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RESEARCH ON REGIONAL SCIENCE AND TECHNOLOGY INVESTMENT BASED ON PLANT GROWTH SIMULATION ALGORITHM

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Abstract. *According to the tolerance capacity and making maximal use resources of regional investment in science and technology, the entity of investment will select the optimization point to determine the funds of input in the whole society investment system for science and technology. This paper takes the optimized innovation investment as the growth environment of plants and the optimal input state as the mechanism of real plants growth. In this way, a simulated plant growth algorithm based on the regional scientific and technological input game analysis model is constructed which is used to find the best optimal state of the financial and technology investment. It provides a new way to understand the optimization problem of regional science and technology innovation.*
Keywords: Investment in regional science and technology innovation, Plant growth simulation algorithm, Optimization research

1. **Introduction.** PGSA (Plant Growth Simulation Algorithm) regards feasible regions of optimization problems as growth environments and global optimization as light sources. The entire process of searching for optimal solutions is regarded as a virtual growth process of plant growth. When the entire plant virtual fully matures the entire optimization process is over, and finally output the result of the optimization question [1-3]. The current algorithms used to solve practical problems are genetic algorithms, ant colony algorithm, simulated annealing algorithm, particle ant colony algorithm, DEA (Data Envelopment Analysis) intelligent algorithm and PGSA. After the simulation of plant photosynthesis is proposed the phototropism of plant growth has made extensive use of different aspects of logistics facilities location, power system optimization and technology alliance investment decision-making. It turns out that PGSA has higher accuracy, faster global optimization ability and more stable solution compared with ant colony, TABU and other algorithms [4,5].

Scientific and technological innovation is the benchmark for supply-side structural reforms. Driven by science and technology innovation that is the core strategy to improve social productivity and overall national strength, it is the direction of the development and growth of the real economy. Regional science and technology innovation-driven development strategy is an important part of the development strategy of China's science and technology innovation, while the investment in science and technology is the most direct impact of regional scientific and technological progress, the most important factor, the core factor of economic development as well [6,7]. The components of regional science and technology innovation system mainly consist of two parts: the innovation body of enterprises and research institutes, the government as the source of financial science

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and technology funding is also the system-maker and the leader of private investment. Enterprises, universities and research institutes, as the providers of important funds, are also the execution themes of funds. They are crucial to the entire system of science and technology investment. Coordinating the relations between the government, enterprises and research institutes are the basis for optimizing the investment in science and technology [8,9]. For all the investment, government investment in science and technology improves the technological innovation ability and social and economic development. The enterprise is changing knowledge-producing activities to actual productivity in line with the characteristics of market demanded to bring economic benefits for the enterprise. In order to carry out basic research on the characteristics of innovation and exploration, universities mainly focus on applied research and technology promotion activity [10]. How to determine the amount of government and non-governmental institutions investments in regional science and technology is not only a decentralized decision-making problem but also an optimization problem.

In the regional science and technology investment system, in order to achieve their own goals all science and technology investment subjects will make the best use of the whole society's science and technology resources and increase the input-output ratio according to their own affordability. It is equivalent to each subject choosing the best growth point in the science and technology investment system and determining the input amount through the growth point. This feature of science and technology investment is consistent with the plant phototropism considered in the simulation of plant phototropism. Through establishing the simulated plant phototropism with technology investment, the optimal scheme of each subject's investment can be analyzed. Therefore, based on the game analysis model of scientific and technological investment [11], this paper studies the feasibility of regional scientific and technological investment using simulated plant growth algorithm, which provides a basis for scientific investment decisions of various innovative subjects, and guides the reasonable allocation of resources, efficient utilization of scientific and technological innovation funds.

2. The Game Analysis Model for Science and Technology Investment.

2.1. The game unit of technology investment.

Assume that $N = \{1, \ldots, n\}$ $(n \geq 2)$ is the main for all investments in science & technology. The main investment i in k (science and technology research institute) is y_{ii}, and the investment of financial science and technology funds in k is y_{ik}, $y_i = (y_{ii}, y_{ik})$ is the regional research and development investment strategy set of enterprise i in k.

In the game of regional scientific and technological capital investment, k is the basic game unit of scientific and technological capital investment. For a single game unit, the income maximization is the decision basis of scientific and technological capital input.

