Delta w_{i,j} &= -\eta_{i,j}(t), \text{if } g(y) > 0 \\ \Delta w_{i,j} &= +\eta_{i,j}(t), \text{if } g(y) < 0 \\ \Delta w_{i,j} &= 0, \text{otherwise} \end{aligned} \quad (22)$$

In the problem of learning rate $\eta_{i,j}(t)$ value change in the elastic backpropagation algorithm, the sign of the gradient in any adjacent moment will change, this change is mainly divided into two cases: if the gradient direction of the error function is different in the previous moment and the current moment, it means that the current moment has missed the minimal value, that is, the growth of the last update of the weights is too large, and then $\eta_{i,j}(t)$ is smaller than $\eta_{i,j}(t-1)$ makes the learning rate of the previous step and the value η^{ep} belonging to the range of $(0,1)$ multiply to get the current learning rate, when the direction of the two times is the same, i.e., it has not yet arrived at the minima of the error function, so that the learning rate of the previous step is multiplied by a value η^{denn} larger than 1 to get the current learning rate, as shown in Eq. (23):

$$\begin{aligned} \eta_{i,j}(t) &= \eta^{ep} \eta_{i,j}(t-1), g(t-1)g(t) > 0 \\ \eta_{i,j}(t) &= \eta^{denn} \eta_{i,j}(t-1), g(t-1)g(t) < 0 \\ \eta_{i,j}(t) &= \eta_{i,j}(t-1), \text{otherwise} \end{aligned} \quad (23)$$

The system inputs to different training networks for classification operations according to the different types of student information data, and then combines the output probability results, using the form of $p*a + (1-p)*b = c$ for the fusion of results. Where p is the weight coefficient, a is the LSTM network prediction result, b is the artificial neural network prediction result, and c is the probability of employment, which ultimately results in the probability of employment of the student, and different degrees of management warning for students.

2.4.4 Network parameter configuration

The most important hyperparameters of the network consist of learning rate, momentum increment, and number of training iterations, which are set to 0.001~0.5, 0.01~4.0, and 100~1000, respectively.

Calculation of the input layer: from the total data matrix K , the LSTM selects j_1 row vectors for training, then the remaining is $j_2 = m - j_1$ rows of data, then the input layer is a matrix of size $j_2 * n$. The number of nodes in the input layer is j_2 , here $j_2 = 15$, and the neurons are fully connected so the weight is 1.

Calculation of the hidden layer: hidden layer, in the learning rate $\gamma = 0.0128$ and the number of hidden layers of 8 layers when the accuracy has reached a high level but the false positive rate is also relatively high, continue to deepen the hidden layer in the learning rate of $\gamma = 0.00428$ and the number of hidden layers of 20 layers when the accuracy of the obvious decline and false positive rate is once again higher, through the elastic back propagation algorithm repeated iterations Through repeated iterations of the elastic back propagation algorithm, the optimal accuracy is obtained when the learning rate and the number of hidden layers is 10.

Calculation of the output layer: since the output result is the probability of student employment, the output layer is the number of nodes 1.

3 System module simulation and optimization

3.1 Simulation of the resource recommendation module for industry-teaching integration

After verifying the application effect of the LDA topic model in the subject interest mining of the industry-education fusion project, it is also necessary to compare and analyze the content recommendation algorithm with the user recommendation algorithm, so as to test the performance of the content recommendation algorithm. To this end, simulation experiments are conducted according to the text data of the integration of industry and education to compare the performance of the content recommendation algorithm with the user recommendation algorithm.

3.1.1 Interest Mining Analysis of Subjects of Industry-Education Integration Projects

This subsection preprocesses the textual data of the production-teaching integration resources by vectorizing the downloaded policy text through Python's pandas library and storing it in the form of an Excel dataset. The first filtering utilizes Python's jieba lexical module to process the vectorized text of education and industry integration resources into lexical processing. Chinese literature has no prominent separating boundaries between words, and punctuation is not enough to separate the text of education and industry integration resources into topic words, and the model can only identify words with characteristic features, so this step is very important and determines the efficiency and accuracy of the LDA topic model. Then, TfidfModel is called to perform TF-IDF calculation, which is proportional to the number of occurrences of a word in a document and inversely proportional to the number of occurrences of the word in the whole corpus. The TF-IDF values are used to filter out the words that appear more than a certain frequency with small weights in the text of the integration of education and production resources, and retain the word items related to the

integration of education and production resources. Finally, the filtered dataset is imported into the LDA model for modeling.

The most important step in the LDA topic model is to determine the number of topics, and it is more common to determine the optimal number of topics by topic consistency and perplexity. Theme consistency, also known as theme coherence, refers to the degree of connection between words within a theme, i.e., whether the word occurs frequently within the same theme. The higher the thematic coherence, the more closely related the words are within the theme, and the higher the interpretability of the theme. Perplexity is used to measure the degree of uncertainty of the model's prediction of the text data, the lower the perplexity, the lower the uncertainty, the better the topic clustering effect, the more accurate and certain the model's generalization and prediction of the topic of the data corpus, the number of topics - perplexity folds are shown in Figure 3.

As the value of the number of topics K increases, the perplexity gradually decreases. When K belongs to (2,4), the perplexity curve gradually decreases. When K is 4, the perplexity curve decreases sharply, but the topic granularity is too large at this time. When num-topics=5, the value of perplexity is low, the clustering effect of themes is better, and the demarcation between themes is more obvious. Therefore, the selected number of topics generated for the integration of production and education resources is 5. Calling the HopPyLDAvis library to visualize the LDA topic model is shown in Figure 4, in which T1~T30 represent the textual lexical items of the integration of production and education resources, which not only intuitively demonstrates the trend of the distribution of textual feature word frequency, but also confirms the application effect of the LDA model in the subjective interest mining of integration of production and education projects.

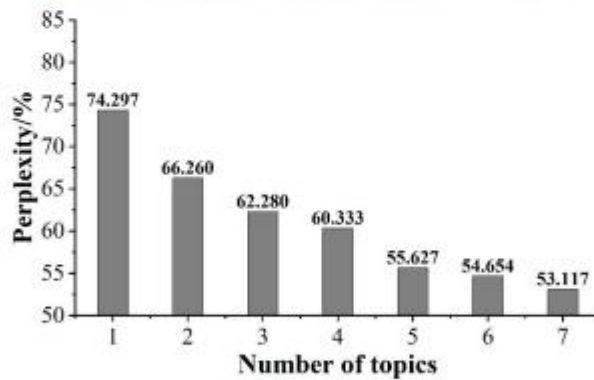


Figure 3: Topic Number - Perplexity Line

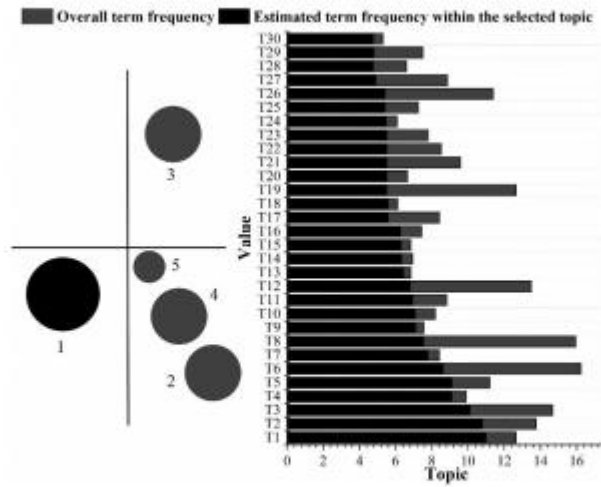


Figure 4: Visual display

3.1.2 Algorithm simulation analysis

In this subsection, the content recommendation algorithm is compared with the user recommendation algorithm for recommending the resources for industry-teaching integration, and the accuracy, check-fullness, and precision rates of the two algorithms are calculated, so as to compare the performance of the two algorithms. The correct rate comparison is shown in Fig. 5, the check rate comparison is shown in Fig. 6, and the precision rate comparison is shown in Fig. 7. Firstly, comparing the correct rate and check rate of the two algorithms, the correct rate and check rate of the content recommendation algorithm increase rapidly with the increment of the number of recommended resources for the integration of education and industry, but the user recommendation algorithm needs to have a more significant increase in the correct rate and check rate when the number of resources for the integration of education and industry is larger, and its value range is $[0, 0.4]$. Then compare the accuracy rate of the two algorithms. As the number of recommended resources for integration of education and industry increases, the accuracy rate of the user recommendation algorithm decreases significantly, while the content recommendation algorithm maintains a high recommendation accuracy rate. Overall, as the number of recommended resources for integration of education and production increases, the correct rate, check rate and accuracy rate of the content recommendation algorithm are not lower than that of the user recommendation algorithm, and the more the number of recommended resources for integration of education and production increases, the more obvious the advantage of the content recommendation algorithm in terms of performance, i.e., the content recommendation algorithm is better than the user algorithm. The results of simulation and analysis confirm the effectiveness of the content recommendation algorithm in the resource module of the integration of education and industry, and to a certain extent verify the application value of the digital twin system in the perspective of the integration of education and industry, which is of great significance to enhance the collaborative effectiveness of the integration of education and industry.

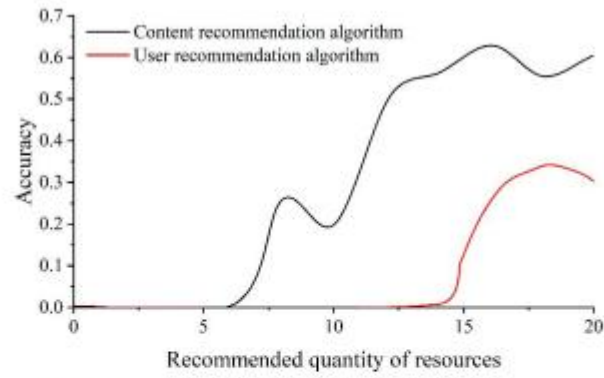


Figure 5: Comparison of accuracy rates

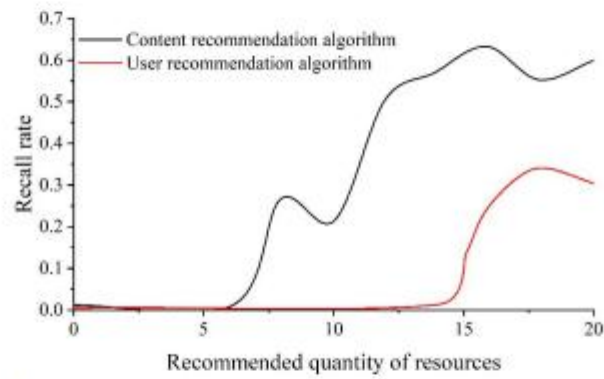


Figure 6: Recall rate comparison

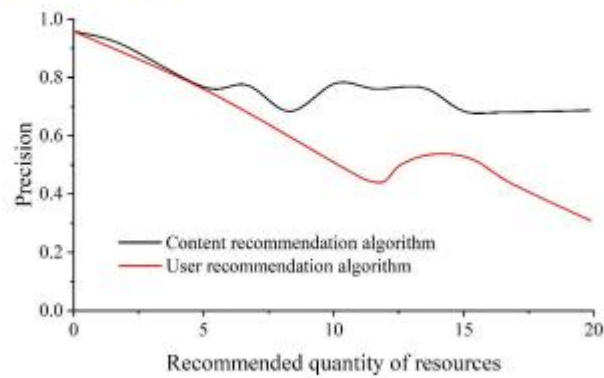


Figure 7: Precision comparison

3.2 Practical training and combat module simulation

3.2.1 Initial condition setting

The computer simulation needs to be set up initially by setting the simulation start time = 2014, simulation termination time = 2023, simulation step (DT) = 1, and time unit (UNIT) = year, and its data is derived from the data crawling program in web mining.

3.2.2 Test analysis

There is also a need to test the module after it has been created, as module testing is used to find errors so that the modeler and the user can understand the limitations of the module and improve it, and ultimately so that the module assists the user in making better decisions. Various specialized guesses are created to find flaws and improve the module, but it is not possible to prove the vulnerability of the module in every aspect, generally the following tests are performed on the module: boundary test, mental model test, quantitative consistency test, structural and behavioral test, parameter estimation test, integral error test, sensitivity test, and extreme case test. The following further performs history test, sensitivity analysis and extreme case test on the module.

(1) Historical Test

In order to make progress in testing the effectiveness and authenticity of the module, the practical training simulation data derived from the simulation is compared with the historical practical training data, and the error rate is whether it is within the value of the error allowable range, and the results of the historical test are shown in Table 1. Most of the relative errors between the simulated real training values and the historical real training values within the process of industry-education integration from 2014 to 2023 are controlled within 5%, and the average value of the relative error rate between the simulated real training data and the historical real training data is 2.42%, and the error value is within a reasonable range. Therefore, the practical training module has excellent application effectiveness.

Table 1: Historical test results

Year	Historical training data	Practical training simulation data	Relative error value
2014	7.623	7.054	0.0807
2015	7.25	7.216	0.0047
2016	9.538	9.583	0.0047
2017	10.103	9.979	0.0124
2018	13.744	13.508	0.0175
2019	8.311	8.302	0.0011
2020	15.309	15.154	0.0102
2021	16.765	16.64	0.0075
2022	10.984	9.973	0.1014
2023	11.812	11.832	0.0017
Mean	11.1439	10.9241	0.0242

(2) Sensitivity test

Set the number of simulations of students' practical ability in the practical training module for 500 times, the sensitivity test results are shown in Figure 8, which shows that the simulation value of students' practical ability fluctuates between 0.7 and 1.0, and there are differences in the results of the run due to the different parameters, but the shape of the graph is basically the same. It shows that the practical training practical module of the students'

practical ability to take the value of insensitive more stable, the model passed the sensitivity test.

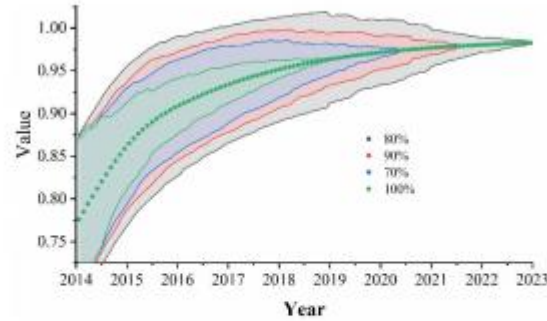


Figure 8: Sensitivity test results

(3) Extreme situation test

Set the number of students participating in the practical training practical module = 0, and carry out the module extreme case test. The results of the extreme case test are shown in Figure 9. When the number of people involved in the practical training module plummets to zero, the simulation results of the practical training module are in line with reality, and the participation in the practical training module becomes 0 in 2018, which means that the model extreme case test passes.

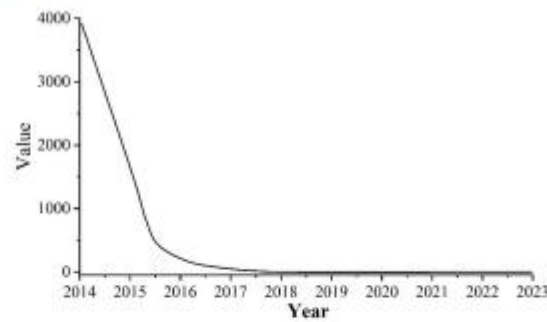


Figure 9: Extreme case test results

3.3 Simulation of Student Management Alert Module

After building the student management early warning model, the training set is substituted, and after the iterative training process based on the back-propagation Rprop algorithm is completed, the data of the test set is input to carry out the simulation and analysis of the student management early warning module, and the results of the simulation and analysis are shown in Figure 10. As can be seen from the data performance in the figure, the error between the simulation value and the actual value of the student management early warning model is controlled within 0.05, which indicates that the prediction of the student management early warning model is very effective, with high accuracy, so that the designed student management

early warning module can better serve the digital twin system, which in turn promotes the enhancement of the effectiveness of the synergy of integration of industry and education.

