The Regulation of Simulation and Decision-making with Grey Systems Model in System Dynamics

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Abstract - The paper discusses the joint application in each link of system dynamics and grey theory by the similarities and differences in them. It probes emphasis into the regulation of the rate variables of system dynamics by GM (1, 1) model with example. This research has positive practical value with simulation and decision analysis in system dynamics.

Index Terms - system dynamics, rate variable, grey systems model

1. Introduction

The system dynamics is a discipline which analyzes the information feedback systems. It highlights the simulation among the structures, functions and behaviors in complex systems. (1) To realize the simulation of complex systems, we have to construct quantitative equations of the variables and adjacent variables in the flow diagram of system dynamics. The key point of realizing the systematic scientific simulation is how to choose proper methods to construct these equations. In the studies we find that there is special value of the grey model in the construction of the equations in system dynamics, especially in the regulation of the rate variables, the value of

2. Object of Study and Method

A. *Object of Study*

The object is the regulation of the rate variables in system dynamics. In the paper we take the training management system of college athletic talents as an example.

B. *Method*

The paper is based on the literature analysis and to illustrate by analyzing the example. It makes use of the system dynamics model and the grey GM (1, 1) model.

3. Results and Analysis

A. *The Similarities and Differences between System Dynamics and Grey System*

The system dynamics and the grey system are two different theory systems. The system dynamics first constructs network structure of the complex system, after which it explores the simulation behaviors of the complex system as a whole with the relationship between the adjacent variables in the network structure. Its focus is on the relationship between the structures and the functions of the system. (2) While the grey system constructs the poor information model with the known information and simulates the development and change of the system. Its focus is on the construction method of the poor information system. (3) (4)

However, there is unusual similarity in the construction of equations of the two theories. That is: the system dynamics holds the thinking of data derivation from the past and present to exploring the future, which is similar to the data analysis principle of the grey system that numbers can be found by other numbers. Especially in the construction of models of small and medium scale in system dynamics, with the lack of the amount of original data, the grey model enjoys incomparable superiority with its feature of poor information, compared with other modeling methods based on the probability theory.

B.The Application of the Grey Theory in the System Dynamics

The three main study processes in system dynamics are: construction of models, establishing of equations and the simulation analysis. (5) The application prospects of the grey theory in the three are all extensive.

First, the construction of the system dynamics models mainly relies on the researcher's practical experience, and the derivation is qualitatively rather than quantitatively, from the causal relationship diagram to the system flow diagram. If the system is too complex and requires simplification of the indicators to construct the structures clearly, the grey relational method becomes a proper screening method. (6) Moreover, the dynamic feature of the grey relational analysis is quite similar to the guiding theory of the system dynamics that the simulation of the system environment of the future should be based on the temporal evolution.

To establish the flow diagram equation in system dynamics, there are many modeling methods, among which we cannot say the grey model is the best. But in the condition that the data information collected by the variables in the system is limited, the grey modeling method undoubtedly enjoys huge superiority.

C. *The Theoretical basis and Operation Method of GM (1, 1) Model in the Regulation of Simulation and Decision-making*

The regulation of simulation and decision in system dynamics is realized by the regulation of the rate variables in the system dynamics flow diagram. Whether the GM (1, 1) model is proper in the regulation of rate variables, we can research from the aspects of theory and operation.

1) Theoretical Basis of GM (1, 1) Model in Regulation of Rate Variables

The rate variables in system dynamics is the starting point of the system simulation analysis. The existence of rate variables leads to the constant change of the system, thus the simulation predication of the future state of the system. (9)

2) Operation Method of GM (1, 1) Model in Regulation of Rate Variables

The simulation of the system dynamics model first changes the magnitude of a certain rate variable, and transmits the numerical values of the changed variables one by one, finally changes the whole system. It will select the relatively ideal model state among the several models produced by the changes of different degrees in the several rate variables. Directed towards the changing way of the rate variables in this state, there comes the relatively ideal decision-making program of the system.

However, there are two serious problems in the traditional selecting way of decision-making in system dynamics. First, the difficulty of the changing of rate variables is not taken into consideration. If a program where the numerical values are ideal, while the operation is difficult, it can never be an ideal decision-making program. Second, the changing range of the rate variables is vague. It is a key point in decision-making in what range the rate variables can be changed, beyond which the reliability of the decision-making will be lost.

About how we can turn from the qualitative regulation of experience to the quantitative regulation of numerical value, the grey model provides an ideal solution.

About the problem of handling the changing of rate variables, if all the rate variables in system dynamics model are estimated by the GM (1, 1) model, the values we get develop naturally in the present state, thus the difficulties of the rate variables reaching the estimated level are generally equal. We can assume the level standard of equal difficulty.

