CSCanada
Management Science and Engineering
Vol. 7, No. 3, 2013, pp. 76-80
DOI:10.3968/j.mse.1913035X20130703.2622

ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

Optimization Model of Higher Education Resources Allocation Based on Genetic Algorithm

ZHANG Xilin[a],*; LI Shiming[a]

[a]University of Electronic Science and Technology of China, Chengdu, China
*Corresponding author.

Received 11 April 2013; accepted 20 August 2013

Abstract
To solve the problem of the shortage of the higher education resources, the limited resources have to be allocated more efficiently and reasonably. In view of this point, the optimization allocation method of higher education resources is investigated in this paper. An optimization model of higher education resources allocation resources is designed according to the social contribution capability of higher education. And to achieve the optimal solution of the model, the resources allocation algorithm based on genetic algorithm is proposed. By this optimization model, the allocation of higher education resources can be optimized and the social contribution capability of higher can be improved. The proposed optimization model can provide a reference scheme to take full use of the limited higher education resources.

Key words: Higher education; Optimization model; Resources allocation; Genetic algorithm

ZHANG Xilin, LI Shiming (2013). Optimization Model of Higher Education Resources Allocation Based on Genetic Algorithm. *Management Science and Engineering*, *7*(3), 76-80. Available from: URL: http://www.cscanada.net/index.php/mse/article/view/j.mse.1913035X20130703.2622
DOI: http://dx.doi.org/10.3968/j.mse.1913035X20130703.2622

INTRODUCTION
In the current era of knowledge economy, as one of the most important knowledge industries, higher education has become an important means to enhance the comprehensive national strength. It has to undertake the task of transferring and creating knowledge, developing science and technology, training advanced talents and so on. It serves the society and contributes to the development of the society in all aspects by its outputs. So the quality and level of higher education has an important influence on a country's overall national quality, level of economic development, science and technology innovation ability, social and cultural development. That is why higher education and its development direction are attracting more and more attention and the countries all over the world develop higher education actively.

The development of higher education depends on the input of resources. The level, scale and achievement of higher education are depending on higher education resources. Usually, the resources that higher education needs consist of human resources, material resources, financial resources, etc. In higher education system, human resources include teaching staff, researchers, counselors, managers, and so on. They reflect the capabilities of institutions of higher education in training students, technical innovation and serving the society. Material resources generally refer to the teaching field for higher education and scientific research field and all kinds of teaching, scientific research equipment and other fixed assets, which is the materialized form of higher education investment. Financial resources mainly refer to the funding investment of higher education, including the teachers' salaries, research fund, student scholarships, social services investment and so on.

During the past three decades, China has increased the investment for higher education and promoted higher education reform continually. Through these efforts, the scale, level and coverage of higher education are improved greatly. But compared with world first-class country, the higher education resources in China are still in short supply. In education spending, for example, in 2012 financial expenditures for education of the country is

4% of GDP, which just reaches the baseline of the world. While the average value of that in the world is around 7%, and it is about 9% in developed countries. Considering the current conditions, it is not reality to increase educational resources by a large margin immediately. So the problems of the shortage of higher education resources are difficult to solve in a short time. Therefore, we must focus on efficient utilization and resources allocation optimization to make full use of the limited higher education resources and make higher education can play a more important role in economic, technological and social development and can make a greater contribution to the society.

In this paper, we design the optimization model of higher education resources allocation, whose aim is to achieve the greatest social contribution of higher education. And to solve this optimal problem, the resources allocation algorithm based on genetic algorithm is proposed. By this optimization model and its solving method, we can give a reference to allocate the limited higher education resources more efficiently to maximize the social contribution of higher education.

1. RELATED WORK

The efficiency of the resource of higher education can be reflected in its social contribution. And the social contribution of higher education originates in its achievements which rely on the investment of higher education resources.

In the field of higher education resources allocation, the researches of foreign scholars are mainly based on case study and empirical analysis, in which many statistical analysis methods are used to evaluate and investigate the efficiency and achievements of resources allocation, such as linear regression analysis method, data envelopment analysis method etc (Amy, Reuven, & Micahel, 2000; Hutchinson & Lovell, 2004; Hooshang, Geraint, Reza, & Robert, 2002). The researches of China scholars mainly include the macro policy researches such as behavior main bodies, market mechanisms and government functions of the higher education resources allocation and so on (Zeng, 2003; Xia & Zhang, 2006; Yang, 2001). The status analysis and efficiency evaluation of regional higher education resources allocation are also studied (Dong, 2003; Zhai, 2006).