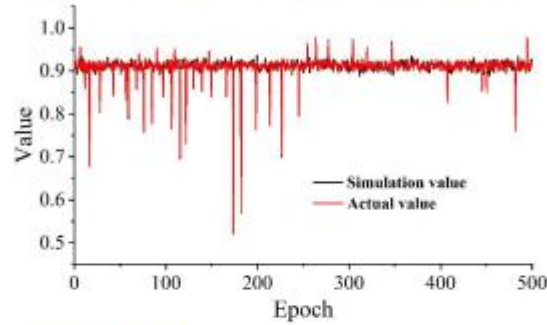


Figure 10: Simulation analysis results

In order to further verify the application value of the student management early warning model in the synergistic efficacy of industry-teaching integration, the model is applied to simulation analysis from the aspect of student employment probability, and the results of the model application simulation analysis are shown in Table 2. Based on the data in the table, it can be seen that this paper's model in the student management warning level simulation analysis, red warning, orange warning, yellow warning, green warning prediction error were 0.0315, 0.0233, 0.0309, 0.0045, prediction error are controlled within 0.05, which fully explains this paper's student management early warning model in the synergistic efficacy of integration of education and industry in the application of value. The model in this paper provides a reference for early warning of students in colleges and universities, which helps teachers in the process of industry-education integration to find students with low employment rate in a targeted way and teach them according to their abilities, so as to guide and intervene in the early stage of learning in a timely manner, thus effectively preventing the occurrence of student unemployment.

Table 2: The simulation analysis results of the model application

Student management warning level	Actual value	Simulation value	Relative error
Red alert	0.476	0.461	0.0315
Orange alert	0.558	0.545	0.0233
Yellow alert	0.744	0.721	0.0309
Green alert	0.892	0.888	0.0045

3.4 Optimization Strategies

3.4.1 Strengthening integrated leadership

It is necessary to strengthen the overall leadership of the integration of industry and education, take the initiative to coordinate the departments involved in the integration of industry and education, such as education, finance, human resources and social affairs, industry and information technology, and establish a perfect joint working mechanism for the integration of industry and education, so as to form a guarantee mechanism for the integration of industry and education with the government's overall planning, scientific deployment and policy

support, as well as a situation of the integration of industry and education with the coordination of the governmental departments, the coordination of the institutions of higher vocational education and the collaboration of enterprises, and the active participation of the industrial organizations, so as to promote the development and optimization of digital twin systems for the synergy between industry and education. The development and optimization of the effective digital twin system will enhance students' practical abilities and problem-solving abilities.

3.4.2 Enhanced capacity-building for services

Accelerate the construction of service capabilities for digital twin systems, comprehensively promote the alignment of professional courses with enterprise production positions, teaching content with occupational standards, and teaching processes with enterprise production processes, so as to further optimize the digital twin system oriented towards the collaborative efficiency of industry-education integration, thereby meeting the employment demands of enterprises and providing a "reassuring pill" for enterprises to actively participate in industry-education integration.

4 Conclusion

With the rapid development of digital twin technology, the high-quality development of economy puts forward higher requirements for the deep integration of university education and industry. This paper constructs a digital twin system for the collaborative effectiveness of industry-education integration from the three dimensions of industry-education integration resource recommendation module, practical training and combat module, and student management early warning module, and simulates and analyzes each functional module of the system.

(1) Through the subject mining of industry-teaching integration of LDA model, the number of subject generation of industry-teaching integration resources is determined to be 5, which shows a better clustering effect, i.e., it reflects the application effect of LDA model in the subject interest mining of industry-teaching integration project. In addition with the increment of the number of recommended production and education fusion resources, the content recommendation algorithm's correct rate, check all rate and accuracy rate are better than the user recommendation algorithm, which indicates the effectiveness of the content recommendation algorithm in the production and education fusion resources module.

(2) The average value of the relative error rate between the value of imitation real training and the value of historical real training within the process of industry-teaching integration from 2014 to 2023 is 2.42%, and the relative error is controlled within 5%, which demonstrates the effectiveness of the application of the practical training module in the digital twin system of this paper, which in turn promotes the high-quality development of collaborative efficacy of industry-teaching integration.

(3) Using the model of this paper to simulate and analyze the warning level of student management, it is found that the prediction errors of red warning, orange warning, yellow warning and green warning are 0.0315, 0.0233, 0.0309, 0.0045 respectively, and the prediction errors are within the permissible range, which demonstrates the application of the student management warning module in the digital twin system in the aspect of the collaborative efficacy of the integration of industry and education. Value.

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Acceptance Letter

Dear Dr [REDACTED]

We are pleased to inform you that your manuscript entitled ***“Digital Twin System Construction and Simulation Optimization for Collaborative Effectiveness of Industry-Education Integration”*** (Manuscript ID: IS-B117) has been accepted for publication in ***Ingegneria Sismica***.

Ingegneria Sismica is an open-access, peer-reviewed journal committed to making research freely accessible to a global audience. An Article Processing Charge (APC) is required to cover publication costs.

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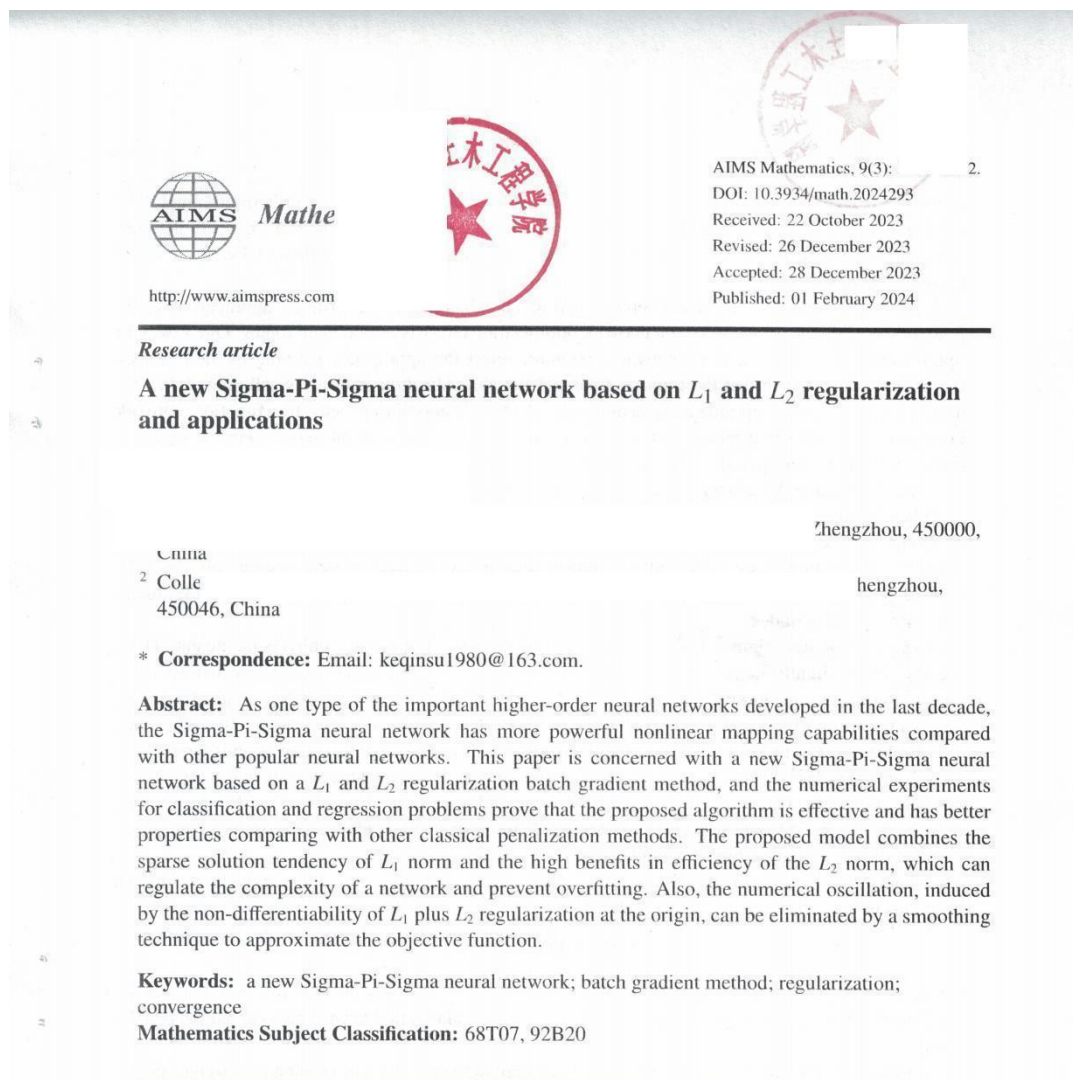


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2.论文: A new Sigma-Pi-Sigma neural network based on L_1 and L_2 regularization and applications



1. Introduction

The Sigma-Pi-Sigma neural network (SPSNN) is a feed-forward neural network composed of Sigma-Pi units, which can be used to achieve a static mapping of multi-layer neural networks [1–3]. In [4], a new model which can be regarded as a subclass of networks on Sigma-Pi units was considered, and the authors showed the origin of the Kronecker product representation from the classical Sigma-Pi units. In [5], a Sigma-Pi network and a new arithmetic were proposed, by which the output representation self-organizes to form a topographic map, whose main contribution was to solve the

frame of reference transformation issues through unsupervised the approximation, convergence performance, and generalization functions were studied, and it was shown that the new algorithm existing literatures.

It is widely recognized that neural network optimization has emerged as a highly significant research topic in recent times. Study on neural network optimization consists of two main topics: One is weight optimization, that is, for a given network structure, select the appropriate learning method to seek the optimal weight such that the training error and the generalization error are small enough [9, 10]. The second is structural optimization, namely the selection of appropriate activation function, network layer number, connection mode, and so on [11–13]. But, the research on neural network structure optimization is far less rich than that on weight optimization. On the other hand, there is no literature showing that more hidden layer neurons yield better generalization ability.

When it comes to neural networks, the number of neurons is a crucial factor. There are two common methods for determining the size of networks. The first method is the growing method, where the network starts with a smaller size and new hidden neurons are added during the training process [14]. Another method is the pruning method [15–19], which begins with a larger network and eventually removes redundant nodes.

These kind of algorithms separates weight learning and weight training, which is inefficient. There are also many slightly more complex algorithms, which further introduce various mechanisms like particle swarm optimization [20], genetic algorithms [21], eigenvalue analysis [22], statistical analysis, and synthetic minority over-sampling techniques [23, 24], so as to enhance the sparsification efficiency. The disadvantage of these algorithms is that the program is complex and the calculation is large.

An appropriately sized network structure is instrumental in enhancing efficiency. Overfitting poses a significant challenge during network training and is particularly problematic for deep neural network learning [25]. Consequently, researchers have extensively explored various forms of sparse regularization techniques, highlighting their indispensability.

Recent years, L_p regularization is diffusely used to solve variable selection and parameter estimation problems in machine learning. This regularization method takes the form

$$E(W) = \widehat{E}(W) + \tau \|W\|_p^p,$$

where $\widehat{E}$ is the normal error function, $\|W\|_p = (\sum_i |W_i|^p)^{1/p}$ denotes the p -norm, τ is the penalty coefficient, and $\|\cdot\|$ represents the euclidean norm. This regularization term is also named the penalty term.

In general, there are several common forms of regularization: weight elimination, weight decay, and approximate smoothing [26–32]. Among them, weight elimination is widely used as the penalty term in pruning feedforward neural networks, mainly to reduce unnecessary connections or optimize the network weights [33]. A little more detailed introduction for different penalty terms are as follows.

For different values of p , the L_2 norm to the standard error function makes it more optimized [34–37]. This practice is called L_2 regularization, and the form is shown as follows:

$$E(W) = \widehat{E}(W) + \tau \|W\|_2^2,$$

where $\|W\|_2^2$ denotes the penalty term, and the L_2 norm solution is popular because of its special relationship with the normal distributions. It can serve as brute force to avoid excessive weights.

But, unfortunately, it is not sparse. This means that, during the training process, it can not drive unnecessary weights to zero.

The L_0 regularization term is the ordinary method for feature extraction and variable selection. Constrained by the number of coefficients, the L_0 regularizer produces the most sparse solutions, which are difficult to calculate, and it is a combinatory optimization problem [38, 39].

As an alternative to the L_0 regularization term, the increasingly important L_1 regularization term (Lasso) has become popular since it just needs to resolve a quadratic programming problem [40]. In [41], the L_1 -norm was combined with the capped L_1 -norm to indicate the amount of information collected by the filter and the control regularization. The L_1 regularization penalty function is generally denoted as follows:

$$E(W) = \widehat{E}(W) + \tau \|W\|_1.$$

It was shown in [42, 43] that, although these algorithms can generate an alternate neural network structure, they do not offer a unified neural network framework to solve a class of problems.

In order to explore more appropriate neural network structures to get over the obstacles posed by suboptimal models, we propose a new SPSNN algorithm based on the L_1 penalty and the L_2 penalty to deal with complex and varied tasks within a unified framework to improve the robustness and generality of the model. Based on the L_1 norm, an L_2 norm is presented in SPSNNs to promote the population sparsity effect to select the relevant hidden node population. Therefore, our proposed variant algorithm benefits from ridge regression and the tendency towards sparse solutions of the L_1 penalty, which generates a more suitable neural network structure than using one of the regular terms alone, and the elastic net algorithm can also be used to solve for these hybrid penalties [44].

In this paper, the penalty method is considered in the case of selecting the weights, which not only overcomes the shortcomings of the L_1 and L_2 norms, (both L_1 and L_2 penalties are used in the same minimization problem), but also has good generalization ability and sparsity. Thus, the mathematical expression for this hybrid penalty as an error function can be expressed as follows:

$$E(W) = \widehat{E}(W) + \tau_1 \|W\|_1 + \tau_2 \|W\|_2^2,$$

where the tuning constants τ_1 and τ_2 are fixed and non-negative. The role of τ_1 provides a choice of variables through a sparse vector, and τ_2 ensures a unique solution and leads to a grouping effect. A penalty term is added that is a convex combination of the L_1 norm $\|W\|_1$ and the L_2 norm $\|W\|_2^2$ of the parameter W .

During the training progress, the usual mixed regularization terms are not differentiable at the origin, which usually give rise to oscillation phenomenon. Therefore, we propose a new smoothing algorithm to get over these difficulties. That is, we can use the smoothing technique of the weight in the neighborhood of the origin of the error function instead of the absolute value of the weight. The main contribution and novelty of this article are as follows:

(1) In this article, in order to obtain the optimal architecture with good generalization performance, we will eliminate the weights in the hidden layer by using the idea of elastic net regularization. It means that, by incorporating the L_1 and L_2 regularization terms, this novel algorithm not only eliminates unnecessary weights but also performs pruning of the network structure in the hidden layers. This pruning reduces the size of the network, leading to an effective optimization of the network structure.

We propose an SPSNN based on elastic net regularized batch gradient methods to obtain an optimal architecture with good generalization performance. By means of smoothing technology, we effectively get over the oscillation phenomenon in the process of network learning.

(3) To test the accuracy and robustness, we apply the proposed method to a large number of regression and classification tasks and compare it with other algorithms that have good sparsity and generalization capabilities.

The rest of the article is arranged as follows: In Section 2 the SPSNN is presented, the batch gradient algorithm for this model is depicted in Section 3, and the novel pruning algorithm based on L_1 plus L_2 penalty term is depicted for more details. Some numerical experiments are provided in Section 4, and finally some conclusions are made.

2. Sigma-Pi-Sigma neural networks

Next, we mainly depict the fabric of SPSNNs, which are composed of an input layer, a hidden layer of summing nodes (Σ_1), a hidden layer of product nodes (Π), and output layer (Σ_2). P , N , Q , and 1 represent the number of the nodes of the input layer, Σ_1 layer, Π layer, and Σ_2 layer, respectively (see Fig. 1)

We can use $W_0 = (w_{01}, w_{02}, \dots, w_{0Q})^T \in \mathbb{R}^Q$ to express the weight vector which connects Σ_2 layer and the Π layer. Let the weight vector connecting the Π layer and the Σ_1 layer be fixed as 1. Meanwhile, using $W_n = (w_{n1}, w_{n2}, \dots, w_{nP})^T$ as the weight vector which connects the input layer and the n th node of the Σ_1 layer, we can set

$$W = (W_0^T, W_1^T, \dots, W_N^T)^T \in \mathbb{R}^{Q+NP}.$$

Let us use $X = (x_1, x_2, \dots, x_P) \in \mathbb{R}^P$ to describe the input of the networks. Assume that $g: \mathbb{R} \rightarrow \mathbb{R}$ is a given sigmoid activation function for the Σ_1 layer. We denote the output vector $\xi \in \mathbb{R}^N$ of the Σ_1 layer as

$$\xi = (g(W_1 \cdot X), g(W_2 \cdot X), \dots, g(W_N \cdot X))^T,$$

where $\cdot$ denotes the inner product between vectors.

