J. COMBIN. MATH. COMBIN. COMPUT. 127a (2025) 4979-4994

Journal of Combinatorial Mathematics
and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Combinatorial Press

Optimization Modeling Research on Multi-Objective Resource Allocation for AI-Enabled Innovation and Entrepreneurship Education

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ABSTRACT

Innovation and entrepreneurship, as an important part of social and economic activities, has received more and more widespread attention. Based on the characteristics of the digital era, the study uses artificial intelligence to empower innovation and entrepreneurship education in colleges and universities. Optimize the allocation of innovation and entrepreneurship education resources in colleges and universities through multi-objective optimization algorithm. Construct an optimization model of resource allocation for innovation and entrepreneurship education in colleges and universities, and verify its resource optimization and allocation performance. Taking 13 colleges and universities in C city as the research object, the optimization of their innovation and entrepreneurship education resource allocation is processed. The MSS cumulative values of this paper's multi-objective optimization model on the CPLX problem and the MATP problem are -1.400 and -1.033, respectively, which are the smallest among all models, with the best performance and ranked the first in resource allocation efficiency. After optimization, the resource allocation level of innovation and entrepreneurship education in all 13 colleges and universities has been improved, and the resource allocation among the colleges and universities is more balanced.The resource utilization efficiency of innovation and entrepreneurship education in the 13 colleges and universities has been improved by 17.02% on average.

Keywords: multi-objective optimization model, resource allocation, innovation and entrepreneurship education, artificial intelligence

1. Introduction

As an emerging comprehensive quality education concept, dual-creation education is continuously promoting the comprehensive deepening of higher education teaching reform, and becoming an

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Received 15 January 2024; Revised 10 March 2024; Accepted 30 November 2024; Published Online 15 April 2025.
DOI: 10.61091/jcmcc127a-281

important direction for the reform of higher education system [1-2]. Dual-creation education is an educational reform made by China based on the overall pattern of higher education development, and it is a new expansion under the goal of comprehensive cultivation of modernized talents [3-4]. However, due to the fact that the development of dual-creation education in Chinese colleges and universities has not been long and lacks sufficient mature experience, the development of dual-creation education in China is still in the early stage, with a variety of deficiencies and problems, especially in the excavation and configuration of dual-creation education resources, there is an obvious short board [5-6]. Under the changing trend of social talent demand in the new period, the reform and development of dual-creation education requires colleges and universities to optimize the allocation of existing educational resources by taking into account the actual development and development needs at this stage, and continuously expand the channels of dual-creation education resources, so as to provide complete support of high-quality educational resources for college and university students [7-9].

"Educational efficiency" is one of the indicators of educational achievement. The optimal allocation of innovation and entrepreneurship education resources in colleges and universities involves how to reasonably allocate the limited resources of colleges and universities to obtain the maximum educational output with the minimum input of the unit of educational efficiency [10-11]. Considering that the education system is a complex system with multiple inputs and outputs, the relationship between inputs and outputs is difficult to quantify and measure, so to improve the efficiency of innovation and entrepreneurship education and optimize the allocation of resources, it is necessary to construct the innovation and entrepreneurship education resource index system and multi-objective optimization mathematical model [12-14].

The optimal allocation of educational resources is an important factor that affects the high-quality development of higher education, realizes educational equity, and enhances the connotation of higher education [15-16]. In order to promote the innovation-driven development strategy and alleviate the employment pressure, although China attaches great importance to innovation and entrepreneurship education in colleges and universities, and the total amount of educational resources invested has been increasing year by year, there still exist problems of insufficient resource investment, uneven allocation, and inefficient utilization [17-20]. Therefore, how to realize the rationalization and maximization of the allocation of resources for innovation and entrepreneurship education in colleges and universities has attracted the attention and discussion of all circles.

In this paper, artificial intelligence is introduced into innovation and entrepreneurship education in colleges and universities to explore the way of AI-enabled innovation and entrepreneurship education. Based on the relatively low allocation of educational resources, the use of multi-objective optimization algorithms, organic deployment of various types of educational innovation and entrepreneurship education resources, to achieve the maximization of the benefits of educational resources. Based on the analysis of the optimization of innovation and entrepreneurship education resource allocation, eight AI innovation and entrepreneurship education indicators are selected to construct an optimization model of innovation and entrepreneurship education resource allocation. The entropy value method is used to solve the weights of each index, and the model is solved. Compare the multi-objective optimization algorithm of this paper with other methods in terms of resource allocation efficiency to test the performance of the model of this paper. Through empirical research, the role of this paper's multi-objective optimization model in improving the level of resource allocation and resource utilization in innovation and entrepreneurship education is supported.