The existing researches mainly focus on the analysis and evaluation of the resource allocation, whereas the researches on the optimization of resources allocation with some optimization goal are rare. While according to the description above, it is more important and significative to allocate the limited resources of higher education with a optimal method. So in this paper, we focus on the resource optimization of higher education through which higher education can make greater contribution to the society. The resource optimization in this paper is a nonlinear multi-objective optimization problem. This kind of problems is NP-hard problem which cannot be solved in polynomial time. To achieve the optimal solution of this kind of problems, some heuristic algorithms are proposed, such as genetic algorithm (Holland, 1975), ant colony algorithm (Dorigo & Gambardella, 1997), particle swarm algorithm (Clerc & Kennedy, 2002) and so on.

Compare with other algorithms, genetic algorithm is not limited to the optimization problems. It can be adapted to any kind of objective function and constraint condition, no matter what function characters. The complexity and the rate of convergence are the weakness of genetic algorithm. Fortunately, to provide the solution of the problem of higher education resource optimization, we do not have to run this algorithm frequently and the algorithm speed is not important. So we use genetic algorithm to solve the optimization problem in this paper.

2. OPTIMIZATION MODEL OF HIGHER EDUCATION RESOURCES

Depending on its resource investment, higher education makes contributions to the society through its achievements in many aspects such as the development of economic, technology and society. The social contribution is the ultimate value of higher education. So in this paper, the optimization of higher education resources allocation is investigated from the perspective of social contribution of higher education. And because the development of higher education has different degrees of effect on economy, science and social development, in order to describe the social contribution of higher education roundly and scientifically, the social contribution is formed by the contributions to economic development, science and technology development and social improvement.

The social contribution of higher education can be defined as

$$C_{total}=W_E \cdot C_{total}(E)+W_T \cdot C_{total}(T)+Ws \cdot C_{total}(S) \quad (1)$$

In which $C_{total}(E)$, $C_{total}(T)$, $C_{total}(S)$ represent the contribution of higher education to economic development, science and technology development and social development respectively. W_E,W_T,W_S represent the weights of the contribution of higher education to economic development, science and technology development and social development in the comprehensive contribution respectively.

According to the achievements and contributions to the society generated by the higher education resources investment, higher education resources can be divided into three aspects including the investment to promote economic development (such as investment for students cultivation, technology training, etc), investment to promote technology development (such as investment for science research, technology development) and investment to promote society development (such as investment for social public welfare, construction of spiritual civilization). In each aspect, the resources include human resources, material resources and financial resources. Social contribution of higher education is finally formed by the investment of these resources.

In this paper, the human resource investment is indicated as α, the material resource investment is indicated as β and the financial resource investment is indicated as γ. In the constant external environment, the contribution of higher education mainly depends on the investment. $C_{total}(E)$, $C_{total}(T)$, $C_{total}(S)$ can be indicated as functions of α, β and γ, such as

$$\begin{aligned} C_{\text{total}}(E) &= A_E(\alpha_E, \beta_E, \gamma_E) \\ C_{\text{total}}(T) &= A_T(\alpha_T, \beta_T, \gamma_T) \\ C_{\text{total}}(S) &= A_S(\alpha_S, \beta_S, \gamma_S) \end{aligned} \quad (2)$$

The emphasis of this paper is to establish the resources optimization model and propose the method to solve it. The specific value of the parameters such as the weights of each index in the model and the expression of contribution of higher education in each aspect have no effect on the optimal problem and its solving method. Therefore, in order to research the optimization of higher education resource, we assume that W_E, W_T and W_S are constants, nothing with the investment of education resource.

Considering the balance among each aspect of the social contribution, we take the balance into account. The balance of the higher education comprehensive contribution can be defined as

$$\Phi_{\text{total}} = \frac{\left(\sum_{s\in(E,T,S)} C_{\text{total}}(s)\right)^2}{3\times\sum_{s\in(E,T,S)} C_{\text{total}}^{\;2}(s)} \quad (3)$$

And when the economic, technology and social contribution of higher education are equal, the balance achieve the maximum, and meanwhile Φ_{total}=1.