Similarly, we take $\delta = (\delta_1, \delta_2, \dots, \delta_Q)^T$ to indicate the output vector of the Π layer. The nodes of the network are connected in two different ways. One is fully connected between the Σ_1 layer and the Π layer, and the other one is sparsely connected. The difference between them lies in the number of product nodes: the former has 2^N product nodes, and the latter is less than 2^N . We can clearly see the structure of the SPSNNs in Figure 1.

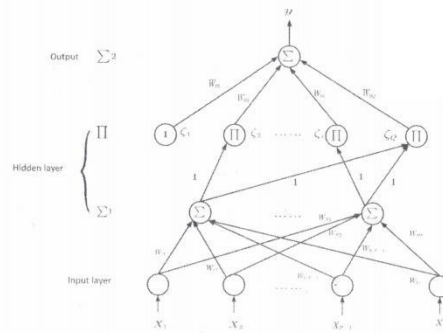


Figure 1. Structure of an SPSNN.

Here, $\mathcal{H}_q (1 \leq q \leq Q)$ represents the set of nodes in the Σ_1 layer connected with the q -th product node, while the set of all product nodes connected with the n -th node in the Σ_1 layer is represented by $\mathcal{F}_n (1 \leq n \leq N)$. We can suppose an arbitrary muster italicize, and $\varphi(a)$ is the number of elements in muster italicize, and we have

$$\sum_{q=1}^Q \varphi(\mathcal{H}_q) = \sum_{n=1}^N \varphi(\mathcal{F}_n),$$

which will be used later.

We can compute the output vector $\delta \in \mathbb{R}^Q$ in the Π layer by

$$\delta_q = \prod_{i \in \mathcal{H}_q} \xi_i, 1 \leq q \leq Q.$$

To make convention, we denote $\prod_{i \in \mathcal{H}_q} \xi_i = 1$ when $\mathcal{H}_q = \emptyset$. In the SPSNNs, the final output can be written as

$$y = g(W_0 \cdot \delta).$$

3. Batch gradient algorithm for Sigma-Pi-Sigma neural networks with elastic net regularization

3.1. Batch gradient algorithm for Sigma-Pi-Sigma neural networks

We introduce the batch gradient algorithm for SPSNNs. Let $\{X^l, O^l\}_{l=1}^L \subset \mathbb{R}^p \times \mathbb{R}$ be the given set of the training samples, where X^l denotes the l th input sample and the O^l is the l th corresponding ideal output. Let $y^l \in \mathbb{R}$ be the real output for each input X^l . The conventional square error function can be given as

$$\begin{aligned}
\widehat{E}(W) &= \frac{1}{2} \sum_{l=1}^L (g(W_0 \cdot \delta^l) - O^l)^2 \\
&= \sum_{l=1}^L \frac{1}{2} (g(W_0 \cdot \delta^l) - O^l)^2 \\
&= \sum_{l=1}^L g_l(W_0 \cdot \delta^l),
\end{aligned}$$

where $g_l(z) = \frac{1}{2}(g(z) - O^l)^2$, $z \in \mathbb{R}$, $1 \leq l \leq L$.

For convenience, we need to provide the following forms:

$$\begin{aligned}
\delta^l &= (\delta_1^l, \delta_2^l, \dots, \delta_Q^l) \\
&= \left(\prod_{i \in \mathcal{H}_1} \xi_i, \prod_{i \in \mathcal{H}_2} \xi_i, \dots, \prod_{i \in \mathcal{H}_Q} \xi_i \right) \\
&= \left(\prod_{i \in \mathcal{H}_1} g(W_i \cdot X^l), \prod_{i \in \mathcal{H}_2} g(W_i \cdot X^l), \dots, \prod_{i \in \mathcal{H}_Q} g(W_i \cdot X^l) \right),
\end{aligned} \tag{3.1}$$

and thus, by virtue of

$$\widehat{E}(W) = \sum_{l=1}^L g_l \left(\sum_{q=1}^Q w_{0q} \cdot \prod_{i \in \mathcal{H}_Q} g(W_i \cdot X^l) \right) \tag{3.2}$$

and some calculation, we can gain

$$\widehat{E}_{W_0}(W) = \sum_{l=1}^L g'_l(W_0 \cdot \delta^l) \cdot \delta^l.$$

It follows from $\delta_q^l = \prod_{i \in \mathcal{H}_Q} g(W_i \cdot X^l)$ that

$$\frac{\partial \delta_q^l}{\partial W_n} = \begin{cases} \left(\prod_{i \in \mathcal{H}_Q \setminus n} \xi_i \right) \cdot g'(W_n \cdot X^l) X^l, & \text{if } q \neq 1 \text{ and } n \in \mathcal{H}_q, \\ 0, & \text{if } q \equiv 1 \text{ or } n \notin \mathcal{H}_q. \end{cases}$$

Then, from the above equality and (3.2), we get

$$\widehat{E}_{W_n}(W) = \sum_{l=1}^L [g'_l(W_0 \cdot \delta^l) \sum_{q=1}^Q (w_{0q} \cdot \frac{\partial \delta_q^l}{\partial W_n})].$$

3.2. Batch gradient algorithm for Sigma-Pi-Sigma neural networks with

To simplify the network structure, we add the elastic net regularization at the group level. So, we can get the corresponding form of the error function

$$E(W) = \sum_{l=1}^L g_l(W_0 \cdot \delta^l) + \tau(\alpha(\|W_0\|_1 + \sum_{n=1}^N \|W_n\|_1) + (1-\alpha)(\|W_0\|_2^2 + \sum_{n=1}^N \|W_n\|_2^2)), \quad (3.3)$$

where τ and α are the tuning parameters that control the performance of the penalty term. With the gradual increase of α , the L_1 regular term dominates, and the error function gets closer to Lasso regression; with the gradual decrease of α , the L_2 regular term dominates, and the error function gets closer to ridge regression. In particular, the error function is equivalent to that of ridge regression at $\alpha = 0$, and the cost function is equivalent to that of Lasso regression at $\alpha = 1$. Let $\tau_1 = \tau \cdot \alpha$ and $\tau_2 = 2\tau \cdot (1 - \alpha)$. Then, we have

$$E(W) = \sum_{l=1}^L g_l(W_0 \cdot \delta^l) + \tau_1(\|W_0\|_1 + \sum_{n=1}^N \|W_n\|_1) + \frac{\tau_2}{2}(\|W_0\|_2^2 + \sum_{n=1}^N \|W_n\|_2^2). \quad (3.4)$$

The gradient of the error function with respect to W_0 and W_n are, respectively, given as

$$E_{W_0}(W) = \sum_{l=1}^L g'_l(W_0 \cdot \delta^l) \cdot \delta^l + \tau_1 \frac{W_0}{\|W_0\|} + \tau_2 W_0 \quad (3.5)$$

and

$$E_{W_n}(W) = \sum_{l=1}^L [g'_l(W_0 \cdot \delta^l) \sum_{q \in \mathcal{F}_n} [w_{0q} (\prod_{i \in \mathcal{H}_q \setminus n} \xi_i^l) \times g'(W_n \cdot X^l) \cdot X^l]] + \tau_1 \frac{W_n}{\|W_n\|} + \tau_2 W_n. \quad (3.6)$$

We notice that elastic net regularization in (3.4) is combined with L_1 norm regularization and L_2 norm regularization. It is clear that (3.4) is not differentiable at the origin, which will yield the oscillation phenomenon, and we propose a smoothing approximation method to overcome this problem caused by the non-smoothness. For any limited dimensional vector $\mathbf{u}$ and a fixed constant $\gamma > 0$, we can define a smoothing function of $\|\mathbf{u}\|$ as follows:

$$h(\mathbf{u}, \gamma) = \begin{cases} \|\mathbf{u}\|, & \text{if } \|\mathbf{u}\| > \gamma, \\ \frac{\|\mathbf{u}\|^2}{2\gamma} + \frac{\gamma}{2}, & \text{if } \|\mathbf{u}\| \leq \gamma. \end{cases} \quad (3.7)$$

imate the elastic net regularization in (3.4). Furthermore, the gradient of vector $\mathbf{u}$ is given as follows:

$$\nabla_{\mathbf{u}} h(\mathbf{u}, \gamma) = \begin{cases} \frac{\mathbf{u}}{\|\mathbf{u}\|}, & \text{if } \|\mathbf{u}\| > \gamma, \\ \frac{\mathbf{u}}{\gamma}, & \text{if } \|\mathbf{u}\| \leq \gamma. \end{cases}$$

Accordingly, the error function (3.4) can be rewritten as

$$\begin{aligned} E(W) = & \sum_{l=1}^L g_l(W_0 \cdot \delta^l) + \tau_1 [h(W_0, \gamma) + \sum_{n=1}^N h(W_n, \gamma)] \\ & + \frac{\tau_2}{2} (\|W_0\|_2^2 + \sum_{n=1}^N \|W_n\|_2^2). \end{aligned} \quad (3.8)$$

According to (3.8), we can get a smoothing elastic net Sigma-Pi-Sigma neural network as

$$E_{W_0}(W) = \sum_{l=1}^L g'_l(W_0 \cdot \delta^l) \cdot \delta_q^l + \tau_1 \nabla_{W_0} h(W_0, \gamma) + \tau_2 W_0, \quad (3.9)$$

$$\begin{aligned} E_{W_n}(W) = & \sum_{l=1}^L g'_l(W_0 \cdot \delta^l) \sum_{q \in \mathcal{I}_n} w_{0q} \left(\prod_{i \in \mathcal{H}_q \setminus n} \xi_i^l \right) \\ & \times g'_l(W_n \cdot X^l) \cdot X^l + \tau_1 \nabla_{W_n} h(W_n, \gamma) + \tau_2 W_n, \end{aligned} \quad (3.10)$$

where $l = 1, 2, \dots, L$.

Beginning with an arbitrary initial weight vector W^0 , by the following iterative formula we define the weight sequence

$$W^{k+1} = W^k + \Delta W^k, \quad (3.11)$$

$$\Delta W_0^k = -\eta E_{W_0}(W^k), \quad (3.12)$$

$$\Delta W_n^k = -\eta E_{W_n}(W^k), \quad (3.13)$$

where η represents the learning rate.

4. Simulation results

In this section, the performance of the models with no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer ($OL_{1/2}$), the smoothing $L_{1/2}$ regularizer ($SL_{1/2}$), and the original group lasso regularizer (OGL) algorithms are compared with the smoothing elastic net regularizer algorithm (SGL) by using four examples: classification problem, parity problem, function approximation problem, and prediction problem.

4.1. Classification problem

In this example, we choose 8 benchmark data sets from the UCI machine learning repository to evaluate the performance of the new algorithm (*SGL*), and compare it with the no regularization (*OL*_{1/2}), the *SL*_{1/2}, and the *OG**L* algorithms.

Table 1 presents the main characteristics of the relevant data sets, which includes the size of datasets, attributes, categories, and sizes of the training and testing sets, where the dataset is randomly partitioned into two subsets: 70% for training and 30% for testing.

Table 1. Detailed description of the classification data sets.

Dataset	Dataset Size	Training set	Testing set	Attributes	Classes
Ecoli	336	224	112	8	7
Olitos	120	80	40	25	4
Seeds	210	147	63	7	3
Iris	150	105	45	4	3
Wine	178	120	58	13	3
Liver	345	240	105	7	2
Sonar	208	138	70	60	2
Diabetes	768	526	242	8	2

As described at the beginning of this paper, we learn the structure of SPSNNs (see Figure 1). Then, we select $P = 13$, $N = 4$, $Q = 16$, and 1, representing the number of the nodes of the input, the Σ_1 , the Π , and the Σ_2 layers, respectively. For each learning algorithm, the initial weights are randomly selected in the interval $[-0.5, 0.5]$, the learning rate η is 0.0028, and the regular factor τ is 0.001, and we conduct 20 trials for every data set to compare the performance of different algorithms.

To assess the performance of the smoothing elastic net regularizer, based on each data set, we compare the number of remaining hidden neurons after pruning (*RNN*), the training accuracy testing accuracy, and training time for each algorithm, and all experimental results are recorded in Table 2. From the table, it can be observed that the training accuracy has slightly improved, while the testing accuracy has increased by approximately 1% to 3%. We can find our proposed smoothing elastic net regularizer is superior to the no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer, the smoothing $L_{1/2}$ regularizer, and the original group Lasso regularizer algorithms.

In addition, we have also compared our approach with other existing methods. In [45], the authors considered the group Lasso regularization method on the Sigma-Pi-Sigma neural network. In [46], the authors applied the group $L_{1/2}$ regularization term on high-order neural networks. Our proposed elastic net regularization method is on par with these approaches.

2. Performance comparison for classification problems.

	n	RNN	Training accuracy	Testing accuracy	Training time(s)
	y	13.30	0.9761	0.9082	17.2756
		13.00	0.9747	0.8980	16.7845
		12.50	0.9749	0.9191	18.1372
		11.80	0.9771	0.9304	16.8050
		12.20	0.9749	0.9191	18.3792
		SGL	11.50	0.9780	0.9314
Olitos		<i>NoPenalty</i>	13.00	0.9573	0.8914
		<i>L₂</i>	12.33	0.9592	0.9053
		<i>OL_{1/2}</i>	12.00	0.9604	0.9160
		<i>SL_{1/2}</i>	11.67	0.9589	0.9245
		<i>OGL</i>	12.00	0.9617	0.9264
		SGL	11.00	0.9628	0.9355
Seeds		<i>NoPenalty</i>	13.33	0.9737	0.9522
		<i>L₂</i>	12.67	0.9761	0.9554
		<i>OL_{1/2}</i>	12.33	0.9791	0.9582
		<i>SL_{1/2}</i>	11.67	0.9797	0.9676
		<i>OGL</i>	12.33	0.9792	0.9629
		SGL	11.33	0.9813	0.9749
Iris		<i>NoPenalty</i>	13.67	0.9715	0.9296
		<i>L₂</i>	13.00	0.9719	0.9390
		<i>OL_{1/2}</i>	12.67	0.9723	0.9458
		<i>SL_{1/2}</i>	12.33	0.9743	0.9554
		<i>OGL</i>	12.33	0.9748	0.9522
		SGL	11.00	0.9791	0.9629
Wine		<i>NoPenalty</i>	12.67	0.9872	0.9729
		<i>L₂</i>	12.67	0.9892	0.9753
		<i>OL_{1/2}</i>	12.00	0.9896	0.9770
		<i>SL_{1/2}</i>	11.50	0.9911	0.9814
		<i>OGL</i>	11.67	0.9906	0.9798
		SGL	10.50	0.9915	0.9833
Liver		<i>NoPenalty</i>	13.33	0.9937	0.9823
		<i>L₂</i>	12.67	0.9943	0.9838
		<i>OL_{1/2}</i>	12.33	0.9947	0.9858
		<i>SL_{1/2}</i>	11.33	0.9951	0.9861
		<i>OGL</i>	11.00	0.9948	0.9868
		SGL	10.33	0.9962	0.9902
Sonar		<i>NoPenalty</i>	12.67	0.9825	0.9756
		<i>L₂</i>	12.67	0.9831	0.9787
		<i>OL_{1/2}</i>	12.33	0.9860	0.9830
		<i>SL_{1/2}</i>	12.00	0.9909	0.9852
		<i>OGL</i>	12.33	0.9892	0.9849
		SGL	11.67	0.9918	0.9860
Diabetes		<i>NoPenalty</i>	13.00	0.9925	0.9937
		<i>L₂</i>	12.50	0.9936	0.9947
		<i>OL_{1/2}</i>	11.67	0.9954	0.9950
		<i>SL_{1/2}</i>	11.33	0.9967	0.9955
		<i>OGL</i>	11.67	0.9961	0.9953
		SGL	11.33	0.9978	0.9961

4.2. 5-bit parity problem

For the parity problem, there is an input set of 2^n samples in n -dimensional space, and every sample is an n -bit binary vector. We consider a 5-bit parity problem which has an input set with 2^5 samples in 5-dimensional space; the ideal output equals to 1 if the number of 1 in the samples is odd, otherwise

it equals to zero. Here, using the above method, we test the performance of elastic net regularizer.