2. Construction of multi-objective optimization model for resource allocation of innovation and entrepreneurship education

2.1. AI Empowerment in Innovation and Entrepreneurship Education

Innovation and entrepreneurship education is a kind of teaching concept and mode that has arisen to meet the needs of the national economic and social development strategy, which is the deep integration of innovation education and entrepreneurship education based on the professional education system, with the concept of innovation education as the forerunner, and with the focus on the innovation spirit, entrepreneurial awareness, entrepreneurial ability and social responsibility of the students.

The two of artificial intelligence and innovation and entrepreneurship education in the digital era are mutually reinforcing. On the one hand, the promotion and application of artificial intelligence technology helps innovation and entrepreneurship education to be “intelligent” and realize the high-quality development of education. On the other hand, the development of innovation and entrepreneurship education can help solve the imbalance between the supply and demand of high-quality technical and skilled talents in the development of artificial intelligence in the digital era, meet the needs of upgrading the social and economic structure and high-quality development, and realize the intelligent transformation of society. Specifically, the unilateral impact of artificial intelligence boosting the development of innovation and entrepreneurship education specifically includes five aspects:

First, artificial intelligence is changing the structure of employment skills and leading the reform of innovation and entrepreneurship talent training. Artificial intelligence machines will replace a large number of routine human work, and will put forward new requirements for the knowledge and skills of the labor force in different positions in different industries, causing a shift in the structure of skills and improving the quality of the labor force. The innovation consciousness and innovation ability compatible with artificial intelligence will play a decisive role in the job work, and the intelligence literacy and ability become more and more important, and lead the development direction of innovation and entrepreneurship education talent training reform.

Secondly, artificial intelligence promotes the evolution of innovation and entrepreneurship education space. The wide application of artificial intelligence technology in innovation and entrepreneurship education elevates innovation and entrepreneurship education to a multi-dimensional space of freedom, openness, communication and cooperation through human-computer interaction, breaks the spatial regulations and constraints of traditional classroom education and practical training teaching, and opens up a new application scene for innovation and entrepreneurship education.

Thirdly, artificial intelligence has given birth to new educational methods and approaches. Artificial intelligence extends human brain power and eye power, expands students' perception, understanding and relevance to education, enhances higher education's ability to serve students' individual needs, gives rise to intelligent changes in education and teaching methods as well as the intelligence of all aspects of teaching and learning, and pushes forward the modernization of education.

Fourth, artificial intelligence has caused changes in educational ethics. Artificial intelligence has promoted the evolution of various educational links and digital scenarios, creating a relatively complete knowledge and skills education system, however, the weakening of human-computer interaction on the emotions of teachers and students has the potential to cause a crisis in digital ethics. This potential danger requires education and teaching to actively respond and control.

Fifth, artificial intelligence improves the scientific nature of educational management decisions. Artificial intelligence has become an important decision-making tool for scientific management of education through the design and application of the management model of innovation and entrepreneurship education, coordinating and analyzing the relevant data, discovering the problems and drawing conclusions, which has powerfully pushed forward the development of informatization, digitization and intelligence of education management.

2.2. The need to optimize the allocation of educational resources

Educational resources refers to the sum of human, material and financial resources used for education. The allocation of educational resources refers to the organic combination of resources between the different directions of use in the education sector [21], which contains two meanings: first, the inflow of resources to the different directions of use in the education sector in the process of national economic and social development, i.e., the formation of educational resources. Secondly, the education sector will inflow of educational resources for different aspects. The allocation of educational resources and the allocation of social resources, is nothing more than to make the best use of people, the best use of things, the best use of money.
1) The allocation of resources for education is not for the purpose of making profits. Education is different from other sectors of material production. For the educated individuals, it is to provide them with a service. For society, it is to train specialists. Education as a special industrial sector, although in its production process, the same need to realize the production and reproduction process under the principle of equal exchange, and make it higher than the cost of income. However, for the individual educated person, the service provided by education is not for their direct enjoyment of recreational consumption, and its personal benefits are delayed, indirect, and uncertain. Therefore, education services can not become a tool and means of chasing high profits, and this characteristic determines that the allocation of educational resources can not be the main purpose of profit.