The optimization model of higher education resource is described as the following optimization problem:

$$\textbf{(P1)} \quad \begin{aligned} &\max C_{\text{total}} \\ &\max \Phi_{\text{total}} \\ \text{s.t.}\quad &C1: \sum_{s\in(E,T,S)} \alpha_s \le \alpha \\ &C2: \sum_{s\in(E,T,S)} \beta_s \le \beta \\ &C3: \sum_{s\in(E,T,S)} \gamma_s \le \gamma \end{aligned} \quad (4)$$

In this problem, α_E, β_E and γ_E refer to the investment of education for economic development, α_T, β_T and γ_T refer to the investment of education for science and technology development, α_S, β_S and γ_S refer to the investment of education for social development. α, β, γ refer to the total human resources, material resources and financial resources can be invested respectively.

This optimization model aims to maximize the social contribution of higher education and make balance among the contribution to each aspect with the limit of higher education resources.

3. SOLVING THE OPTIMIZATION PROBLEM BASED ON GENETIC ALGORITHM

3.1 Design of the Population and the Fitness Function

Genetic algorithm simulates the biology evolution scheme, which can solve almost all optimization problems. The basic and main operations of genetic algorithm are encoding, fitness function calculating, selection, crossover and mutation. In genetic algorithm, many possible solutions of the optimization problem form a population. Each possible solution forms a chromosome. Through crossover and mutation, new chromosomes are born generation by generation, and finally, the chromosome which maximizes the fitness function can be selected as the solution of the optimization problem. In this paper, we solve the optimization problem of higher education resources allocation by genetic algorithm. The allocation of higher education resources is the needed solution. So the chromosomes are formed by α_S, β_S and γ_S described in P1. And we encode the chromosomes into binary strings, as shown in Table 1.

Table 1
The Structure of the Chromosome

α_E	α_S	α_T	β_E	β_S	β_T	γ_E	γ_S	γ_T
101...01	01...01	1010...01	100...011	1...1001	1011...01	101...0100	101...0011	101...01101

The chromosomes can be described as

$$X_i = \{x_1, x_2, ..., x_j, ...\}, \quad x_j \in \{0,1\} \quad (5)$$

The population formed by many chromosomes is

$$P=\{X_1, X_2, ..., X_i, ...\} \quad (6)$$

The fitness function is usually the objective function of the optimization problem. In P1, there are to objective functions, so we try to transform the two objective functions into one fitness function. Although the fairness constraint has been transformed into the objective function in P1, the complexity of the solution is not reduced. To decrease the complexity of the solution, problem P2 can be simplified as

$$\max C_{\text{total}} \,\&\&\, \max \Phi_{\text{total}} \rightarrow \max \Phi_{\text{total}} \tag{7}$$

Despite the arrow on the left are sufficient conditions on the right side of the problem, but not necessary conditions. In most cases, if the inequality constraint conditions C1, C2 and C3 establish, two objective functions can be approximately equal. Besides, the constraint conditions C1, C2, C3 can be transfer into the objective function by using penalty functions.

$$\begin{aligned}&(\mathbf{P}2)\max \Phi_{\text{total}}\\ &\rightarrow \max\left(\Phi_{\text{total}} - \varpi_1|\alpha-\alpha_S-\alpha_E-\alpha_T| - \varpi_2|\beta-\beta_S-\beta_E-\beta_T| - \varpi_3|\gamma-\gamma_S-\gamma_E-\gamma_T|\right)\\ &= \max L\end{aligned} \tag{8}$$

In which $\varpi_1|\alpha-\alpha_S-\alpha_E-\alpha_T| - \varpi_2|\beta-\beta_S-\beta_E-\beta_T| - \varpi_3|\gamma-\gamma_S-\gamma_E-\gamma_T|$ can make sure that the resources are fully used, which means that the utility function can be maximized. Once the resources are underused or is beyond the scope constraint, the objective function will be punished, meanwhile $\varpi_1, \varpi_2, \varpi_3$ represent the punish degrees to different resources. The fitness function is design as

$$L = \Phi_{\text{total}} - \varpi_1|\alpha-\alpha_S-\alpha_E-\alpha_T| - \varpi_2|\beta-\beta_S-\beta_E-\beta_T| - \varpi_3|\gamma-\gamma_S-\gamma_E-\gamma_T| \tag{9}$$

3.2 The Progress of Higher Education Resources Optimization based on Genetic Algorithm

The progress of higher education resources optimization based on genetic algorithm (GA) is shown in Figure 1.