Similarly, we can study the structure of SPSNNs. We select $P = 13$, $N =$ number of the nodes of the input, Σ_1 , Π , and Σ_2 layers, separately. In the initial weights are randomly selected, the learning rate η is 0.0045, and the regular factor τ is 0.001. For each learning algorithm we carry out 20 experiments, and we train up to 40,000 steps or we stop once the error is less than $1e - 4$. So, as to assess the sparsity and convergence of the smoothing elastic net regularizer, we compare the average error (AVE) and the number of remaining hidden neurons after pruning (RNN) with the no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer, the smoothing $L_{1/2}$ regularizer, the original group Lasso regularizer, and the smoothing elastic net regularizer, which are listed in Table 3.

Table 3. Emulation results for 5-bit parity problem.

Learning Methods	AVE	RNN
<i>NoPenalty</i>	0.004433	17.00
L_2	0.003967	17.00
$OL_{1/2}$	0.003929	17.14
$SL_{1/2}$	0.004033	17.33
<i>OGL</i>	0.003925	17.00
<i>SGL</i>	0.003471	16.71

The results show that the proposed smooth elastic net regularizer outperforms the no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer, the smoothing $L_{1/2}$ regularizer, and the original group Lasso regularizer.

Figure 2(a) shows the error performance of the original group Lasso regularizer and smoothing elastic net regularizer via the 5-bit parity problem. Figure 2(b) shows that the norm of the gradient curve of the error function, based on the 5-bit parity problem, approaches a small positive constant. This indicates that the smoothing elastic net regularizer removes the oscillation of occurring in the original group Lasso regularizer in the learning process.

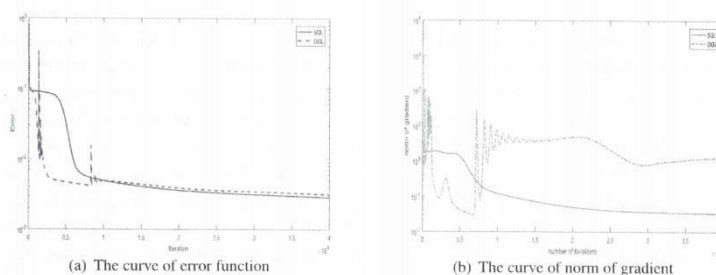


Figure 2. The performance results based on 5-bit parity problem with *OGL* and *SGL*.

Approximation problem

In this experiment, we study the multi-dimensional Gabor function to compare the approximation above algorithms.

$$k(x, y) = \frac{1}{2\pi(0.5)^2} \exp\left(-\frac{x^2 + y^2}{2(0.5)^2}\right) \cos(2\pi(x + y)).$$

As described at the beginning of this paper, we learn the structure of the SPSNNs. Then, we select $P = 13$, $N = 4$, $Q = 16$, and 1 for the number of the nodes of the input layer, Σ_1 , Π , and Σ_2 layers, separately.

In this experiment, we select 169 training samples from an evenly spaced 6×6 grid on the square $-0.5 \leq x \leq 0.5$ and $-0.5 \leq y \leq 0.5$. In the interval $[-0.5, 0.5]$, the initial weights are randomly selected, the learning rate η is 0.0028, and the regular factor τ is 0.001. For each learning algorithm we carry out 20 experiments, and we train up to 40,000 times or until the error is less than $1e-4$ stop iterations.

To assess the sparsity and convergence of the smoothing elastic net regularizer, we compare the average error (AVE) and the number of remaining hidden neurons after pruning (RNN) with the no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer, the smoothing $L_{1/2}$ regularizer, the original group Lasso regularizer, and the smoothing elastic net regularizer, which are shown in Table 4. We can see our proposed smoothing elastic net regularizer is superior to the no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer, the smoothing $L_{1/2}$ regularizer, and the original group Lasso regularizer.

Table 4. Emulation results for identifying the Gabor function.

Learning Methods	AVE	RNN
NoPenalty	0.003940	18.00
L_2	0.003560	18.00
$OL_{1/2}$	0.003783	17.67
$SL_{1/2}$	0.004486	17.37
OGL	0.003523	16.87
SGL	0.003286	16.14

For each learning algorithm, we show the error function and the norm of gradient of one of the 20 experiments after 40,000 epochs in Figures 3–5. Figure 3(a) shows the oscillation phenomenon of no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer and the original group lasso regularizer. Figure 3(b) shows the error curve of the smoothing $L_{1/2}$ regularizer and the smoothing elastic net regularizer. Figure 4(a) shows the norm of gradient curve of the no regularizer, the L_2 regularizer, the original $L_{1/2}$ regularizer, and the original group Lasso regularizer. Figure 4(b) shows the norm of the gradient curve of the smoothing $L_{1/2}$ regularizer, and the smoothing elastic net regularizer. Obviously, it approaches to a small positive constant. Figure 5 shows a typical performance for one of 20 experiments, and we can see that it has a good approximation effect compared with other algorithms. In each learning algorithm for the same parameters, we get the corresponding results. We can see the learning method with the smoothing elastic net regularizer converges faster than

other learning methods, and the smoothing elastic net regularizer method over oscillation phenomenon. It also shows that during the iterative process the error monotonically decreasing and converge to zero, which also validates our theoretic

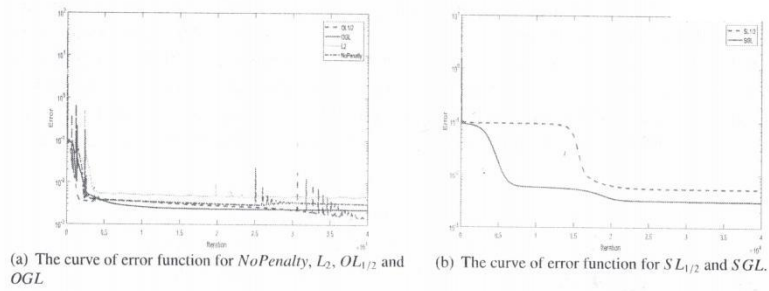


Figure 3. The performance results of the error function for the above algorithms.

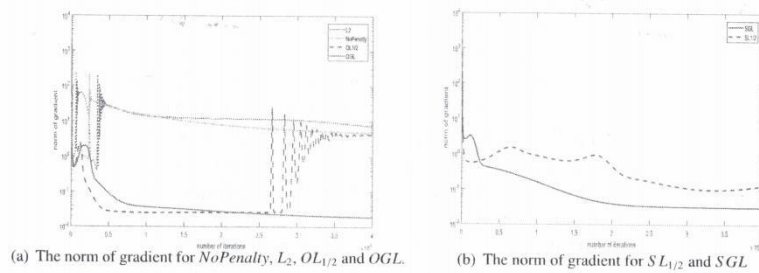


Figure 4. The performance results of the gradient norm for the above algorithms.

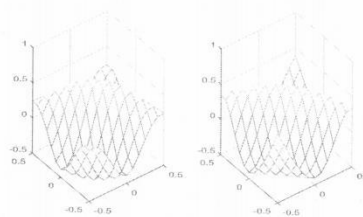


Figure 5. The approximation result of the smoothing elastic net regularizer.

n

ness of the algorithm further, this part takes an interval shield tunneling project in Hangzhou City, China, as an example. In order to monitor the impact of the excavation process on the surface buildings and structures, 10-meter intervals are used to set observation points in advance in each shield tunneling section, and the surrounding buildings are monitored. JGC1, the closest settlement observation point of the signal tower to the right line of the shield structure, is selected as the objective of study, and the Leica DNA03 level is used to collect data 10 days before the shield structure is excavated to the closest point of JGC1, for a total of 40 days, and the frequency of observation is once a day. In this experiment, we use the data of the first 30 days as the training data set and the data of the last 10 days as the test data set (see Table 5).

Table 5. Measured settlement of metro shield at point JGC1.

Time	JGC1 (mm)	Time	JGC1 (mm)
2015.3.18	+0.21000	2015.3.31	0.003286
2015.3.19	-0.13000	2015.4.2	+0.10000
2015.3.20	+0.11000	2015.4.3	-0.02000
2015.3.21	-0.06000	2015.4.4	+0.08000
2015.3.22	-0.23000	2015.4.5	-0.16000
2015.3.23	-0.23000	2015.4.6	+0.06000
2015.3.24	-0.15000	2015.4.7	-0.18000
2015.3.25	-0.03000	2015.4.8	+0.28000
2015.3.26	0.003286	2015.4.9	-0.07000
2015.3.27	0.003286	2015.4.10	+0.07000
Time	JGC1 (mm)	Time	JGC1 (mm)
2015.4.11	+0.01000	2015.4.22	+0.01000
2015.4.12	-0.01000	2015.4.23	0.00000
2015.4.13	-0.15000	2015.4.24	+0.19000
2015.4.14	+0.08000	2015.4.25	-0.21000
2015.4.15	-0.09000	2015.4.26	+0.10000
2015.4.16	+0.14000	2015.4.27	-0.12000
2015.4.17	-0.02000	2015.4.28	+0.05000
2015.4.18	-0.26000	2015.4.29	+0.15000
2015.4.19	+0.42000	2015.4.30	-0.17000
2015.4.20	-0.22000	2015.5.1	-0.07000

In this experiment, we learn the structure of the SPSNNs. Then, we select $P = 5$, $N = 4$, $Q = 16$, and 1 for the number of the nodes of the input layer, Σ_1 , Σ_2 , and the output layer, respectively. We use the sigmoid activation function at the Σ_1 and output layers, respectively, and our stopping criteria in this experiment is an error of less than 1×10^{-5} or 5000 iterations.

Figure 6 is the error curve of the training set with 5000 iterations, in which red is the error curve without the regularization term and blue is the error curve with the smoothing elastic net regularization,

it can be obtained that the error of the network with the smoothing elastic net faster, and after 500 iterations, the error is smaller than that without the re; precisely verifies the theoretical results of this paper and the effectiveness of t

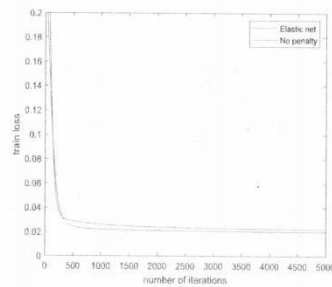


Figure 6. The curve of the error function for no penalty and for the smoothing elastic net.

5. Conclusions

In this paper, a new batch gradient algorithm for SPSNNs with an L_1 plus L_2 regularization algorithm is proposed as an effective weight pruning technique. It can handle multi-output regression and multi-class classification problems within a unified framework. This algorithm obtains good performance in both Lasso and ridge regression, penalizing the weights by reducing the weight vectors to zero, which is more efficient than other various pruning strategies. Moreover, the theoretical results and the advantages of this algorithm are also illustrated by numerical experiments.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Author contribution

Conceptualization, methodology, original draft preparation, J. Jiao; software, editing, K. Su.

Conflict of interest

All authors declare there is no conflict of interest.

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作者: Jiao, JW (Jiao, Jianwei); Su, KQ (Su, Keqin)

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摘要: As one type of the important higher-order neural networks developed in the last decade, the Sigma-Pi-Sigma neural network has more powerful nonlinear mapping capabilities compared with other popular neural networks. This paper is concerned with a new Sigma-Pi-Sigma neural network based on a L1 and L2 regularization batch gradient method, and the numerical experiments for classification and regression problems prove that the proposed algorithm is effective and has better properties comparing with other classical penalization methods. The proposed model combines the sparse solution tendency of L1 norm and the high benefits in efficiency of the L2 norm, which can regulate the complexity of a network and prevent overfitting. Also, the numerical oscillation, induced by the non-differentiability of L1 plus L2 regularization at the origin, can be eliminated by a smoothing technique to approximate the objective function.

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基于能力培养的工科课程过程性评价设计与实践 ——以“结构力学”课程为例

王 芳, 河南 郑州, 450000

摘要:文章首先阐述了工科课程评价方式存在的问题,然后分析了基于能力培养的工科课程过程性评价的优势,接着论述了基于能力培养的工科课程过程性评价设计,最后以“结构力学”课程为例,探索了基于能力培养的工科课程过程性评价实践。

关键词:工科课程;过程性评价;能力培养;“结构力学”课程

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人工智能的发展,使传统课堂及育人方式面临巨大的挑战^[1]。人工智能技术的应用使学生可以随时随地进行学习,并且根据自己的需要安排个性化的学习。同时,人工智能还可以为学生提供一对一的辅导,帮助他们解决学习过程中遇到的难题和困惑。这使得教师不得不改变自己的教学策略,由传统的讲授式转变为以学生为中心的翻转课堂、对分课堂、BOPPPS 教学模式等^[2]。对学生学习效果的检验不再是掌握了某个知识点,而是如何运用所学知识解决实际问题的能力^[3]。在此背景下,教师布置的学习任务及课程的考核评价标准也不得不随之改变。

为了适应快速发展的社会环境及职业市场的需要,大学生需要具备信息素养、批判性思维、沟通与协作能力、创新与创造力、自我管理与自主学习能力、跨文化理解与全球意识等多种核心素养和能力^[4-5]。基于此,学生的学习任务将围绕这些方面进行设置,教师在教学活动中要强调沟通合作学习,鼓励团队合作,注重学生能学到什么和能做什么,重视产出和能力的培养,鼓励批判性思维和创新思维的养成。随着教学模式的逐渐改变,传统的评价方式存在的问题越来越突出,因此教学评价也必须做出相应改变,对应的评价标准要突出大学生的核心素养和各项能力。

人工智能的发展、新时代大学生核心素养的培养需求、以学生为中心的教育理念,都说明学生学习效果的评价方式必须做出改变,强调过程性评价的重要性。过程性评价作为教育评价的重要方法,是评价体系中不可或缺的一部分,对于提高教学质量、促进学

生学习具有重要作用。与传统的终结性评价不同,过程性评价强调在学习过程中对学生进行评价,以便及时反馈、调整教学策略,提高学生的学习效果。在过程性评价中,如何检测学生的学习效果和能力达成情况,是亟待思考的问题;如何科学合理地对学生们的学习成果及其思想行为进行过程性评价,是急需解决的问题。本文旨在探讨过程性评价的优势,进而以“结构力学”课程为例,探索其过程性评价设计与实践,为相关教学工作提供参考。

一、工科课程评价方式存在的问题

大多数教师已经意识到传统教学评价在实施过程中存在一些问题,这些问题随着教育的发展和社会的进步逐渐显现出来,具体如下。

第一,唯分数倾向。中共中央、国务院已经在 2020 年 10 月将破除“五唯”评价体系这一改革措施写入《深化新时代教育评价改革总体方案》,明确在教育评价中过分强调分数不利于科学全面地评价教育质量和人才培养效果。然而,在实际教学中,部分教师没有转变观念,仍然以期末考试为中心,期末成绩占比较大,过分强调考试分数,导致学生平时的学习也仅是围绕期末试卷,忽略了自主学习能力和创新能力的培养,使得育人成效不佳。

第二,评价标准单一。传统的评价方式往往只采用统一的评价标准,即“一刀切”,标准答案具有唯一性,忽视了不同学科和课程的特殊性和多样性,限制了学生的个性化发展和创新思维的培养。

第三,缺乏过程性和发展性评价。传统评价体系

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大多侧重结果评价,缺乏对学生学习过程和教师教学过程的持续跟踪和评价。这种评价方式难以全面反映学生的学习进步情况和教师的教学改进情况。

第四,评价结果存在局限性。传统的评价结果仅能表现出学生学习成绩的优良好坏,却不能真正反映其学习效果,学生即便掌握了知识点,但是到底会不会应用于实际,则完全无法确认。此外,这种评价方式只能在期末考试后才可以看出学习效果,如果学习效果差,考试分数较低,学生已经没有了弥补的时间和机会,这实际上忽视了评价结果在教学改进和个人发展中的应用,从而限制了评价的激励和反馈功能的发挥,不利于形成教师持续改进教学和学生持续自我提升的教育环境。

二、基于能力培养的工科课程过程性评价的优势

任何事物的发展过程都是动态的,课程教学的过程性评价也不例外^[6]。过程性评价依据考核形成的学习或实践成果和被评价者的行为表现对能力达成情况进行判断、分析,并给出结论。在人工智能快速发展的时代和以学生为中心的教育理念下,评价应该是基于能力和素养的过程性评价。