However, this is not the same as saying that the allocation of educational resources does not need to pay attention to effectiveness and efficiency. On the contrary, the effective allocation of educational resources is not only important but also necessary.
2) The goal of optimizing the allocation of educational resources is consistent with the goal of social and economic development. Educational resources are an important social resources, which is based on the level of economic development. The proportion of investment in education to the total value of the national economy and the proportion of fiscal expenditure can only fluctuate within a certain range, and cannot be too large or too small. Investment in education does not take profit as its main purpose, but takes the needs of economic and social development as its goal, therefore, the optimization goal of educational resource allocation is consistent with the goal of social and economic development.
3) The multiplicity of educational benefits. The multiplicity of educational benefits means that education can promote the development of productive forces through a variety of ways. These ways are: ① education makes material production laborers master science and technology, improve production skills. ② education training of professional scientific and technological personnel to develop and design new products, new technologies, new equipment, new processes to improve production efficiency. ③ The intellectual services provided by education directly promote the development of production. ④ The social scientific talents trained by education directly or indirectly promote the development of the economy. ⑤ Through educators transferring scientific and technological knowledge and production skills to each other among the working masses, it promotes the continuous popularization and improvement of culture and science and technology in the whole society, thus contributing to the growth of the economy. ⑥ The scientific research function of education promotes the rapid development of social productive forces.

2.3. *Multi-objective optimization algorithm*

2.3.1. The concept of multi-objective optimization:

1) Multi-objective optimization problem. Multi-objective optimization problems are commonly found in various fields of social reality [22], the essence is to balance the contradictions between multiple

objectives on the basis of limited resources to the maximum benefit, to achieve the overall optimization of the system problem. Previous studies tend to favor single-objective problems, but with the development of social economy, the problem is becoming more and more diversified and complex, so there are more and more objectives to consider.

A multi-objective problem is a problem that contains two or more objectives and there are contradictions between the objectives. We usually consider the minimized multi-objective problem, whose mathematical expression is shown below:

$$\min f = (f_1(X), f_2(X), ..., f_n(X)) \tag{1}$$

$$g_i(X) \le 0, i = 1, 2, ..., I \tag{2}$$

$$h_j(X) = 0, i = 1, 2, ..., J \tag{3}$$

Where, n is the number of objective functions, $f(x)$ is the objective function, $g(x)$ is the inequality function, $h(x)$ is the equation function, I is the number of inequality constraints, and J is the number of equation constraints.

2) Pareto optimal solution set. Multi-objective optimization from the economic point of view will be some contradictory, difficult to directly compare and analyze the objectives combined to form a multi-objective optimization problem, and for the first time introduced the concept of Pareto optimal [23]. Multi-objective optimization problems usually do not have a single optimal solution, but produce a set of non-inferior solution set, which is the Pareto optimal solution set.Pareto front refers to the Pareto optimal solution set reflected in the objective function of the space of a region or a group of points, when the number of objective function is 2, the Pareto front embodied in the space as a curve. When the objective function is 3, it is a surface. Therefore, solving the Pareto solution set is crucial for solving multi-objective optimization problems, and ultimately the appropriate solution is selected from the Pareto optimal solution set based on the decision maker's preference or the real demand.

Pareto dominance relation: for two solution vectors in a multi-objective optimization problem, if the following equation is satisfied:

(1) There is $f_k(X_1) \le f_k(X_2)$ for all $\forall k \in \{1, 2, ..., K\}$.

(2) There is at least $k \in \{1, 2, ..., K\}$ such that $f_k(X_1) \le f_k(X_2)$.

Then X_1 is said to dominate X_2. And every optimal solution in the Pareto set of optimal solutions does not dominate each other in the solution space, also known as non-inferior solutions.

2.3.2. Methods for solving multi-objective problems. The solution methods of multi-objective optimization problems can be mainly divided into two categories: classical mathematical optimization algorithms and group intelligence optimization algorithms. The classical algorithms include linear programming method, nonlinear programming method and large system decomposition coordination. The traditional algorithms have higher requirements for modeling the problem, and most of the classical algorithms are applied to solve some single-objective problems in the early stage. Later, with the continuous deepening of the research, the emergence of multi-objective model exposes the limitations of the traditional algorithms, and then appeared the ideal point method, linear weighting method, the main objective function method, the maximum-minimum method, the objective planning method, the fuzzy mathematical solution, etc., which converts the multi-objective problems into single-objective solutions, each time a Pareto solution is obtained, and a set of Pareto near-optimal solutions are obtained after many runs. Obviously these traditional optimization algorithms are of high complexity and have problems such as slow computation speed, low quality of optimal solutions, and difficulty in solving high-dimensional multi-objective optimization. Currently with the emergence and rapid development of intelligent algorithms, the multi-objective problem has been better solved. The essence of intelligent algorithms is to solve multiple objectives simultaneously and seek the optimal Pareto solution set, which has the advantages of low model requirements, flexible operation, multiparameter settings, and good optimization effect. Currently the common swarm intelligent algorithms are particle swarm algorithm, neural network, genetic algorithm and cuckoo algorithm.