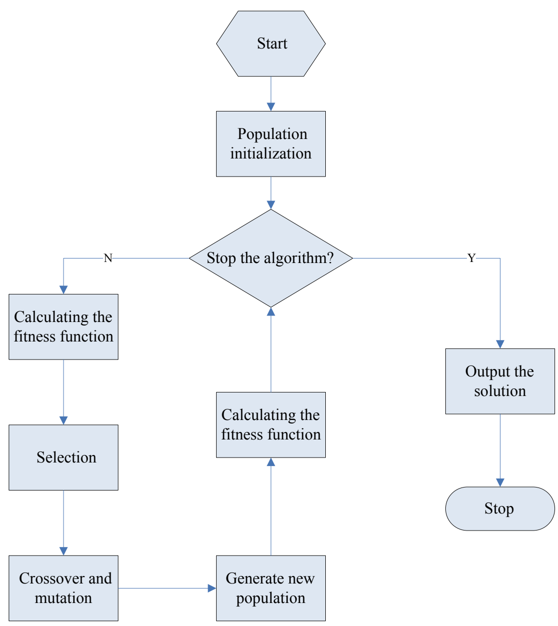

Figure 1
The Flow Chart of Resources Allocation Optimization Based on GA

The detail of each step is described as follows.

(a) Population initialization

In this paper, we generate a population of 100 chromosomes. The chromosomes are initialized by using the average principle. For the *i*th chromosome, the initialized values of the resources are

$$\begin{aligned}&\alpha_S^i = \frac{\alpha}{3} + n^i{}_{\alpha_S} && \beta_S^i = \frac{\beta}{3} + n^i{}_{\beta_S} && \gamma_S^i = \frac{\gamma}{3} + n^i{}_{\gamma_S}\\ &\alpha_E^i = \frac{\alpha}{3} + n^i{}_{\alpha_E} && \beta_E^i = \frac{\beta}{3} + n^i{}_{\beta_E} && \gamma_E^i = \frac{\gamma}{3} + n^i{}_{\gamma_E}\\ &\alpha_T^i = \alpha-\alpha_S^i-\alpha_E^i-n^i{}_{\alpha_T} && \beta_T^i = \beta-\beta_S^i-\beta_E^i-n^i{}_{\beta_T} && \gamma_T^i = \gamma-\gamma_S^i-\gamma_E^i-n^i{}_{\gamma_T}\end{aligned} \tag{10}$$

In which $n^i{}_{\alpha_S}$, $n^i{}_{\alpha_E}$, $n^i{}_{\alpha_T}$, $n^i{}_{\beta_S}$, $n^i{}_{\beta_E}$, $n^i{}_{\beta_T}$, $n^i{}_{\gamma_S}$, $n^i{}_{\gamma_E}$, $n^i{}_{\gamma_T}$, are nonnegative random variables which follow Gaussian distribution.

According to the structure of the chromosome shown in Table 1, these values are encoded into a binary string, which is a chromosome X_i. And the chromosomes of *n*th population are $X^n{}_i$. The *n*th population is

$$P^n = \left\{X^n{}_1, X^n{}_2, \ldots, X^n{}_i, \ldots\right\} \tag{11}$$

(b) Calculating the fitness function

For each chromosome, calculate the fitness function value according to formula (9).

(c) Selection

Select the first *m* chromosomes that have higher fitness as the possible parent chromosomes. The descendants are generated by these excellent parents.

Select the crossover parents in these chromosomes randomly with probability P_c^n. And select some mutation chromosomes randomly with probability P_m^n. Considering the ripeness of the population and the diversity of chromosomes, the crossover probability P_c^n should be decreased generation by generation, while the mutation probability P_m^n should be increased generation by generation. So we design the crossover probability and the mutation probability as

$$\begin{aligned}P_c^n &= P_c\,(1-n/M)\\ P_m^n &= P_m\,(n/M)\end{aligned} \tag{12}$$

In which, M is the number of the generations in the whole genetic progress. And n is the sequence number of the current generation.