2.2. Investment income from main body of science and technology investment.

Based on the basic model of game analysis of science and technology input by Wang [11], take account of the public properties of science and technology resources. The revenue from financial science and technology investment is as follows.

$$R_i = f(y_{ii} + y_{ik}) + \theta_i \tag{1}$$

where $f(Z_i)$ $(Z_i = y_{ii} + y_{ik})$ is a production function, and if $f'(Z_i) > 0$, $f''(Z_i) < 0$, and θ_i is an exogenous variable that is not controlled by the technology investment subject, $\theta_i \sim N(0, \theta^2)$ at the same time. It is assumed that the linear relationship between y_{ik} and y_{ii} is satisfied: $y_{ik} = \alpha_i + \beta_i y_{ii}$, α_i and β_i are designed as constants, then

$$Z_i = \alpha_i + (1 + \beta_i) y_{ii} \tag{2}$$

Suppose the investor's distribution of income is: $P_i = mR_i$, m is the share of output shared by the investors (assuming m is constant, $0 < m < 1$), then the revenue of the

investment in regional science and technology funds is $\lambda_i = R_i - y_{ik} - P_i$. If the utility function of investment in science and technology is $v(x)$, then the corresponding utility is $v(\lambda_i)$, the net income of independent investment is: $\delta = P_i - y_i$, then the utility of independent investment is $u(\delta) = u(P_i - y_i)$, $u(\delta_0)$ that retains the utility, and then the regional science and technology to maximize the benefits of science and technology investment model can be expressed as:

$$\begin{aligned} &\text{Max } E[v(R_i - y_{ik} - P_i)] \\ &\text{s.t. } E[u(P_i - y_{ii}) \geq u(\delta_0)] \\ &y \in \arg\max E[u(P_i - y_{ii})] \end{aligned}$$

Suppose the market is effective. The expected utility of the main body of science and technology funding is equal to the expected return, and that is for the main financial technology investment:

$$E[v(R_i - y_{ik} - P_i)] = E(R_i - y_{ik} - P_i) = (1 - m)f(Z_i) - (\alpha_i + \beta_i y_{ik}) \tag{3}$$

For non-financial science and technology input main body:

$$E[u(P_i - y_{ik})] = E(P_i - y_{ik}) = mf(Z) - y_{ik} \tag{4}$$

So the equivalent form of the above model is:

$$\begin{aligned} &\text{Max } \pi(y_{ii}, y_{ik}) = (1 - m)f(y_{ii} + y_{ik}) - (\alpha_i + \beta_i y_{ik}) \\ &\text{s.t. } mf(Z) - y_{ik} \geq \delta_0 \\ &Z \in \arg\max mf(Z) - y_{ik} \end{aligned}$$

3. **Financial Science and Technology Investment Algorithm Based on PGSA.** The increase of revenue from regional science and technology investment will increase its enthusiasm for investment in science and technology [11]. However, the increase of the revenue from financial science and technology investment will increase the overall income of the region and the investment in science and technology to maximize the benefits not only affected by the investment in science and technology, but also by non-financial entities. Therefore, indecision of investment in science and technology, the income of investor is affected by all the subjects of science and technology investment. How to optimize the investment structure is the key to maximize regional revenue.

Considering that there are investors in the system of scientific and technological capital investment, the final result of investment decisional is to maximize $\pi(y_{ii}, y_{ik})$. Therefore, this decision can be expressed as the investment structure of technology investment subject under the premise of portfolio optimization investment in science and technology investment y_{ik} and non-financial investment in science and technology to optimize the main investment y_{ii} regional economic returns to maximize investment decisions. It can be expressed as:

$$\max \sum_{i=1}^{n} (1 - m)f(y_{ii} + y_{ik}) - (\alpha_i + \beta_i y_{ik})$$

In the simulation plant growth optimization model of investment decision in science and technology the optimal growth point is found by the optimization of the investment subject's investment in the random growth of the expected return through the growth point. The process is as follows: in the science and technology capital investment system, based on the premise of market efficiency, the investment in science and technology in the probability of space in accordance with the growth of plants randomly adjusts the amount of capital investment until the optimal combination is found. What plant dendrite concentration to a certain degree is the same process. The process of simulation of plant growth mathematical simulation is as follows.