2.4. Construction of the optimization model of resource allocation for innovation and entrepreneurship education

2.4.1. Optimization Analysis of Resource Allocation for Innovation and Entrepreneurship Education. The objectives of resource allocation for innovation and entrepreneurship education in colleges and universities are fairness, efficiency and meeting standards. This chapter takes the allocation of educational resources for innovation and entrepreneurship in a school as the research object, based on the principles of fairness, efficiency and meeting the standards, so that the educational resources of the school can be maximized in terms of their outputs under the guarantee of fairness and limited inputs, establishes the corresponding multi-objective optimization model, chooses the appropriate method to determine the proportion of each index, and, determines the solution algorithm according to the characteristics of the model. The schematic diagram of educational resource allocation is shown in Figure 1.

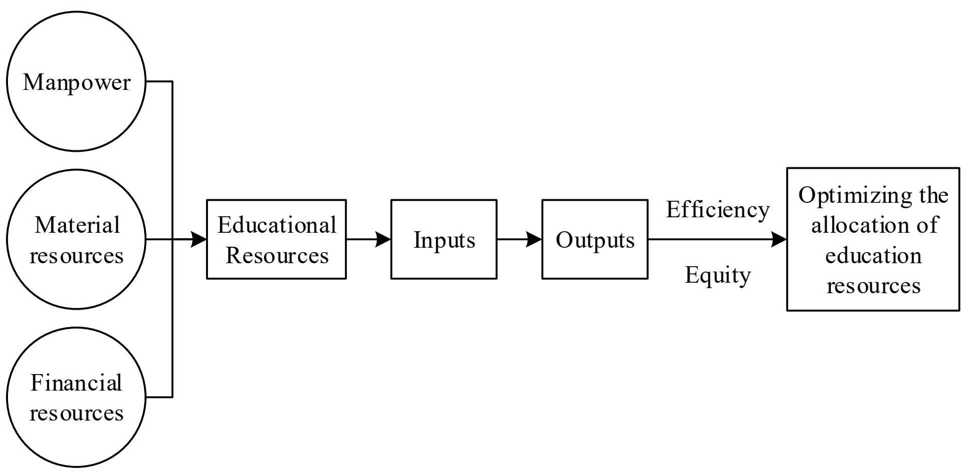

Fig. 1. The diagram of education resources allocation

The key issue of resource allocation for innovation and entrepreneurship education in colleges and universities lies in giving full play to the maximum effect of education with as little consumption of human, material and financial resources as possible, i.e., realizing the maximum educational benefits with the minimum resources.

The eight indicators of educational resources established by the optimization model of innovation and entrepreneurship education resource allocation designed in this study are shown in Table 1.

Table 1. The meaning of innovation entrepreneurship educational resources allocation indices

Index	Index name	Symbol
Index 1	Professional teacher number	V1
Index 2	Above prescribed number of teachers	V2
Index 3	The number of intermediate and above professional and technical teachers	V3
Index 4	PC number	V4
Index 5	Teaching equipment assets per student	V5
Index 6	AI equipment	V6
Index 7	Teaching and auxiliary room area	V7
Index 8	Innovative entrepreneurship laboratory	V8

2.4.2. Construction of an optimization model for resource allocation in innovation and entrepreneurship education. Innovation and entrepreneurship education resource allocation needs to solve the problem is as much as possible to the reasonable optimization of educational resources, there are many factors to consider in the allocation of the problem, such as how to allocate the development of the school is beneficial or how to allocate the resources will make in the school's resources to achieve the optimal utilization rate. The key to the efficiency of the optimization of the allocation of educational resources lies in the balanced allocation of educational resources to the actual situation of the universities in C city at the appropriate input costs, so that the schools try to obtain the maximum output rate to a certain extent, and minimize the differences between the schools.

The solution of the optimization problem of educational resource allocation is to determine the specific optimization strategy according to the actual problem under the condition of satisfying the constraints, and transform each problem into an objective function to seek the optimal solution of the multi-objective optimization problem under the corresponding conditions.