过程性评价应该关注学生的全面发展,涵盖知识、能力、情感、态度和价值观等各个方面^[7-8]。通过多元化的评价内容和方法,能促进学生在德智体美劳等方面实现均衡发展。过程性评价注重教学过程中学生的自主学习和师生之间的互动,其优势包括以下方面。

第一,落实立德树人这一根本任务。过程性评价将立德树人这一根本任务作为最基本的评价标准,不仅要传授知识和技能,还要注重学生的道德教育和全面发展。教师要通过课堂讨论、案例分析、角色扮演等方式,引导学生深入思考和实践社会主义核心价值观。此外,还会在评价中融入德育元素,如学生的学习态度、团队合作精神和责任感等。

第二,注重能力培养。过程性评价关注学生的全面发展,不仅评价学生掌握和运用知识的能力,更重要的是评价其在真实世界中运用知识创造性地解决实际问题的能力、创新能力实践能力、与他人沟通合作的能力等,涵盖知识与技能、过程和方法、情感态度与价值观等各个方面,这与复杂学习目标的匹配度较高^[9]。

第三,注重个性化发展。根据不同学生的个性特点和需求,施行个性化培养,提供个性化的指导和支持,因材施教,可使每个学生都有所收获。同时,关注学生的自我认识、自我管理和自我提升。

第四,强调学习过程。过程性评价强调关注学习过程中的各个环节,而不只是在期末终结时对考试结

果进行评价。它要求教师收集并保存学生学习过程中的各项关键资料,并对这些资料进行呈现和分析,以形成评价。

第五,强调多元化评价。通过社会、家庭、行业企业的共同参与,过程性评价方式可以实现多元化发展,形式多样,具体包括自我评价、同伴评价、教师评价、企业评价、学生满意度评价等,不再仅依靠测验考试这一把“尺子”,而是多把“尺子”协作,使每个学生都有机会成为学习过程中的优秀者,最终促成每个学生的成功。

第六,有利于持续改进。过程性评价中,学生学习和教师教学过程都能得到持续跟踪和评价,进而能及时获得反馈,使学生了解自己的学习状况,发现学习中的不足和问题,以便调整学习策略,改进学习方法,从而建立发展性评价系统。同时,过程性评价也有助于教师监控学生的学习进度,发现学生的学习困难和需求,进而及时调整教学策略,提高教学质量。

需要注意的是,过程性评价也存在一些不足,如经验不足的教师很难为学生设置高质量、完美的学习任务;教师需要投入更多的时间和精力进行观察、记录和分析,增加了评价成本,教师负担重;学生完成学习任务需要花费许多时间和精力,尤其是存在一些持续时间长和跨学科的学习任务;等等。

三、基于能力培养的工科课程过程性评价设计

(一)过程性评价的实施步骤

在实施过程性评价时,需要遵循公平、客观、有效的原则。过程性评价一般遵循以下步骤。

1.确定评价目标。根据某专业的培养目标和毕业要求,确定课程的学习目标。将课程学习目标分解为可衡量的具体行为,制定评价内容和评价标准。

2.设计具体学习任务。考虑学生水平、时间、空间、设备情况等不同要素,设计学生需要完成的具体任务,并选择适当的评价工具和方法,如小组汇报、角色扮演、作业分析等。

3.实施任务。在实施任务过程中进行实际过程性评价,教师要注重观察学生完成任务时的各项表现,记录学生的实际操作表现或学业成果,注重收集并整理保存关键信息资料。为了给予学生可靠的评价结论,教师必须多次观察,多次收集材料,然后进行综合分析。

4.按照评价量表进行评价。对收集到的信息进行分析,识别学生的优点和不足,按照评价标准进行客观评价,采用学生自评、学生互评、教师评价、企业指导教师评价等多元评价方式。例如,教师在收齐布置给学生的作业后,要在网上公开展示,并设置投票功

能,让学生进行自我评价。这样可以促使学生在评价过程中得到更多的分享和学习机会,同时也促进了评价的公开公正。

5.反馈评价信息。分析评价结果,向学生和教师提供反馈,可以指导学生调整学习策略,方便教师改进教学策略,也可以由教师与学生共同制定改进措施。同时,教师要对整个过程性评价进行反思和改进,不断优化评价过程和方法。

(二)过程性评价的内容

过程性评价是一种关注学生在学习过程中各方面表现的评价方式,其强调评价的动态性和发展性。过程性评价的内容多样,皆致力于全面了解学生的学习情况,促进学生的全面发展^[10]。目前常见的过程性评价内容如下。

- 1.学习态度与参与度。教师可以观察学生在课堂讨论、小组合作、作业完成等方面的表现,给出关于他们学习态度的评价。同时,教师要关注学生的课堂积极参与程度和对学习内容的感兴趣程度。
- 2.学习策略的运用。教师评估学生在学习过程中的时间管理、资源利用、问题分析、方案提出、问题解决等能力,观察学生如何运用不同的学习策略达成学习目标,如信息技术应用能力、人工智能大数据应用能力等。
- 3.知识和技能的掌握程度。通过小测验、作业、实验报告、活动方案等形式,教师能了解学生对知识和技能的掌握情况。其间,教师要动态跟踪学生的学习进度,及时调整教学内容和方法。
- 4.批判性思维和自我监控能力。鼓励学生进行自我反思,评价自己的学习收获和不足。同时,可通过同伴互评,让学生从他人视角了解自己的表现,培养批判性思维和自我监控能力。
- 5.小组任务的完成情况。通过小组学习活动,观察学生在活动中的表现和最终成果的贡献。具体要评估学生在团队合作、沟通协调、问题解决、创新思维等方面的表现。

过程性评价有助于教师更好地了解学生的学习状态和需求,以便为学生提供及时的反馈和支持,促进学生的自我发展和终身学习能力的培养。学生过程性评价模型如图1所示。

四、基于能力培养的工科课程过程性评价实践

以某校土木工程专业为例,该专业旨在培养适应区域经济社会发展需要,具有家国情怀、进取精神、社会责任感,具有较扎实的土木工程专业理论基础、较深厚

的专业知识、较强的实践能力与创新能力的德智体美劳全面发展的高素质应用型人才。毕业时,学生要具备人文社会科学知识、创新创业和工程知识、专业技术能力和实践能力、研究能力、人文素养和职业素养等能力。

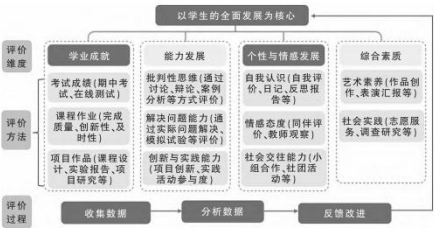


图1 学生过程性评价模型

以该专业“结构力学”课程为例,设计过程性评价。该课程的教学目标为以工程结构的力学分析为主线,通过线上线下混合式学习、翻转课堂、体验式、参与式等学习方式,开展深度学习,使学生学会工程结构的简化、几何构造分析,掌握静定结构和超静定结构的受力分析和位移计算的理论知识和方法,能够熟练分析与计算静定结构与超静定结构的内力 and 位移。通过工程案例,培养学生将工程实践中的实际问题抽象为相应的力学模型并综合应用结构力学知识进行求解的能力,同时让其对工程实践中相关结构力学问题进行基础研究,从而具备初步的专业研究能力。通过团队合作、小组研讨,引导学生学会自主学习和终身学习,养成求真务实的态度及严谨的科学精神,培养科技创新、大国工匠精神和社会主义核心价值观。

针对课程的知识目标、能力目标和素养目标,设计过程性评价,包括自主学习评价(20%)、课堂表现评价(20%)、综合作业评价(30%)、拓展作业评价(30%)四个部分,主要内容和评价标准如下。

第一,自主学习评价。可以通过学习通、雨课堂等平台发布相关测试,包括课前在线预习和自学测试、课中随堂作业(测试)、阶段性测试、课后作业(测试)等,由教师参考答案给予学生评价。课前,教师发布预习视频,学生进行学习及测试;课中,教师讲授重点知识,随堂测验学生学习效果;课后,教师布置作业和阶段性测试。在学习过程中,教师定期进行小测验可以评估学生对知识的掌握程度,也能及时发现学生的学习困难并加以解决。这种评价方式可以及时反馈学生的学习情况,同时也能促使学生积极参与课堂讨论,提高学习效果。通过自主学习评价,教师可以更好地了解学生

的学习情况,据此及时调整教学策略,提高教学质量。

第二,课堂表现评价。教师通过观察学生在课堂上的发言、回答问题的情况、参与度等表现,及时记录相关信息,并根据评价量表进行评价。课堂上的教学效果可以通过观察学生表情、问答互动、抽检问答等方式直接获得,并通过随机提问、讨论发言、学生互评、教师点评等形式进行评价。课堂互动能够鼓励学生主动参与讨论,营造积极的课堂氛围,发挥学生的主体作用。其实施关键在于如何科学、准确地评估学生的学习表现。因此,在制定评估标准时,教师要充分考虑学生的学科特点、实际需求和学习阶段等因素,确保评估结果能够更具客观性和公正性。同时,教师需要关注学生的个体差异,尊重学生的个性发展,帮助学生发掘自身的潜力和优势,激发其学习动力和自信心。课堂表现可以通过参与度(权重 0.3,如积极组织讨论,且发言次数超过小组总发言次数的 1/3)、沟通和分工协作能力(权重 0.4,如小组分工明确,配合完美)、学习效果(权重 0.3,如计算结果完全正确)三个方面对学生进行评价。

第三,综合作业评价。学生按照要求分组、选题。每

组 4—5 人,自由组合,选出一名组长,并给小组命名。每个组选择一种结构(包括钢筋混凝土梁桥、拱桥、斜拉桥、多层办公楼梁板柱结构、钢结构屋架等),自选身边熟悉的典型工程案例,讨论分析后得到合理的工程结构的计算简图,分析工程结构上的荷载,选择合适的计算方法(如虚功原理、力法、位移法、渐近法),求解内力和位移,并进一步探讨结构设计的标准等。总结汇报方面,教师在每组随机选一个学生进行汇报,注意要做 PPT。根据作业完成态度和进度(权重 0.1)、基本概念掌握程度(权重 0.2)、分析和解决问题能力(权重 0.3)、沟通与演示能力(权重 0.1)、团队协作能力(权重 0.1)、作业成果质量(权重 0.2)设计评价量表,对学生进行评价。

第四,拓展作业评价。该课程的过程性评价结合全国大学生结构设计竞赛,培养学生的实践能力和创新能力,以达到以赛促学的目的。拓展作业为采用竹皮和 502 胶等简单的工具制作工程结构模型,测量模型的质量,在模型上模拟荷载加载,以质量轻荷载大作为模型最终打分依据。教师根据评价量表进行评价,如表 1 所示。

表 1 拓展作业评价

观测指标	A(90—100 分)	B(80—89 分)	C(70—79 分)	D(60—69 分)	E(59 分以下)
作品质量(权重 0.3)	作品认真完成,精致。质量小于 0.1 kg	作品认真完成,精致程度一般。质量为 0.1—0.2 kg	作品认真完成,精致程度一般。质量为 0.2—0.3 kg	作品认真完成,粗糙。质量为 0.3—0.4 kg	作品认真完成,粗糙。质量为 0.4—0.5 kg
作品承载能力(权重 0.3)	作品承受竖直荷载 20.0 kg 以上	作品承受竖直荷载 15.0—20.0 kg	作品承受竖直荷载 10.0—15.0 kg	作品承受竖直荷载 5.0—10.0 kg	作品承受竖直荷载 0—5.0 kg
团队协作与沟通能力、演示能力(权重 0.4)	分工明确,能清晰、专业地表达想法,并具有条理性。有出色的团队协作能力	分工明确,能有效地沟通想法;演示清晰且组织良好。与团队合作良好	分工基本明确,充分表达想法,但演示时缺乏清晰度或组织性。与团队充分协作,但可能有轻微的冲突或沟通问题	分工不明确,沟通不清晰、杂乱无章或不适合目标受众。难以与团队合作,影响进度	分工不明确,严重缺乏沟通,影响了对彼此观点的理解。无法有效协作,影响了团队的整体进度

五、结语

实践证明,基于能力培养的工科课程过程性评价能够有效提高学生的兴趣和学习效果。通过实施过程性评价,可培养学生的协作沟通能力,促进学生的全面发展。此外,过程性评价能够及时反馈,帮助教师更好地理解学生的学习需求,及时调整教学策略,提高教学质量。然而,如何保证评价的规范性和客观性,如何利用现代技术手段进行过程性评价来减轻教师负担,以及如何将过程性评价与终结性评价有机结合,以更全面地反映学生的学习状况,仍需进一步探讨。

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4.论文：新质生产力视域下产教融合促进建筑行业 BIM 人才培养 路径研究



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新质生产力视域下 产教融合促进建筑行业 BIM 人才培养路径研究

土木工程学院, 河南 郑州 450000)

摘要: 随着新质生产力时代的到来, 建筑行业对 BIM 专业人才的需求逐渐上升。聚焦新质生产力视域下 BIM 人才培养的产教融合路径, 深入分析当前 BIM 人才培养的现状和存在的问题, 探讨产教融合在培养适应新质生产力需求的 BIM 人才中的关键作用, 并据此提出具体的产教融合实施路径和策略, 旨在为提升 BIM 人才的培养质量、推动建筑行业的创新发展提供理论支持和实践指导。

关键词: 新质生产力; BIM 人才培养; 产教融合; 建筑行业

新质生产力作为一种由科技创新和数字化转型等多个要素驱动的新型生产力, 正在对建筑业的发展模式产生深远的影响。BIM (建筑信息模型) 技术被视为建筑行业向数字化转型的关键技术, 在提升建筑项目效率、质量和持续性方面起到了至关重要的作用。随着建筑领域对 BIM 技术的应用逐渐深入, 对具备 BIM 技术专长的专业人员需求量也急速上升。但是, 现阶段 BIM 的人才培养与行业的真实需求存在差异, 加上教学资源的短缺, 导致新质生产力背景下建筑行业的人才快速增长需求难以得到满足。产教融合作为一种将产业和教育深度融合的人才培养模式, 为解决 BIM 人才培养的问题提供了新的思路 and 路径。

一、新质生产力与 BIM 人才培养产教融合的理论分析

(一) 新质生产力的内涵与特征

与传统生产力相比, 新质生产力具有创新、数字化、智能化和绿色化的独特属性。它以科技创新作为其核心动力, 借助新技术、新产业、新业态和新模式的不断发展, 推动经济和社会的高质量发展。在建筑行业, 数字化设计、智能施工和绿色建筑等均是新质生产力的具体体现, 而 BIM 技术是实现新质生产力的关键支撑技术之一。

(二) 新质生产力视域下对 BIM 人才的能力要求

新质生产力视域下, BIM 专业人才不仅要具备如建模、碰撞检测和施工模拟等坚实的 BIM 技术基础, 还需要具有创新思维、数字思维、团队合作能力, 以及对建筑行业新技术和新趋势的敏锐洞察力。同时, 这类人才还应具备跨学科的知识储备, 并能将建筑、结构、机电等多个专业领域的知识融合应用于 BIM 项目之中。

(三) 新质生产力与 BIM 人才培养产教融合的内在联系

新质生产力为 BIM 人才培养与产教融合提供了明确的指导方向。在这一背景下, 科技创新逐渐成为建筑行业进步的关键驱动力。而 BIM 技术作为建筑行业数字化转型的核心技术, 其广泛应用和持续发展对提升建筑行业生产效率起到了至关重要的作用。新质生产力与 BIM 人才培养在产教融合中互相促进, 共同推动了建筑行业的进步。新质生产力的发展为 BIM 人才培养、产教融合带来了新的推动力, 这也推动了学校和企业人才培养策略和机制上持续创新, 进而提升 BIM 人才培养的整体质量和标准。而 BIM 人才培养产教融合的深入推进, 能够为新质生产力的发展提供高质量的人力资源, 进一步推动 BIM 技术在建筑行业领域的普及和创新, 助力建筑行业向数字化和智能化的转型和升级。