Plants are composed of roots, trunk, branches, and growing points. Black-box experiments in biology have confirmed that plant growth has the property of growing light, because of the auxin, also known as the morpheme. The growth order and phototropism of stems and branches are determined by the concentration of auxin in the growing points distributed on the branches. When the morphemes concentration is greater than zero the growth point of the main stem and branch begins to grow and the growth rate of morpheme concentration is higher. The morphemes will be reallocated to each growing point during growth according to the changes in the environment of new system. The growth process can be described as follows. First, a stem breaks through the soil and distributes new growth on the growing point. Second, most of the new branches grow again, which is repeated. Third, different branches are similar to each other and the whole plant has a self-similar structure.

Assuming that a plant begins to grow from the point S_0 at the root, and there are k spots on the trunk m that are better than the roots which are $S_{m1}, S_{m2}, \ldots, S_{mk}$, then the morphemes concentrations $P_{m1}, P_{m2}, \ldots, P_{mk}$ can be expressed by the following formula:

$$P_{mi} = \frac{f(S_0) - f(S_{mi})}{\sum_{i=1}^{k} (f(S_0) - f(S_{mi}))}, \quad i = 1, 2, \ldots, k \tag{5}$$

where $f(*)$ is the environmental information function for each point, by the following formula:

$$\max \sum_{i=1}^{n} (1 - m) f(y_{ii} + y_{ik}) - (\alpha_i + \beta_i y_{ik})$$

The smaller value is, the better light conditions are, and the concentration range of the morpheme is $(0, 1)$, which can be obtained from Formula (5). That is the concentration of the morphemes at all growing points constitutes the space shown in Figure 1.

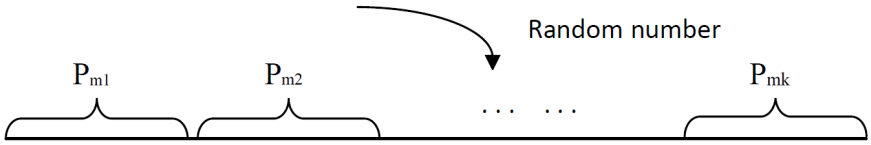

FIGURE 1. Concentration range of the morpheme

Using a random number between $[0, 1]$ generated by computer, the number is like a ball thrown between $[0, 1]$ in Figure 1, it falls on $P_{m1}, P_{m2}, \ldots, P_{mk}$, in a certain state space, the corresponding growth point will be given priority to grow. Assuming that the ball falls within the P_{m3}, then S_{m3} will be preferential growth, assuming that q growing points $S_{m1}, S_{m2}, \ldots, S_{mq}$ grow better than the root lighting conditions with a concentration of $P_{m1}, P_{m2}, \ldots, P_{mkq}$, at this time, the plant's growth environment has changed, the morpheme concentration of each growth point needs to be redistributed according to the changes in the environment of the new system, and the formula is:

$$\begin{cases} P_{mi} = \dfrac{f(x_0) - f(S_{mi})}{\sum_{i=1}^{k} (f(x_0) - f(S_{mi})) + \sum_{j=1}^{q} (f(x_0) - f(S_{mj}))} \\ P_{mj} = \dfrac{f(x_0) - f(S_{mj})}{\sum_{i=1}^{k} (f(x_0) - f(S_{mi})) + \sum_{j=1}^{q} (f(x_0) - f(S_{mj}))} \end{cases} \tag{6}$$
$$i = 1, 2, \ldots, k, \quad j = 1, 2 \ldots, q$$

From Formula (6) we know that $\sum_{i=1}^{k} P_{mi} + \sum_{j=1}^{q} P_{mj} = 1$. At this point, the old growth points of the new branches will be removed from the growth set, and the new growth points will be added, and the process will be repeated until no new branches are produced. The above program into matlab software, we can get the optimal market investment in the region under the optimal investment.

4. **Algorithm Simulation Analysis.** Based on seven of the 2017 Beijing manufacturing technology that enable the larger small class industry as the research object, with sales of new products to represent its scientific output (Table 1), the transportation equipment manufacturing industry of fiscal inputs of science and technology is the largest, which is 286.46 million. The largest financial investment of enterprises in science and technology is the motor manufacturing industry, which is 3886.77 million, nonmetallic mineral industry is 578.24 million which input is the Minimum.