1) Assumptions of the model. Through the above analysis of the optimization objectives of innovation and entrepreneurship education resource allocation, this paper will carry out multi-objective model building. In order to facilitate the search for the optimal solution of the model, make sure that the model meets the following conditions:

(1) Information completeness. In this study, in the process of optimization of resource allocation, the data related to the eight indicators V1, V2, V3, V4, V5, V6, V7 and V8 of each school are known and can be statistically collected.

(2) Information Accuracy. This study is aimed at the allocation of resources for innovation and entrepreneurship education in City C. It is assumed that the raw data of the resources of each school do not change arbitrarily in the course of the study.

2) Objective function of the model. Through the in-depth research on the optimization of innovative and entrepreneurial education resource allocation in City C, the objective function of this study on the optimization of innovative and entrepreneurial education resource allocation has the following objectives:

(1) Improve the efficiency of resources and establish the following objective function:

$$F_{eff} = \max \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{8} e_{eff} \tag{4}$$

Since the impact of the eight indicators V1, V2, V3, V4, V5, V6, V7 and V8 on education is different, the proportion of each target in education, i.e., the corresponding weight of the indicators, should be taken into account when modeling the goal of improving the efficiency of resources. Therefore, for the goal of improving the efficiency of resources, the weights φ1, φ2, φ3, φ4, φ5, φ6, φ7, and φ8 should be introduced into the objective function value, and the weighted objective function is proposed:

$$F_{eff} = \max \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{8} \varphi_k eff_{ijk} \tag{5}$$

(2) Reduce the variance case and create the following objective function:

$$F_{fair} = \min \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{8} fair_{ijk} \tag{6}$$

(3) To meet the specified criteria, establish the following objective function:

$$F_{norm} = \min \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{8} norm_{ijk} \tag{7}$$

Due to the single objective function is more single, its research can be carried out a certain characteristic of the targeted research, but can not be well represented in the actual problem of the factors, and the above objectives are on the optimization of the allocation of educational resources have an important impact on the determinants, so the subject of the establishment of the objective function of the allocation of resources for:

$$\begin{cases} \max \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{8} \varphi_k eff_{ijk} \\ \min \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{8} fair_{ijk} \\ \min \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{8} norm_{ijk} \end{cases} \tag{8}$$

where eff_{ijk}, $fair_{ijk}$ and $norm_{ijk}$ denote the three objective functions of the model, respectively.

(3) Constraints of the model

According to the relevant regulations of the Ministry of Education, schools of innovation and entrepreneurship education have certain standards for the allocation level of teacher resources, teaching instruments and equipment assets.

2.4.3. Methods for solving the weights of indicators in the model. According to the actual problem, for the calculation of the weight of the selected comprehensive indicators, this study chooses the "entropy weight method" to determine the weight of each indicator, which is a kind of objective weighting method, relying on the discrete nature of the data itself [24].

The judgment of entropy weight method is based on the variation of indicators in the evaluation index system. If the amount of information of an indicator is larger, which means that its uncertainty is smaller, the entropy of the indicator is smaller. If the amount of information of an indicator is smaller, indicating that the greater its uncertainty, the greater the entropy of the indicator.

If the sample data take equal values under a certain indicator, it means that the influence of the indicator on the overall evaluation is 0, therefore, the weight of the indicator is 0.

The assignment steps of the entropy weight method are as follows:

(1) Data standardization. For a given k indicator $X_1, X_2, \ldots, X_k$, where $X_i = \{x_1, x_2, \ldots, x_n\}$. each evaluation indicator is standardized to a value of $Y_1, Y_2, \ldots, Y_k$, then the standardization result for the i th data item of the j th evaluation indicator is:

$$Y_{ij} = \frac{x_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \tag{9}$$

(2) Calculate the information entropy of each indicator. For an evaluation system, n evaluation indicator is used to evaluate m objects. Assuming that the evaluation matrix is $A = [a_{ij}]$ and the

standardized evaluation matrix is $R=[r_{ij}]$, and the dimensions of these two matrices are $m\times n$, the information entropy for the j th evaluation index is calculated as follows:

$$E_j=-\frac{1}{\ln m}\sum_{i=1}^{m}p_{ij}\ln p_{ij},\ j=1,2,\cdots,n \tag{10}$$

Among them:

$$p_{ij}=\frac{Y_{ij}}{\sum_{i=1}^{m}Y_{ij}},i=1,2,\cdots,n \tag{11}$$

When $p_{ij}=0$, $p_{ij}\ln p_{ij}=0$.