二、产教融合在 BIM 人才培养中的作用及困境

(一) 产教融合在 BIM 人才培养中的重要作用

1. 促进人才培养与产业需求对接。通过产教融合, 学校能够及时掌握建筑企业对 BIM 人才的需求动态, 并根据行业的实际需求来调整人才培养策略和课程内容, 确保培养的 BIM 人才能够满足企业的真实需求, 提升人才培养的针对性和实用性。

2. 提升实践教学质量。企业可以为学校提供真实的 BIM 项目实践环境, 有效锻炼学生解决实际问题的能力。同时, 企业技术专家可深度参与教学指导, 将行业最新技术和实践经验融入教学, 丰富实践教学内容, 切实提高实践教学的质量。

3. 推动教学资源共享与优化。通过产教融合, 高校可以将企业先进的设备、软件工具和工程项目

基金项目: 河南省教育厅产教融合研究项目“产教融合背景下应用型 BIM 人才‘四通进、四融合’育人模式创新研究与实践”(编号: 教办高[2024]13号-55); 2023年度河南省本科高校研究性教学系列项目“‘四通进、四融合’创新型 BIM 人才培养新模式探索与实践典型案例”(编号: 教高[2023]388号-45)

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案例等用于专业教学活动。同时,高校的师资队伍和科研成果能为企业提供有力的支持,实现双方优势互补和资源共享,从而共同提升 BIM 人才培养的整体质量。

4.促进学生就业与职业发展。企业为学生搭建了更广阔的就业渠道与职业成长平台。学生在企业进行实习实践时,可以与企业建立紧密的联系,为自身争取更多就业机会。通过参与企业的实际工程项目,学生能深入理解行业的发展趋势和职业需求,为未来职业生涯做好规划。

(二) 产教融合在 BIM 人才培养中的困境剖析

从院校层面来看,部分高校仍偏重理论教学,政策落实不到位是产教融合面临的首要困境。尽管国家和地方政府出台了一系列鼓励产教融合的政策法规,如《国务院办公厅关于深化产教融合的若干意见》等,明确提出深化产教融合,促进教育链、人才链与产业链、创新链的有机衔接,为产教融合提供了政策支持和指导方向,但这些政策在实际执行过程中往往难以落地。部分地方政府对产教融合的重视程度不够,缺乏有效的政策执行机制和监督评估机制,导致政策的实施效果大打折扣。

校企合作动力不足也是产教融合面临的突出问题。从学校层面来看,部分高校过于注重理论教学,对实践教学的重视不够,缺乏与企业合作的主动性和积极性。部分高校的教师评价体系主要以科研成果为导向,教师参与校企合作需要投入大量的时间和精力,其科研成果产出水平提升却不明显。从企业层面而言,参与产教融合的动力也相对不足。企业是以营利为目的的经济组织,追求经济效益最大化是其首要目标。参与产教融合需要企业投入一定的人力、物力和财力,如提供实习岗位、安排企业导师指导学生、参与学校课程开发等,这在一定程度上会增加企业的运营成本。

利益分配不均是影响产教融合深入发展的关键因素之一。产教融合涉及学校、企业和学生三个主要的利益相关方,各方的利益诉求存在差异。学校希望通过与企业合作,提高人才培养质量,提升社会声誉和影响力;企业则希望通过产教融合,获得高素质的人才,解决企业的人才短缺问题,同时借助学校的科研力量,推动企业的技术创新和产品升级;学生则期望通过参与产教融合项目,获得实践经验、提升技能水平,为未来的就业打下坚实的基础。然而,在实际合作中,由于缺乏合理的利益分配机制,各方的利益往往难以得到平衡和保障。这种利益分配不均的情况,容易引发各方之间的矛盾和冲突,影响产教融合的可持续发展。

综上,产教融合在 BIM 人才培养中面临着政策落实不到位、校企合作动力不足、利益分配不均

等诸多困境。要实现产教融合的深度发展,提高 BIM 人才培养质量,需要政府、学校和企业共同努力,采取有效措施破除困境,构建互利共赢的产教融合模式。

三、新质生产力视域下 BIM 人才培养产教融合路径

(一) 搭建信息化教学资源共享平台

1.打造 BIM 教学资源库。高校与企业联合,利用大数据和云计算等技术,共同打造涵盖 BIM 基础理论、软件操作教程、实际项目案例等多类型的教学资源库。高校教师将理论知识和课程案例上传至资源库,企业则提供最新的行业项目资料、前沿技术应用案例等。通过资源整合与分类,为学生提供一站式学习资源服务,学生可以根据自身需求随时随地进行学习。

2.搭建虚拟仿真实验平台。借助虚拟现实(VR)和增强现实(AR)技术,搭建 BIM 虚拟仿真实验平台。企业将实际工程项目进行数字化建模,转化为虚拟仿真场景,学生可以在虚拟环境中进行 BIM 模型的创建、修改、分析等操作,身临其境地体验项目全生命周期的管理过程。这种方式不仅提高了学生的学习兴趣,还能有效降低实践教学成本和风险。

(二) 推行数字化教学模式

1.实施线上线下混合式教学。高校依托慕课、智慧树等在线教学平台,开展 BIM 课程的线上教学。教师录制知识点讲解视频,发布作业和讨论话题,引导学生在课前进行自主学习。线下课堂则以案例分析、小组讨论和实践操作指导为主,教师针对学生在线学习中遇到的问题进行解答和辅导。通过线上与线下的有机结合,有效提升教学效率与人才培养质量。

2.引入人工智能辅助教学。引入人工智能教学系统,基于学生的学习行为和数据进行精准分析,为其制定个性化的学习建议和计划。例如,系统可根据学生在 BIM 软件操作练习中的错误类型和频率,智能推送相关的知识点讲解和练习题目,帮助他们有针对性地提高学习效果。同时,人工智能还可以实现自动批改作业和智能答疑,减轻教师的教学负担。

(三) 深化校企联合培养模式

1.定制人才培养方案。校企双方成立联合培养小组,根据企业对 BIM 人才的岗位需求、职业能力要求以及行业发展趋势,共同制定人才培养方案。方案中明确课程设置、教学内容、实践环节和考核标准,确保培养的学生能够直接满足企业的实际需求。例如,针对企业在装配式建筑 BIM 应用方面的需求,在课程中增加相关的理论知识和实践项目。

2.共建特色课程体系。依托企业实际项目和行业前沿技术,校企共同开发具有特色的BIM课程体系。企业技术骨干参与课程设计和教材编写,将实际项目案例融入课程内容。同时,根据企业的项目进度和需求,动态调整课程安排,使学生所学知识与企业实际应用紧密结合。

3.交替式学习与实践。采用“2+1”或“3+1”等培养模式,即学生前2年或3年在学校进行理论学习和基础实践,最后1年到企业进行实习和毕业设计。实习期间,学生参与实际项目的BIM应用工作,由企业导师进行一对一指导。通过这种交替式的学习与实践,学生能够更好地将理论知识应用到实际工作中,提高实践操作能力和解决实际问题的能力。

4.双导师全程指导。为每个学生配备学校导师和企业导师,建立双导师全程指导机制。学校导师负责学生的理论学习指导、学业规划和思想教育,企业导师主要负责学生在企业实习期间的实践操作指导以及项目管理能力和职业素养培养。两位导师定期沟通,共同关注学生的学习和成长情况,及时解决学生遇到的问题。

(四)培养适应新质生产力的“双师型”教师队伍

1.开展教师信息化培训。高校定期组织教师参加BIM技术和信息化教学能力培训,并邀请企业技术专家和信息化教学专家进行授课。培训内容包括BIM软件的最新功能应用、虚拟仿真教学技术、在线教学平台的使用等,通过培训全面提升教师的信息化教学水平和BIM技术应用能力。

2.建立教师企业实践信息化管理机制。建立教师企业实践信息化管理系统,对教师企业实践的过程和效果进行跟踪和评估。教师在企业实践期间,通过系统实时上传实践日志、项目成果等信息,由企业导师对其实践表现进行评价。学校根据系统数据对教师的企业实践情况进行考核,激励教师深入企业积累实践经验,提升“双师”综合素养。

(五)加强产学研用信息化协同创新

1.建立产学研用信息交流平台。搭建产学研用信息交流平台,促进高校、企业、科研机构之间的信息共享和合作交流。各方可在平台上发布科研成果、技术需求、合作意向等信息,借助平台智能匹配功能,实现产学研用的精准对接。

2.开展数字化科研合作项目。校企联合开展数字化科研合作项目,利用大数据、物联网、区块链等新技术,探索BIM在建筑全生命周期管理中的应用创新,通过科研项目的实施,培养学生的创新能力和科研素养。同时,将科研成果转化为实际生产力,推动建筑行业的数字化转型和新质生产力发展。

(六)产教融合实施保障措施

1.政策支持与保障。政府应出台相关政策,鼓励和支持高校与企业开展BIM人才培养产教融合工作。例如,给予参与产教融合的企业税收优惠、财政补贴等政策支持;建立产教融合评估机制,对产教融合成效显著的院校和企业予以表彰和奖励。

2.资金投入与保障。高校和企业要共同加大对BIM人才培养产教融合的资金投入力度。高校可通过争取政府财政支持、吸纳社会捐赠等方式筹集资金,用于建设实践教学基地、购置教学设备、开展师资培训等;企业可通过设立奖学金、助学金、参与项目投资等方式,为产教融合提供资金支持。

3.质量监控与评估。建立健全BIM人才培养产教融合质量监控与评估体系,对产教融合各个环节进行全程监控和评估。定期对人才培养方案、课程教学质量、实践教学效果等进行评估,根据评估结果及时调整和优化产教融合工作,确保BIM人才培养质量。

四、总结

新质生产力视域下,建筑行业数字化转型加速,BIM人才已成为行业发展的关键支撑。产教融合在BIM人才培养中至关重要,不仅能实现人才培养与产业需求的精准对接、提升实践教学质量、优化教学资源,还能为学生就业铺就道路。本研究提出的系列实施路径,涵盖搭建信息化教学资源共享平台、推行数字化教学模式、深化校企联合培养模式、打造“双师型”教师队伍以及加强产学研用协同创新等。同时,需要政策、资金支持与质量监控保障,确保产教融合顺利开展。通过这些举措,预期为建筑行业输送大量契合新质生产力需求的BIM人才,推动行业创新发展。但随着技术和行业发展,产教融合模式仍需要持续探索和完善。

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5.论文：新工科背景下工科专业融合新技术实践探索—— 专业为例



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引文检索: 新工科背景下工科专业融合新技术实践探索——以

土木工程”专业为例 [J]. 重庆建筑, 2024, 23 (7): 85-86+89.

新工科背景下工科专业融合新技术实践探索

——以

专业为例

土木工程学院, 河南郑州 450049)

摘要: 当前, 工科专业建设存在与智能时代和未来社会需求相脱节的情况。基于新工科建设的内涵要求和国内外土木工程行业发展现状, 工科专业升级已迫在眉睫。应全面修订面向新工科要求的人才培养方案, 增设微专业, 增加跨学科课程选修, 课程内容融入 BIM 技术、信息化、智能建筑、绿色建筑、人工智能等前沿知识, 构建适应当前行业需求和社会发展的课程体系, 促进“土木工程”专业的转型升级, 培养自主学习能力强、团队协作能力强、具有批判思维、创新意识、适应社会发展、学科交叉融合的高素质复合型人才。

关键词: 新工科; “土木工程”专业; BIM 技术

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Exploration of Integrating Advanced Technologies into Engineering Majors under the Framework of New Engineering Education

——A Case Analysis of the “Civil Engineering” Major at

Abstract: Amidst the ongoing transformation towards the smart era, the development of engineering majors often lags behind the evolving societal and industrial needs. In light of the core principles of New Engineering Education (NEE) and the current state of the civil engineering industry globally, the urgent need for upgrading engineering majors becomes evident. Comprehensive reforms to the talent cultivation programs, tailored to the tenets of NEE, are paramount. This includes the introduction of micro-majors, the expansion of interdisciplinary elective courses, and the integration of forefront technologies such as Building Information Modeling (BIM), informatization, intelligent construction, green buildings, and artificial intelligence (AI) into the curriculum. Such endeavors aim to establish a curriculum system that resonates with current industry demands and societal advancements, thereby facilitating the transformation and enhancement of the “Civil Engineering” major. The ultimate objective is to nurture versatile, interdisciplinary talents who possess robust self-learning capabilities, adept teamwork and communication skills, critical thinking abilities, an innovative mindset, adaptability to societal shifts, and the capacity to bridge various disciplines.

Keywords: New Engineering Education (NEE); Civil engineering; Building Information Modeling (BIM); Advanced technologies integration

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1 传统工科专业的现状及问题

“土木工程”专业着重于培养具有较好的专业理论基础、较深厚的专业知识、较强的实践能力与创新能力, 能在土木工程及相关行业中的施工类、监理类、开发类、设计类、管理类企事业单位和政府机关部门, 从事建筑、桥梁、隧道、道路等土木工程设施的施工、管理与设计的德智体美劳全面发展的高素质应用型人才。我国大部分地区已经实现了从精英高等教育向普及高等教育的跨越。新时代大学生的核心能力是合作沟通能力、批判性思维、创造性思维。传统的教学模式已经不能适应未来社会的需要。

1) 课程知识落后, 跟不上时代发展

智能时代的到来, 随着智能建造、信息化技术、BIM 技术、大数据技术、装配工业化、人工智能等的发展, 传统的工科专业已经无法满足社会的要求。课程知识滞后、没有新技术、新工艺、新理论的发展, 先进的前沿知识没有在教学内容中充分体现, 未能融合行业智能化、信息化、互联网等新技术手段。

2) 学科单一, 不能适用未来社会对人才的需求

传统“土木工程”专业学科知识单一, 培养的学生建筑只懂建筑、桥梁只懂桥梁、水利只懂水利, 不利于解决工程复杂的实践问题。新时代需要学科知识融会贯通全面发展的综合素质高的学生。“土木工程”专业跟信息技术相融合、跟 BIM 技术融合已成为未来发展的趋势。知识交叉融合, 理应培养学科交叉相融人才。

3) 教学模式传统, 学生被动学习

传统的“土木工程”专业大多采用满堂灌的教学模式, 学生上课被动听课, 学习积极性差, 教学效果差。未来社会需要能够自主终身学习的学生, 应培养学生的自主学习能力、沟通协调能力, 促进教学方式 and 教学手段的改变, 如讨论式学习等。

2 新工科背景下人才培养升级改造的路径及实践

2.1 修订基于新工科要求的人才培养方案

新工科要求学科间交叉相通, 未来社会需要培养德智体美劳全面发

在对课程思政的教学效果和学习效果进行评价时,需要注意将评价的视角从单纯的专业知识评价维度向学生的价值、知识和能力几个方面综合考察、细化评价标准,课题组根据该课程的特点,提出了平时和期末考试两大板块考核评价体系,平时考核注重全过程,分作业、考勤、调研等内容,每个部分都包括了专业知识、思政素养和能力培养三个部分。

表2 课程思政评价体系构成表

项目	总成绩占比(%)	成绩占比(%)			备注
		专业知识	思政素养	能力培养	
调研	10	40	30	30	
平时 作业	20	50	20	30	
考勤	10				
期末考试	60	60	10	30	

4 结语与展望

如何将红色资源与土木工程专业课程思政体系互融互促研究是一个新课题。本文选取剑英纪念馆为研究对象,探索将其精神融入到 BIM 技术与应用课程中,采用显性和隐性授课相结合的方法,价值塑造与传授知识相统一,做到以提升能力为导向,培养具有“深厚家国情怀、坚定理想信念、崇高职业道德和卓越工匠精神”的大学生。并基于 OBE 理念,以产出为导向,不断优化和完善课程评价体系,将知识、价值和能力三者都纳入评价中,发挥了思政的育人功能,同时,通过课程思政的建设丰富了红色资源的内涵,为课程思政建设提供了一种更加有益的探索。

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4 结语

基于新工科的背景, 传统的“土木工程”专业升级改造迫在眉睫, 结合新时代大学生核心素养要求, 修订人才培养方案, 开设微专业, 增设跨学科选修课程。在教学课程中融入 BIM 技术、信息化技术等前沿知识, 有效激发了学生的学习兴趣, 学生由被动学习转变为主动学习。通过学科竞赛, 学生的团队意识、沟通能力增强, 人才培养质量不断提高。