(d) Crossover and mutation

Crossover is to exchange the genes in each two parents to generate the new chromosomes. And then the new chromosomes form the new population. Assume that the parents which are going to crossover are $X^n{}_1$ and $X^n{}_2$. They will generate two descendants, which are $X^{n+1}{}_1$ and $X^{n+1}{}_2$. Let

$$\begin{aligned}X^n{}_1 &= \left\{x^n{}_{11}, x^n{}_{12}, \ldots, x^n{}_{1j}, \ldots\right\}, \quad x^n{}_{1j} \in \{0,1\}\\ X^n{}_2 &= \left\{x^n{}_{21}, x^n{}_{22}, \ldots, x^n{}_{2j}, \ldots\right\}, \quad x^n{}_{2j} \in \{0,1\}\end{aligned} \tag{13}$$

Then there descendants by crossover are

$$X^{n+1}{}_{1}=\left\{x^{n+1}{}_{11},x^{n+1}{}_{12},...,x^{n+1}{}_{1j},...\right\},\quad j=1,2,...N$$
$$X^{n+1}{}_{2}=\left\{x^{n+1}{}_{21},x^{n+1}{}_{22},...,x^{n+1}{}_{2j},...\right\},\quad j=1,2,...N \tag{14}$$

In which

$$x^{n+1}{}_{1j}=rx^{n}{}_{1j}+(1-r)x^{n}{}_{2j}$$
$$x^{n+1}{}_{2j}=rx^{n}{}_{2j}+(1-r)x^{n}{}_{1j} \tag{15}$$
$$r\in\left\{0,1\right\}$$

Mutation is to change some binary bits in each chromosome randomly with P_m^n so that a new chromosome is generated.

In order to get the most excellent chromosomes, when generate new chromosomes, the chromosome which has the best fitness in the previous generation will not be change.

(e) Checking the stop conditions

Set M is the number of all the generations in this genetic algorithm and n is the sequence number of current generation. If $n=M$, the algorithm stop. And if the maximal value of the fitness function does not change during ten generations, the genetic algorithm stop. And the chromosome which has the best fitness can be get as the optimal solution of the optimization problem.

By running the proposed algorithm, when the algorithm stops, the optimal solution will be achieved. The solution is the optimal allocation scheme of higher education resources. And by this allocation scheme, under the limit of total resources, the largest social contribution of higher education can be reached, and meanwhile the all aspects of the social contribution can be made balance.

CONCLUSION

The shortage of the higher education resources is one of the most serious problems which restrict the development of higher education. Since it is difficult to increase the total quantity of higher education significantly in a short time, trying to improve the allocation efficiency of higher education resources is more important and meaningful. To make higher education contribute to the society more under the limit of resource quantity, an optimization model of higher education resources allocation based on genetic algorithm is proposed in this paper. By this optimization model and its solving method, the resource of higher education can be allocated more efficiently and reasonably to improve the contribution capability of higher education.

REFERENCES

Amy, C., Reuven, R. L., & Micahel, C. S. (2000). Determining the relative efficiency of MBA programs using DEA. *European Journal of Operational Research*, *125*(3), 656-669.

Clerc, M., & Kennedy, J. (2002). The particle swarm-explosion, stability, and convergence in a multidimensional complex space. *IEEE Transactions on Evolutionary Computation*, *6*, 58-73.

Dong, Y. (2003). *Analysis on distribution of S&T resource of Hebei's higher education institutions based on game theory* (Unpublished academic dissertation). Hebei University of Technology, Hebei. (In Chinese).

Dorigo, M., & Gambardella, L. M. (1997). Ant colonies for the travelling salesman problem. Biosystems, 43(2), 73-81.

Holland, J. H. (1975). Adaptation in natural and artificial systems. Ann Arbor: University of Michigan Press.

Hooshang, I., Geraint, J., Reza, O., & Robert, C. (2002). Stochastic frontier estimation of a CES cost function: The case of higher education in Britain. *Economics of Education Review*, *21*(1), 63-71.

Hutchinson, S. R., & Lovell, C. D. (2004). A review of methodological characteristics of research published in key journals in higher education: Implications for graduate research training. *Research in Higher Education*, *45*(4), 383-401.

Xia, L. P., & Zhang, Z. Y. (2006). The subject of higher education resource allocation in China. *Journal of Southwest University for Nationalities (Humanities and Social Science)*, (1), 238-240. (In Chinese).

Yang, D. L. (2001). On the optimization in the allocation of resources and the industrialization in higher education. *Economic Survey*, (5), 28-30.

Zeng, J. R. (2003). About the problem of optimizing the allocation of higher educational resources. *Journal of Southwest Jiaotong University (Social Sciences)*, (1), 12-16. (In Chinese).

Zhai, X. H. (2006). Governance mechanism: The complementary mechanisms for the allocation of higher educational resources. *Journal of Inner Mongolia Normal University (Education Science)*, (1), 28-30. (In Chinese).