(3) Calculate the entropy weight of each indicator. Therefore, for the j rd evaluation indicator, its entropy weight is calculated as follows:

$$w_j=\frac{1-E_j}{n-\sum_{j=1}^{n}E_j},\ j=1,2,\cdots,n \tag{12}$$

2.4.4. Ideas for solving the model. Generally speaking, to solve a multi-objective optimization problem, each objective function in the multi-objective optimization model is transformed into a single-objective function after corresponding processing or mathematical transformation, and then single-objective optimization techniques are applied to solve the problem.

For the multi-objective optimization model established in this paper, the nature of the problem is first defined, and this study designs the model as a minimization problem, so the transformed objective function is as follows:

$$\begin{cases}\min\left(-\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{8}\varphi_k eff_{ijk}\right)\\ \min\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{8}fair_{ijk}\\ \min\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{8}norm_{ijk}\end{cases} \tag{13}$$

where φ_k denotes the proportion of each indicator, i.e., the proportion of that indicator in the allocation of resources to education. eff_{ijk} denotes the output rate target for each of the eight education indicators, and $fair_{ijk}$ denotes the objective function for ensuring equity for each of the eight indicators. $norm_{ijk}$ denotes the objective function of meeting the targets of the eight indicators.

Through analysis, the multi-objective optimization solution method chosen for the optimization model proposed in this study is the weighted method, which transforms the three objective functions above into the following objective functions:

$$F=\min\left(\omega_1\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{8}fair_{ijk}-\omega_2\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{8}\varphi_k eff_{ijk}+\omega_3\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{8}norm_{ijk}\right) \tag{14}$$

where ω_1, ω_2 and ω_3 denote the weight coefficients of the three objective functions, respectively, and satisfy the conditions: $\omega_1+\omega_2+\omega_3=1$, $0\le\omega_1,\omega_2,\omega_3\le 1$.

3. Analysis of experimental results

3.1. Algorithm Example Analysis

In order to comprehensively examine the algorithmic performance of the multi-objective optimization model constructed in this paper on a variety of problems, the test problems that we encapsulate in our comparative analysis include complex multi-objective optimization benchmark problems (CPLX), as well as multiobjective optimization benchmark problems with super-multi-tasks (MATP). Two problem types, CPLX and MATP, were selected for testing. An evaluation criterion Mean Standard Score (MSS) was used to compare and rank the different multi-objective optimization algorithms, with smaller MSS representing the relatively better optimization performance of the algorithms compared to other algorithms on all tasks.

The comparative analysis consists of two parts. The first part is to analyze the relative superiority of the multi-objective optimization model in this paper compared to the baseline approach, which here refers to the basic multi-objective optimization algorithm MOMFEA, and the basic multi-objective optimization resource allocation component MFEARR. The second part is to analyze the relative performance improvement of the multi-objective optimization model in this paper over the current optimal multi-objective optimization algorithms, including the current optimal multi-objective optimization algorithm MMDE, and the current optimal or most flexible resource allocation component MTO-DRA.

The MSS values obtained by comparing this paper's multi-objective optimization model with the optimal method on the complex benchmark problem and the super-multi-task benchmark problem after 25 independent runs are shown in Tables 2 and 3. Observing Table 2, it can be seen that the cumulative MSS values of this paper's multi-objective optimization model, MTO-DRA algorithm and MMDE are -1.400, 0.954 and 3.152 respectively, and in general this paper's multi-objective optimization model has the best results and ranks first. The MSS values of this paper's multi-objective optimization model are minimum on all CPLX problems except CPLX2, CPLX4, CPLX5 and CPLX6. From Table 3, it can be found that the cumulative MSS value of this paper's multi-objective optimization model is ranked first at -1.033. The MSS values on the MATP problems except MATP2 and MATP6 are all minimum values. It can be seen that the resource allocation efficiency of the multi-objective optimization model constructed in this paper is significantly higher than other methods.