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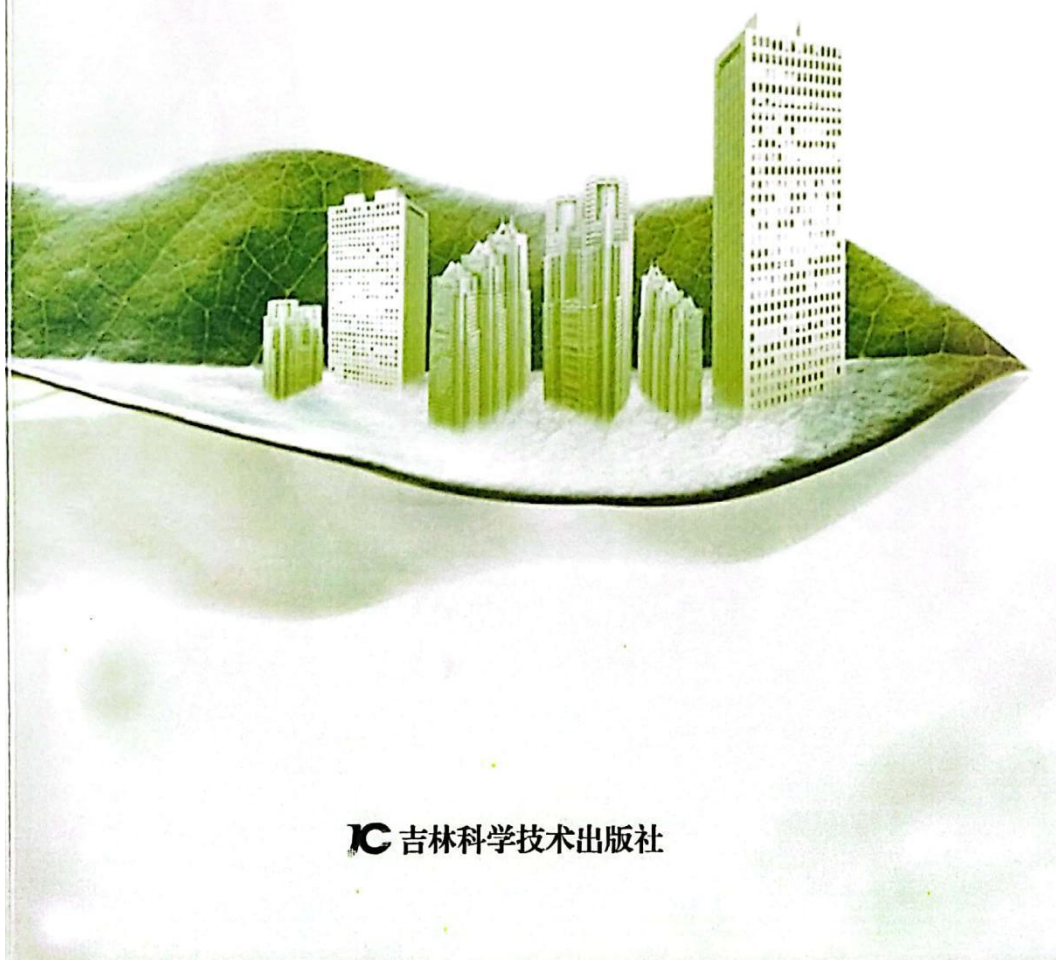
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6.论著：现代建筑绿色低碳研究

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前言

随着当前经济与社会的不断发展,我们更加注重环境保护,尤其在建筑行业发展的过程中,运用低碳理念推动绿色建筑建设,满足可持续发展的要求。在绿色建筑建设过程中,要充分利用可再生资源,提高能源利用率,同时降低建设成本,提高生态效益。此外,要加强对绿色建筑的认知,形成绿色建筑低碳评价标准,进一步推动绿色建筑行业的稳定发展。绿色建筑的低碳发展是当前时代的特色。本书探讨了低碳理念在绿色建筑中的应用原则,强调了对可再生资源的合理利用,以减少内部耗能,提高建筑建设效果。同时,本书也提出了低碳理念下绿色建筑发展的对策,包括对新能源的利用,进行保温节能设计,对施工成本进行有效控制,促进节能环保材料的应用等,进一步推动绿色建筑可持续发展等内容。

建设绿色低碳建筑的主要目标是降低建筑整体环境负荷,实现建筑与当地环境的融合,这一举措不仅有利于人们的身心健康,还可以有效减少建筑资源消耗,减少对环境造成的污染,保护建筑生态环境。基于低碳要求的建设是人与自然的融合,人与自然的和谐发展。绿色发展是指知识与实践的统一,生产生活方式的统一。绿色发展已成为时代要求,建设绿色建筑是推进生态文明建设、促进生态文明建设的重要举措。将绿色发展理念融入到建筑设计中,在建筑空间建设和绿化研究中找到精准平衡。建设绿色建筑,不仅能有效地保护建筑及其周边生态环境,还能减少人们日常活动中可能产生的环境破坏和污染,减少建筑资源消耗,做到建筑生态的可持续发展和绿色发展,能够更好地使建筑生态践行“绿水青山就是金山银山”的理念,更好地落实绿色建筑政策实施,为人们的活动创造更好的环境。

目前,人们的环保意识不断提高,低碳节能理念得到广泛推广和应用,它直接关系自然环境和人类健康,建筑设计应逐步向低碳、节能方向发展。实践表明,设计模式应基于相应的规划体系和可持续发展原则,科学合理地设计和规划建筑,大力采用环保节能设计材料,确保符合低碳节能设计标准,为人们创造舒适、健康、环保的环境,广泛利用太阳能、风能、水电等再生自然能源,既能降低能源消耗,促进社会经济发展,又能保证建筑的舒适性和环保性,提高用户对建筑功能的体验。国家大力倡导创建环保节能型社会,建设绿色低碳建筑可以为环境保护做出巨大贡献,我们要致力于建设绿色低碳建筑,设计绿色建筑,实现节约能源资源、保护绿色环境、改善气候的目标。

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7.论著：建筑结构设计 with 施工质量控制研究



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前言

PREFACE

建筑结构设计是根据建筑、给排水、电气和采暖通风的要求,合理地选择建筑物的结构类型和结构构件,采用合理的简化力学模型进行结构计算,然后依据计算结果和国家现行结构设计规范完成结构构件的计算,最后依据计算结果绘制施工图的过程,可以分为确定结构方案、结构计算与施工图设计三个阶段。因此,建筑结构设计是一个非常系统的工作,需要我们掌握扎实的基础理论知识,并具备严肃、认真和负责的工作态度。

优秀的结构设计师,不仅需要树立创新意识,建立开放的知识体系,还需要不断吸取新的科技成果,从而提高自己解决各种复杂问题的能力。创新不是标新立异和哗众取宠,其基础在于工程实践。建筑结构设计作为一门实践性强,紧密联系现行国家结构设计规范的课程,其目的就在于发展学生的空间思维,培养学生解决和处理实际工程问题的能力与创新意识。

建筑工程质量是建筑业参与各方及管理者追求的永恒主题,建筑质量涉及的范围极广,包括决策者、设计的构造措施、材料的材质选择及相互匹配、施工企业素质及操作人员技术修养和熟练程度、工程全过程监理和质量监督及试验检测的技术水平,因而是一个很庞大的系统工程,某一个方面的措施达不到质量标准,都会影响到预期目标的实现。为了给建设和使用者提供安全、可靠、耐久的各类建筑,建筑业多年来从国家到地方各级都制定了相应的规范标准和规程,如果切实执行对保证建设质量极其有效。

本书严格按照建筑工程结构设计与施工质量验收规范,并秉承以理论知识够用为度,以培养面向生产第一线的应用型人才为目的进行。在内容上有了较大幅度的充实与完善,进一步强化了实用性和可操作性,更能满足教学工作的需要。

本书的工作主要遵循以下原则和要求进行:

- 1.进一步突出了实际操作性,以能力为本,注重结合施工实际,努力使内容能做到简单明了,通俗易懂。
- 2.可以使读者能够带着目的性去理解书中内容,使全书内容层次分明,条理清晰。
- 3.结合建筑结构设计与工程施工质量管理相关标准规范对建筑工程质量与安全控制的内容进行阐述。

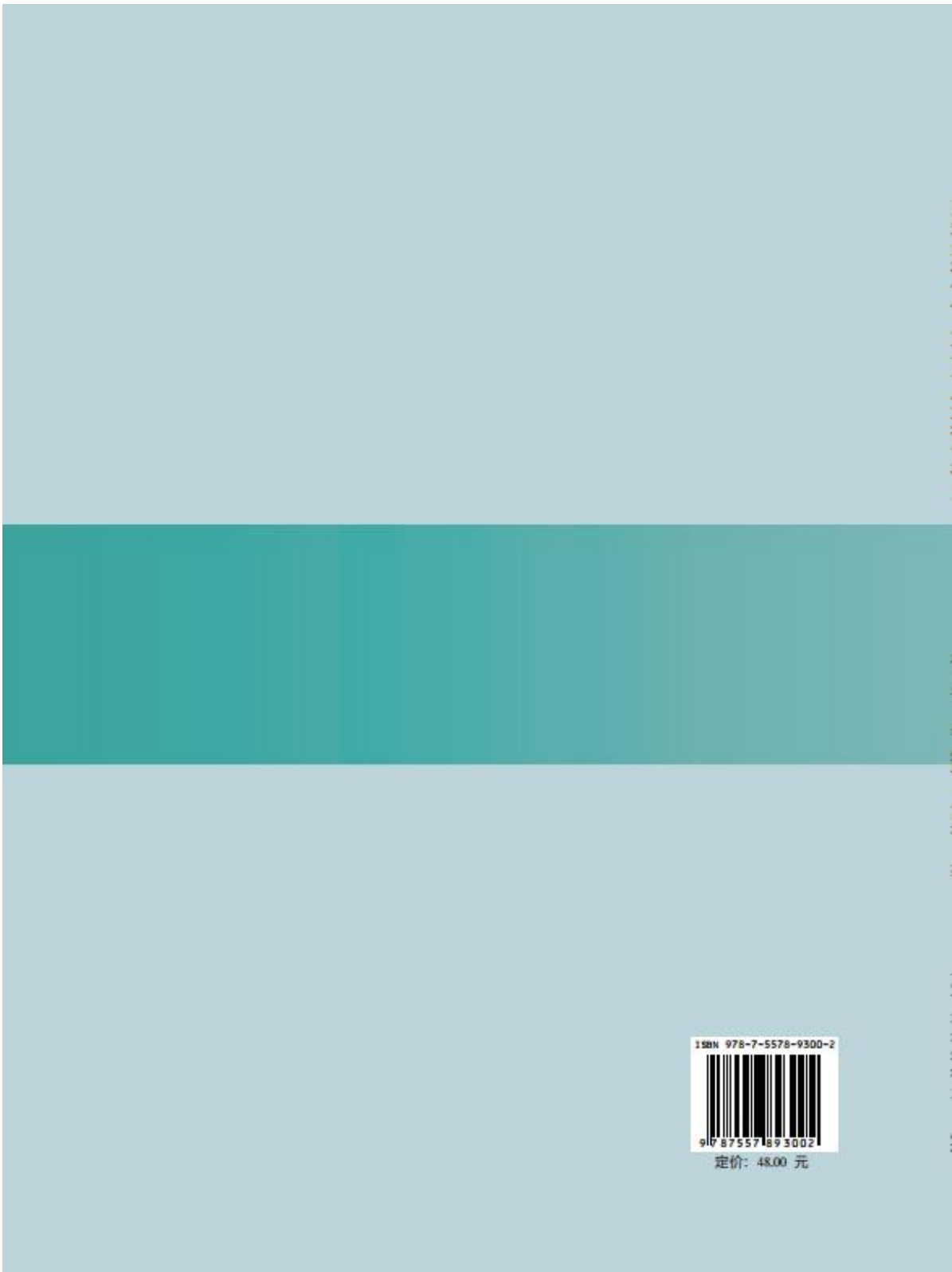
本书由 担任著者, 负责第一章、第二章的撰写, 负责第三章、第四章的撰写, 负责第五章、第六章的撰写。限于作者水平,书中难免有不妥之处,恳请专家和广大读者批评指正。



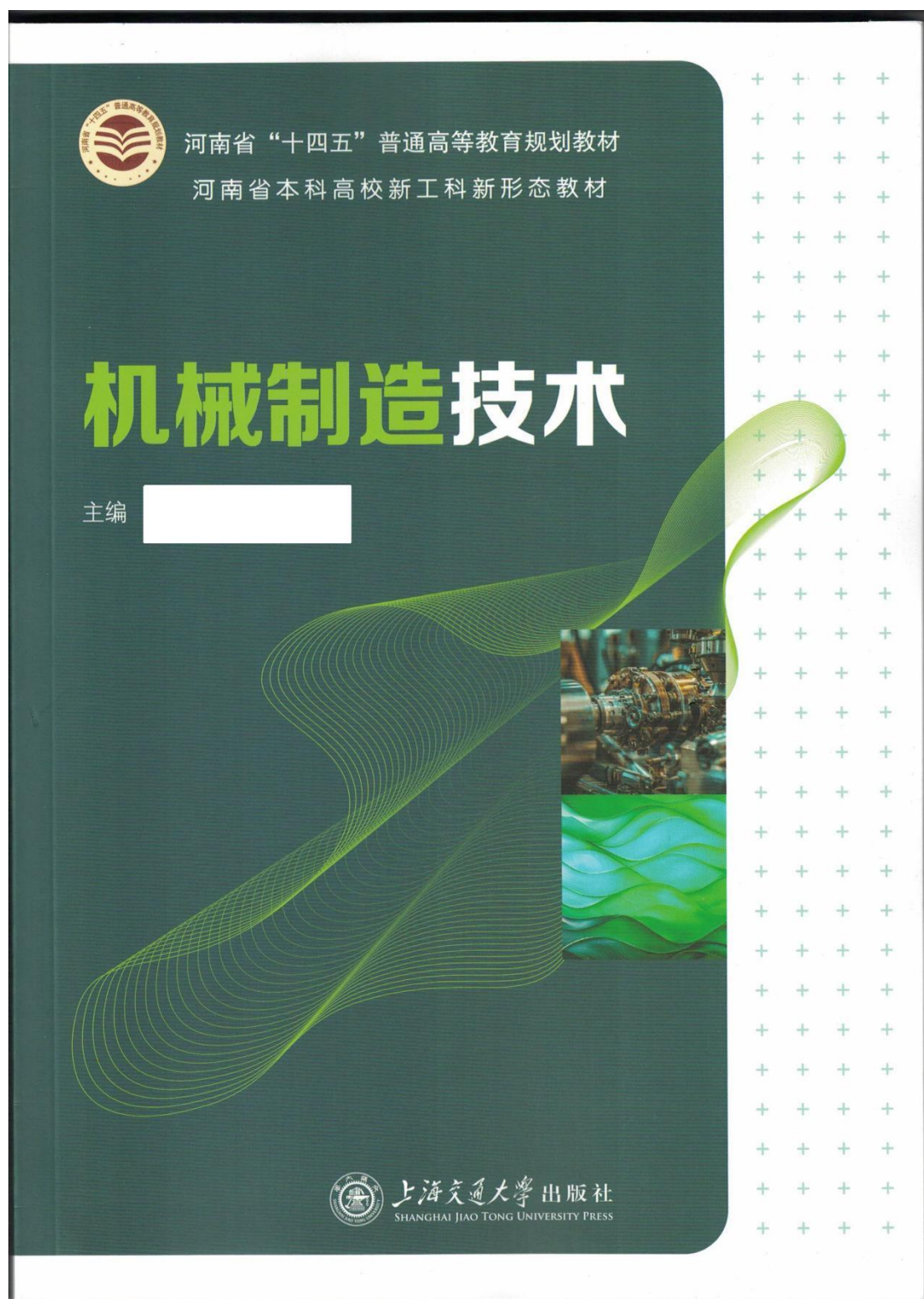
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8.教材：机械制造技术