Table 1. Input and output of science and technology

Industry	Financial	Company	Sales revenue of new products
pharmaceutical industry	7961	195069	1738715
ordinary machinery	3224	122252	2023103
special equipment	11122	187121	2324728
motor industry	2537	388677	9467665
transportation equipment	28646	134716	1626283
electrical machinery	1956	216074	3783315
nonmetallic mineral	1822	57824	1670964

Table 2. Optimization results

Industry	Financial	Company
pharmaceutical industry	10286.23	208579.56
ordinary machinery	9876.49	135976.24
special equipment	10875.51	198679.48
motor industry	2465.79	216897.71
transportation equipment	37854.37	128954.20
electrical machinery	6589.43	235432.82
nonmetallic mineral	3598.26	62314.59

Through the regional science and technology investment algorithm program based on simulated plant growth algorithm, we get the optimal investment amount of corresponding science and technology innovation investment. The results are shown in Table 2: pharmaceutical industry, ordinary machinery, transportation equipment manufacturing, electrical machinery and nonmetallic mineral manufactures should increase financial investment in science and technology, and special equipment and the fiscal expenditure on motor industry manufacturing can be reduced. At the same time, pharmaceutical manufacturing, ordinary equipment manufacturing industry, special equipment manufacturing, transportation equipment manufacturing, electrical machinery and nonmetallic mineral manufactures should increase its corporate research inputs. It indicates that there is a lot of room for improvement in the investment of manufacturing technology in Beijing.

5. **Conclusions.** In global competition environment, technological innovation is the drive source of transformation and upgrading of regional industrial structure adjustment. The core of promote transformation and upgrading of enterprise strategy is to improve the

social productivity and comprehensive strategic support. The investment optimization of regional science and technology innovation has always been the focus and difficulty of scholars at home and abroad. The simulated plant growth algorithm is a new optimization algorithm. Moreover, PGSA does not need to set multiple parameters, and the problem solving process does not have too many restrictions, opening a new door for new scientific and technological innovation investment research.

Based on the analysis, it can be seen that the optimal input amount of each investment entity can provide a more practical reference for the national management practice and enterprise development support. It can also provide references for enterprises to make decisions on their own research and development activities, so as to promote the realization of sustainable development of enterprises and ultimately enhance their competitiveness and further growth of enterprises. Colleagues can guide the rational allocation of scientific and technological innovation funds. Of course, this is only the beginning, and there are still some shortcomings in the algorithm. In the next step, enterprises can be selected as the investment subject for verification.

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REFERENCES

[1] K. R. Shi, Z. J. Ruan, Z. R. Jang, Y. Zhang and Q. P. Lin, Research on the improved strategy of simulated plant growth algorithm and optimization of derivative structure, *Journal of Architectural Structure*, vol.39, no.1, pp.120-128, 2018.

[2] P. Dietmar and F. Moller, Digital manufacturing or industry 4.0, *Guide to Computing Fundamentals in Cyber-Physical Systems*, Springer, 2016.

[3] Q. K. Cao, X. Y. Liu and X. Y. Ren, Vehicle scheduling problem based on simulated plant growth algorithm, *Systems Engineering – Theory & Practice*, no.6, pp.1449-1456, 2015.

[4] G. H. Fan, G. D. Wu, Q. Zhou and Y. Le, Research on simulation modeling method of teaching virtual plant growth, *Journal of Hebei Agricultural University*, vol.19, no.5, pp.68-72, 2017.

[5] T. Li and Y. C. Chen, Simulated plant growth algorithm for solving nonlinear bilevel programming problems, *Management Science in China*, vol.20, no.4, pp.160-166, 2012.

[6] B. Zhu and D. S. Ren, Multi-index extension comprehensive evaluation of science and technology development capability under innovation driven – Fuzhou as an example, *Science and Technology Management Research*, no.17, pp.85-92, 2017.

[7] D. Coe and E. Helpman, International R&D Spillovers, *European Economic Review*, vol.39, pp.859-887, 1995.

[8] Y. T. Sun, F. C. Liu and X. Xu, Analysis on the evolution of regional S&T input structure based on specialization coefficient in China, *Management Commentary*, vol.23, no.2, pp.80-87, 2011.

[9] J. L. Zhao, Optimized allocation of regional science and technology resources for independent innovation, *Academic Exchanges*, no.6, pp.102-105, 2012.

[10] C. Shen and Y. H. Lou, Path selection and countermeasures for optimal allocation of science and technology resources, *Business Economics*, no.7, pp.19-21, 2010.

[11] L. S. Wang, The game analysis model of technology input, *Mathematical Statistics and Management*, no.1, pp.109-111, 2005.