Table 2. MSS value of our model and optimal method in the complex benchmark problem

Problem	Ours	MTO-DRA	MMDE
CPLX1	-0.199	0.425	-0.128
CPLX2	0.153	-0.636	-0.405
CPLX3	-0.699	-0.487	1.226
CPLX4	0.354	-0.148	0.986
CPLX5	0.233	-0.705	0.487
CPLX6	-0.263	0.974	-0.715
CPLX7	-0.142	0.078	1.134
CPLX8	-0.153	1.196	0.081
CPLX9	-0.004	0.003	0.001
CPLX10	-0.675	0.254	0.485
Sum	-1.400	0.954	3.152
Rank	1	2	3

Table 3. MSS value of our model and optimal method in the multi-objective benchmark problem

Problem	Ours	MTO-DRA	MMDE
MATP1	0.000	0.000	0.000
MATP2	0.067	-0.049	-0.012
MATP3	0.000	0.000	0.000
MATP4	-0.235	-0.092	-0.137
MATP5	-0.068	0.095	-0.031
MATP6	-0.152	-0.228	-0.065
MATP7	-0.234	0.192	0.032
MATP8	-0.162	0.019	0.143
MATP9	-0.201	0.033	0.173
MATP10	-0.048	0.058	-0.014
Sum	-1.033	0.028	0.089
Rank	1	2	3

3.2. Analysis of the results of optimal allocation of multi-objective resources for innovation and entrepreneurship education

3.2.1. Analysis of resource allocation levels. In this subsection, through the simulation experiment conducted by each per-pupil evaluation index, 13 colleges and universities (numbered C1~C13) in City C are used as the simulation experimental objects, and the result after the allocation of innovation and entrepreneurship education resources is multiplied by the number of students enrolled in each school, which is the optimized resource allocation scheme of each school. The optimization scheme of innovation and entrepreneurship education resource allocation in each school is shown in Table 4, where each line of data in the table represents the optimization result of innovation and entrepreneurship education resource allocation in a university, and the allocation of innovation and entrepreneurship education resources is elaborated in detail in the next section with the university C1 as an example:

The current number of full-time teachers (V1), the number of teachers with higher than required academic qualifications (V2), the number of teachers with intermediate and above professional and technical positions (V3), the total number of computers (V4), the per capita teaching instrument and equipment assets (V5), the number of AI equipment (V6), the area of teaching and auxiliary rooms (V7), and the number of innovation and entrepreneurship laboratories (V8) in university C1 are 288, 38, 28, respectively, 1385 units, 1279, 1406 units, 2967 square meters, and 11.

After the experiment, after the optimization of the distribution of resources for C1 innovation and entrepreneurship education in colleges and universities, the number of full-time teachers (V1), the number of teachers with higher than the required academic qualifications (V2), the number of teachers with intermediate and above professional and technical positions (V3), the total number of computers (V4), the per capita assets of teaching instruments and equipment (V5), the number of AI equipments (V6), the area of teaching and auxiliary rooms (V7), and the number of innovation and entrepreneurship laboratories (V8) are respectively were 488, 89, 51, 2,061 units, 2,338, 2,037 units, 7,201 square meters, and 35.

Table 4. The resource allocation optimization results of colleges in C city

	V1	V2	V3	V4	V5	V6	V7	V8
C1	488	89	51	2061	2338	2037	7201	35
C2	381	101	61	2067	2475	2060	7514	65
C3	392	81	44	2134	1946	2182	6326	50
C4	503	92	58	2216	1932	2056	6076	53
C5	348	87	42	2078	2197	2029	6371	56
C6	452	105	67	2197	2545	2177	7374	59
C7	423	85	60	2216	2373	2071	6419	59
C8	415	77	40	2035	1986	2031	6436	36
C9	435	107	59	2050	2302	2042	7465	37
C10	414	75	67	2080	2337	2078	7478	60
C11	463	77	62	2073	2382	2036	5953	36
C12	431	92	49	2112	1995	2082	7344	36
C13	376	107	37	2126	2359	2021	5578	47

In order to more intuitively observe the contrast between the schools before and after the configuration, the data of the objective function of the level of innovation and entrepreneurship education resource allocation in the model of this paper is now represented by a bar chart, and the comprehensive level of innovation and entrepreneurship education resource allocation in each school is shown in Figure 2. From this, it can be concluded that before the experiment, the level of innovation and entrepreneurship education resource allocation among schools is low, especially in college C8. After the experiment, the level of resource allocation for innovation and entrepreneurship education in each school has rebounded, with C1 of colleges and universities increasing from 6.0498 to 8.2003, and C8 of colleges and universities increasing from 4.7974 to 10.8985, and tending to be more balanced among schools.