内容提要

本书除绪论外共分为6章,内容包括金属切削原理与刀具、金属切削机床与加工方法、金属切削机床夹具设计、工艺规程的设计、机械加工质量、先进制造技术。

本书既可作为普通高等院校机械制造技术课程的教材,也可作为相关技术人员的参考用书。

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前言

机械制造工业作为国民经济的基石,其技术水平体现了国家的综合实力。在科技迅猛发展的今天,机械制造技术持续推陈出新。《教育强国建设规划纲要(2024—2035年)》明确指出,要落实立德树人根本任务,加快建设高质量教育体系,培养德智体美劳全面发展的社会主义建设者和接班人,加快建设现代职业教育体系,培养大国工匠、能工巧匠、高技能人才。这为机械制造领域的教育发展指明了方向。

在此背景下,编者紧密贴合行业发展与政策导向,深入了解行业发展动态,广泛调研企业实际需求,并与中国一拖集团有限公司、东风汽车集团有限公司、郑州宇通集团有限公司等8家企业深度合作,按照机械制造技术的内在逻辑,遵循从基础理论到实际应用的原则编排了本书。本书从介绍金属切削原理等基础知识入手,再逐步深入阐释机床夹具设计、机械加工工艺规程设计等内容,帮助学生建立起完整的知识体系。书中还编入了先进制造技术,如增材制造技术、智能制造技术等;融入了行业的新标准、新工艺、新方法、新材料,让学生了解学科前沿动态,增强了教材的时代感;紧密结合生产实际,选取合作企业中具有代表性的真实工程案例,将理论知识融入实际问题的解决中,帮助学生提高运用所学知识解决实际工程问题的能力,突出了实践能力培养、创新能力培养和工程素养培养的特色。教材编排结构合理、图表丰富,文字表述准确、简洁、通俗易懂;提供丰富的配套教学资源,如电子教案、课件、习题库、案例库等,为教师的教学和学生的学习提供便利。

本书在编写过程中,结合机械制造技术课程的特点,深度践行课程思政理念。通过讲述机械制造领域大国工匠故事、剖析民族企业崛起历程等内容,将爱国主义精神、工匠精神、创新精神等巧妙融入知识学习中,在提升学生专业知识技能的同时,培养其家国情怀与责任感,引导学生努力把科技自立自强信念自觉融入人生追求之中,努力把自我发展融入推动全面建成社会主义现代化强国、实现第二个百年奋斗目标、以中国式现代化全面推进中华民族伟大复兴的实践中,自觉为我国从制造大国迈向制造强国贡献力量。

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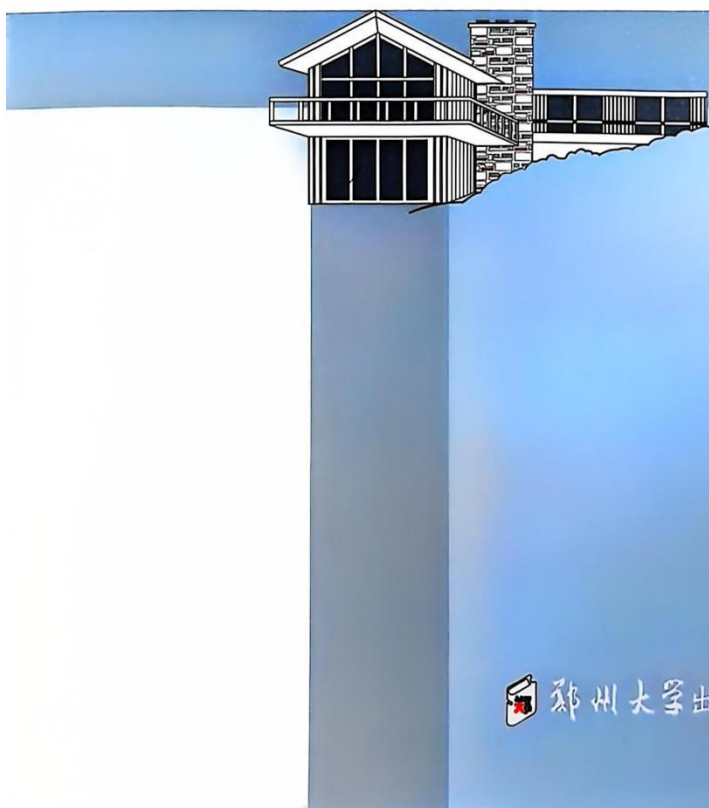


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GANGJIEGOU JIBEN YUANLI

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前言

.....

本书根据《普通高等学校本科专业类教学质量国家标准》中对钢结构课程教学的基本要求,按照《钢结构设计标准》(GB 50017—2017)、《钢结构工程施工质量验收标准》(GB 50205—2020)和新颁布的有关标准,结合编者多年的教学体会、工程实践经验编写而成。

本书共分8章,主要内容有绪论、钢结构材料、钢结构的可能破坏形式、钢结构的连接、轴心受力构件、受弯构件、拉弯构件和压弯构件、钢结构识图与加工制作。

最近十几年,我国钢铁工业得到迅猛发展,钢产量连续多年居世界第一,钢材的品种、质量亦有了极大提高,基本满足了我国钢结构事业发展的需要。本书在编写时,内容与传统教材相比有了较大变化,删除了一些理论分析部分,增加了钢结构识图与加工制作方面的内容,力求使学生能对钢结构工程有较系统的了解。当然,由于时间仓促,也有取舍不当或叙述不到之处,使用本书时,可根据具体情况对内容进行增删。

本书由 任主编,编写第1章、第3章;商丘学院的杨雪任副主编,编写第6章 编写第2章、第5章;洛阳理工学院的浮海梅编写第4章;河南城建学院的周海涛编写第7章、第8章。

本书可供应用型本科院校土木工程专业学生使用,也可作为高职高专建筑工程技术专业学生、工程管理和工程造价本科专业学生的学习参考书。

在编写过程中,本书参考和引用了已公开发表、出版的有关文献和资料,在此谨对所有文献的作者和曾关心、支持本书出版的同志们深表谢意。

限于编者水平有限,时间仓促,书中存在的缺点和不妥之处,敬请广大读者批评指正!

编 者
2023.1

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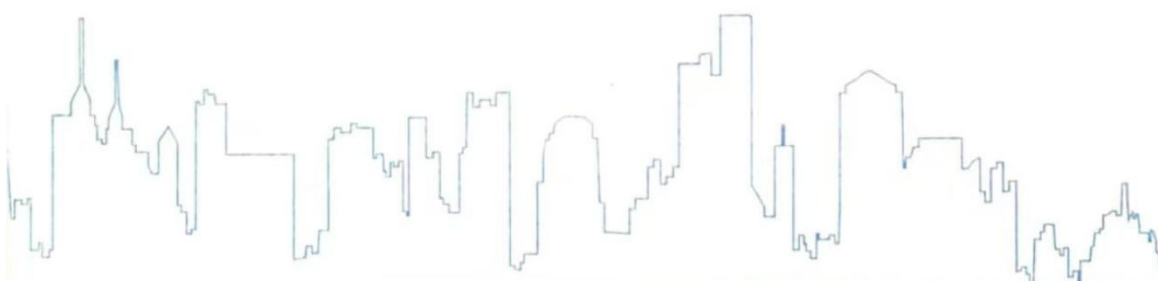
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THE HISTORY OF THE
CHINESE PEOPLE



《钢结构基本原理》教材使用情况

郑州大学出版社有限公司出版的教材《钢结构基本原理》(第二版)(ISBN: 978-7-5645-9328-5), 由 任主编。该教材 2020 年首次出版, 2024 年修订出版第二版。截至目前已累计印刷 10000 册, 销售 8000 册。

教材出版后在洛阳理工学院、哈尔滨工业大学威海校区、安徽农业大学 河南城建学院、商丘工学院、黄河交通学院等多个高校的土木工程、工程管理及其相关专业使用, 受到各教学单位和读者的一致好评。

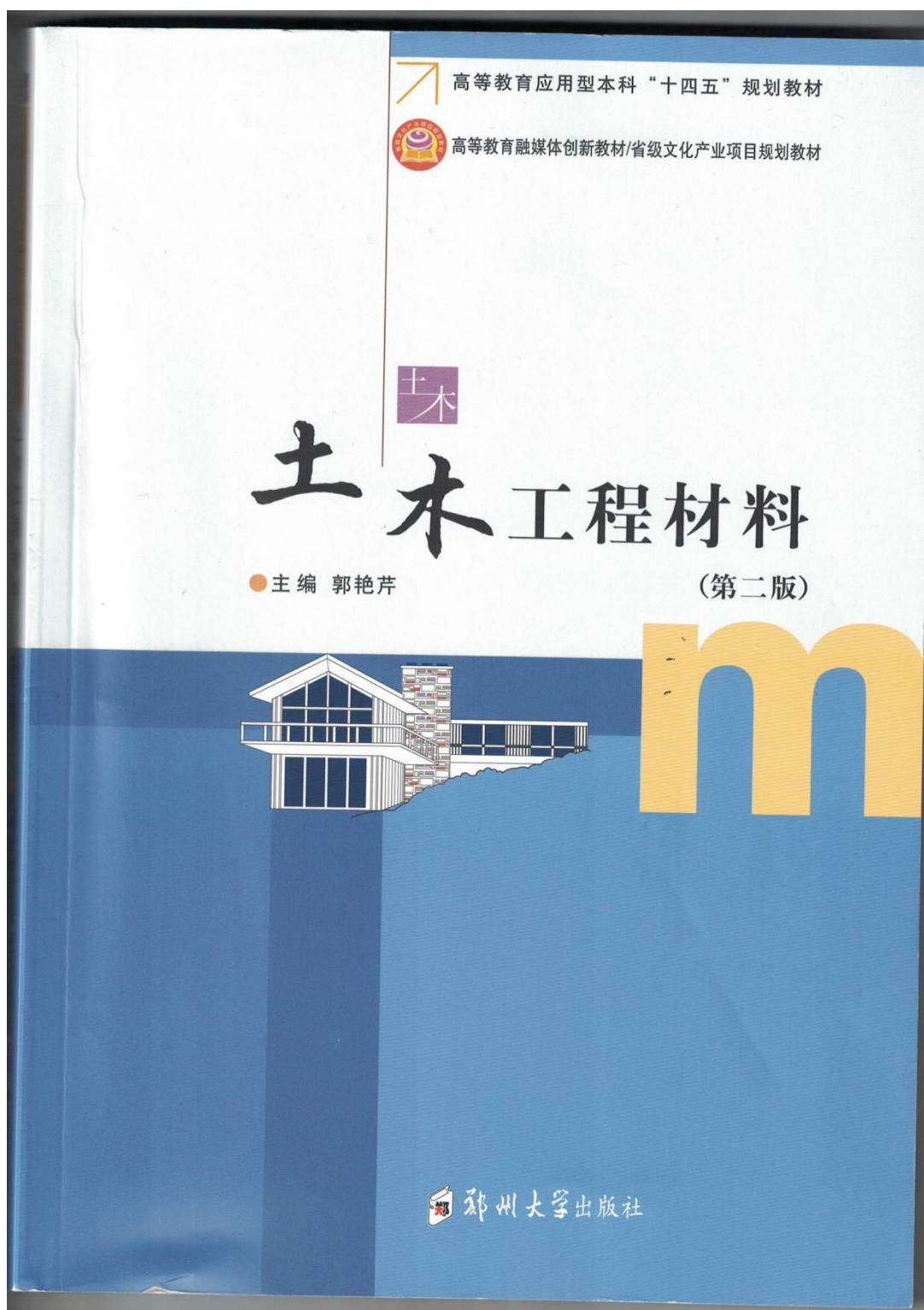
使用院校的教师和学生反映: 该教材内容精炼, 讲解浅显易懂, 覆盖面广。与教材配套的教学课件制作精美, 既方便教师备课、授课, 又便于学生学习理解。

教材使用效果优良, 并能对后续课程和实际工作起到很好的支撑作用。

特此证明。



10.教材：土木工程材料



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序

Preface

近年来,我国高等教育事业快速发展,取得了举世瞩目的成就。随着高等教育改革的不断深入,高等教育工作重心正在由规模发展向提高质量转移,教育部实施了高等学校教学质量与教学改革工程,进一步确立了人才培养是高等学校的根本任务,质量是高等学校的生命线,教学工作是高等学校各项工作的中心的指导思想,把深化教育教学改革,全面提高高等教育教学质量放在了更加突出的位置。

教材是体现教学内容和教学要求的知识载体,是进行教学的基本工具,是提高教学质量的重要保证。教材建设是教学质量与教学改革工程的重要组成部分。为加强教材建设,教育部提倡和鼓励学术水平高、教学经验丰富的教师,根据教学需要编写适应不同层次、不同类型院校,具有不同风格和特点的高质量教材。郑州大学出版社按照这样的要求和精神,组织土建学科专家,在全国范围内,对土木工程、建筑工程技术等专业的培养目标、规格标准、培养模式、课程体系、教学内容、教学大纲等,进行了广泛而深入的调研,在此基础上,分专业召开了教育教学研讨会、教材编写论证会、教学大纲审定会和主编人会议,确定了教材编写的指导思想、原则和要求。按照以培养目标和就业为导向,以素质教育和能力培养为根本的编写指导思想,科学性、先进性、系统性和适用性的编写原则,组织包括郑州大学在内的五十余所学校的学术水平高、教学经验丰富的一线教师,编写了本、专科系列教材。

教材教学改革是一个不断推陈出新、反复锤炼的过程,希望这些教材的出版对土建教育教学改革和提高教育教学质量起到积极的推动作用,也希望使用教材的师生多提意见和建议,以便及时修订、不断完善。

王发之

前言 (第二版)

Preface

本书为土建类应用型本科“十四五”规划教材——土木工程专业系列教材中的一册,教材遵循教育教学规律和人才培养规律,以培养新工科人才为导向,以素质教育和能力培养为根本,参照教育部土建类专业教学指导委员会制定的培养方案和基本要求,结合应用型本科教育教学情况和实际,加强理论与实践的结合,加强实践教学和突出工程训练,注重能力培养,全面反映土木工程材料及其应用技术的发展现状与趋势,融入相关土木工程材料领域科研最新发展以及当前最新标准、规范和规程,充分考虑土木工程材料课程与选修课程和后续课程的衔接,同时将有关就业岗位技术要求贯穿于教材内容中,以便适合现代土木工程材料的知识需求和教学要求。本书不但注重土木工程材料专业知识和基本技能,而且更注重分析、解决问题的能力,紧密结合新工科人才培养模式,培养创新精神,提高综合素质,实现“知识、能力、素质”有机统一。本书特点如下:

(1)每章前的学习提要提示本章内容重难点、学习方法、学习收获,方便学生学习。

(2)每章节内容中加入了材料的工程实例应用分析,主要体现材料在工程中的应用,根据工程实例设置问题和讨论,在学生学习过程中引起学生的重视与深思,达到培养学生学以致用用的目标,重点强调应用性与创新性。

(3)每章课后增加了相关材料的前沿发展趋势,开阔学生的视野,增加学生的学习兴趣,培养学生的创新意识。

(4)教材中嵌入了教学视频资源。学生可通过扫描书中二维码反复观看教师对重点和难点内容的讲解视频。方便学生课下预习、复习和查漏补缺。

本书由黄河科技学院郭艳芹担任主编,由商丘工学院刘兰君、黄河科技学院李荫、三门峡职业技术学院卫国芳担任副主编。本书编写分工如下:郭艳芹负责编写绪论、第1、4、8、12章及全书统稿,负责编写第6、9章;刘兰君负责编写第2、3章;李荫负责编写第5、7章;卫国芳负责编写第10、11章。

本书的编写和出版得到了郑州大学出版社的大力支持与帮助,谨在此致以衷心的感谢。

由于编者水平有限,书中难免有不当和错误之处,敬请广大读者批评指正。

编者

2022年3月

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《土木工程材料》教材使用情况

郑州大学出版社有限公司出版的教材《土木工程材料》(第二版)(ISBN: 978-7-5645-8894-6), 由黄河科技学院的郭艳芹任主编。该教材 2017 年首次出版, 2022 年修订出版第二版。截至目前已累计印刷 8000 册, 销售 6000 册。

教材出版后在河南师范大学、信阳师范大学、黄河科技学院、商丘工学院、黄河交通学院等多个高校的土木工程、工程管理及其相关专业使用, 受到各教学单位和读者的一致好评。

使用院校的教师和学生反映: 该教材内容精炼, 讲解浅显易懂, 覆盖面广。与教材配套的教学课件制作精美, 既方便教师备课、授课, 又便于学生学习理解。

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