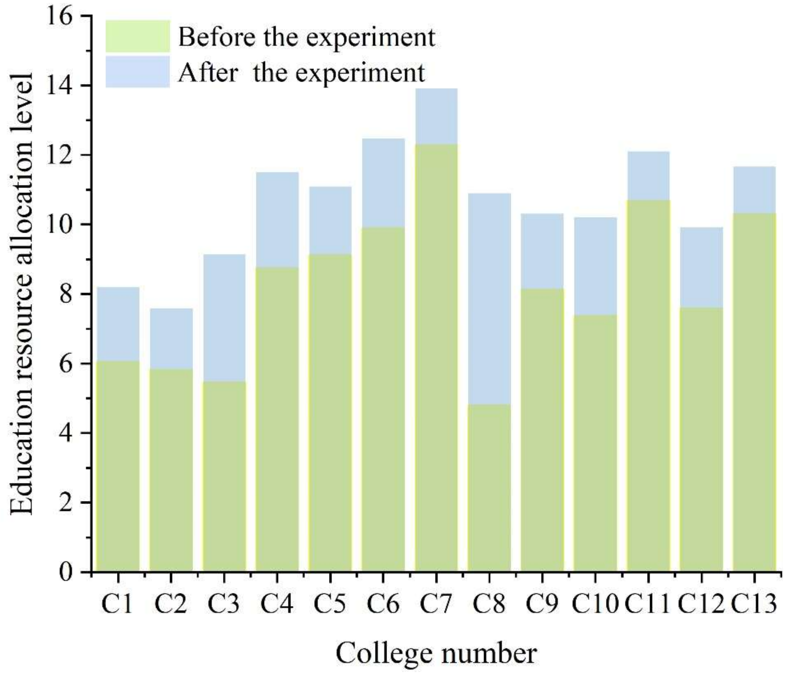

Fig. 2. Comprehensive level of resource allocation in each college

3.2.2. Analysis of resource utilization efficiency. In order to verify whether the multi-objective optimization model constructed in this paper improves the utilization efficiency of innovation and entrepreneurship education resources, 13 colleges and universities in C city are taken as examples to analyze the experimental results. The utilization efficiency of innovation and entrepreneurship education resources in each university before and after the experiment is calculated, and the results obtained are shown in Table 5.

The utilization efficiency of innovation and entrepreneurship education resources of each university before and after the experiment is improved, with an average increase of 17.02%, and the utilization efficiency of innovation and entrepreneurship education resources of each university tends to be balanced. In C1, C3, C8 and C11, which are colleges and universities with lower resource utilization efficiency, the utilization efficiency of innovation and entrepreneurship education resources increases from 0.753, 0.789, 0.736 and 0.645 before optimization to 1.043, 1.032, 1.031 and 1.076 respectively, with an improvement rate of 29%, 24.3%, 29.5% and 43.1%.

Table 5. The efficiency of resource utilization of all colleges before and after the experiment

College number	Education resource utilization efficiency		
	Before	After	Improvement rate
C1	0.753	1.043	0.290
C2	0.913	1.033	0.120
C3	0.789	1.032	0.243
C4	0.990	1.055	0.065
C5	1.004	1.057	0.053
C6	0.953	1.024	0.071
C7	0.802	1.072	0.270
C8	0.736	1.031	0.295
C9	0.869	1.045	0.176
C10	1.028	1.038	0.010
C11	0.645	1.076	0.431
C12	0.991	1.068	0.077
C13	0.927	1.038	0.111

4. Conclusion

The article empowers artificial intelligence for innovation and entrepreneurship education in colleges and universities, adopts multi-objective optimization algorithm to optimize the allocation of innovation and entrepreneurship education resources in colleges and universities, and constructs innovation and entrepreneurship education resource allocation optimization model, aiming to improve the resource allocation efficiency and resource utilization of innovation and entrepreneurship education in colleges and universities. The MSS cumulative values of this paper's multi-objective optimization model, MTO-DRA algorithm and MMDE algorithm on CPLX problem are -1.400, 0.954 and 3.152 respectively, and the MSS cumulative values on MATP problem are -1.033, 0.028, and 0.089 respectively, and this paper's model is ranked the first in terms of the efficiency of resource allocation on the two types of problems. After this paper's multi-objective optimization model for innovation and entrepreneurship resource optimization, the number of current full-time teachers in college C1 increased by 200, the number of teachers with higher than the required academic qualifications increased by 51, the number of teachers with intermediate and above professional and technical positions increased by 23, the total number of computers increased by 676, the average per capita teaching instrument and equipment assets increased by 1,059 yuan, the number of AI equipment increased by 631, and the area of teaching and auxiliary rooms increased by 4,234 square meters, and the number of innovation and entrepreneurship laboratories increased by 24.The utilization efficiency of innovation and entrepreneurship education resources in the 13 colleges and universities in City C increased by 17.02% on average.

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