About the problem of defining the changing range of the rate variables, we can calculate the grey interval of the values of rate variables. Though this interval may not be the definite maximum changing interval of rate variables, it is the definite possible interval. The reliability of the decision-making is guaranteed if we make adjustment of the rate variables in this interval.

D. Analysis with Example of GM (1, 1) Model in Regulation of Rate Variables

We take the example of the training management system of table tennis athletes in Ningbo University. The high-quality enrollment of college athletic talents can enhance the athletic levels as well as the publicity of the college, thus improve the funds sponsored by society in the training of college athletic talents and help the employment of these talents. Excellent athletic levels and a good environment of employment will encourage more excellent athletic talents to apply for the examination of the college, which improve the enrollment quality of the college athletic talents. A continuously rising virtuous circle is formed.

From above, we get the system dynamics flow diagram of the process of the training and management of the table tennis athletes in Ningbo University.

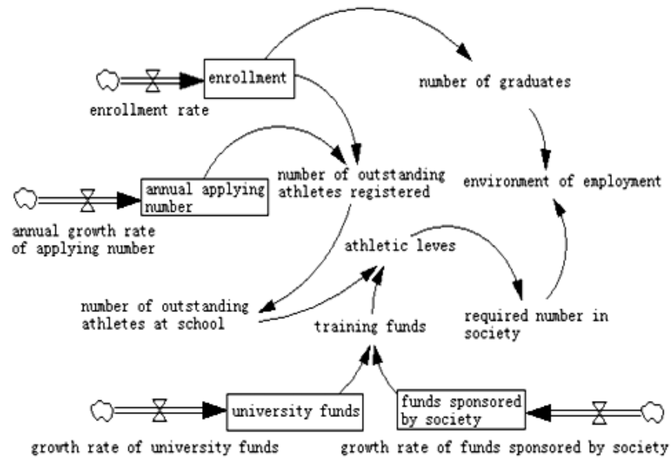

Fig. 1 System dynamics flow diagram of the training and management of college athletic talents

From the above figure, the equations of the variables are:

Enrollment= enrollment* enrollment rate

Number of graduates= DELAY1I (enrollment, 4, 8)

Annual applying number= annual applying number* annual growth rate of applying number

Number of outstanding athletes registered= IF THEN ELSE (-0.9523+ 0.6153* enrollment + 0.2084* annual applying number >= enrollment, enrollment, -0.9523+ 0.6153* enrollment +0.2084* annual applying number)

Number of outstanding athletes at school= IF THEN ELSE (-15.949 +5.249* number of outstanding athletes registered>= number of outstanding athletes registered* 4, number of outstanding athletes registered* 4, -15.949+ 5.249* number of outstanding athletes registered)

University funds= university funds* growth rate of university funds

Funds sponsored by society= funds sponsored by society* growth rate of funds sponsored by society

Training funds= university funds + funds sponsored by society

Athletic levels= -4.0512+ 0.1025* training funds+ 0.1211* number of outstanding athletes at school

Required number in society＝IF THEN ELSE (0.6+ 1.72* athletic levels >= 20,20,0.6+ 1.72* athletic levels)

Environment of employment= required number in society / number of graduates

1) The Defining of the Difficulty of Changing the Rate Variables in System Dynamics

In the analyzing process of the model simulation and decision-making, we first construct GM (1, 1) model with the four variables of “enrollment”, “annual applying number”, “university funds” and “funds sponsored by society”. As follows:

The actual numerical values of “enrollment” in the recent 6 years are:

$$x^{(0)}=(4, 6, 8, 9, 10, 10)$$

Model obtained:

$$\hat{x}^{(1)}(t+1)=58.300000\,e^{0.110540t}–54.300000$$

Check:

$$C=0.2648,\ P=1.0000$$

Predicted value:

$$\hat{x}^{(0)}(t+1)=11.84258;\ \hat{x}^{(0)}(t+2)=13.22675$$

Thus, “enrollment rate”

$$=(\hat{x}^{(0)}(t+2)-\hat{x}^{(0)}(t+1))/\hat{x}^{(0)}(t+1)=0.11688$$

In a similar way,

“annual growth rate of applying number”=0.17974

“growth rate of university funds”=0.02755

“growth rate of funds sponsored by society”=0.16216

Take the values of the rate variables of “enrollment rate”, “annual growth rate of applying number”, “growth rate of university funds” and “growth rate of funds sponsored by society” into the system dynamics model one by one, we can get the influential degrees of different rate variables to the system in the normal state (i.e. with the same difficulty). As the following figure:

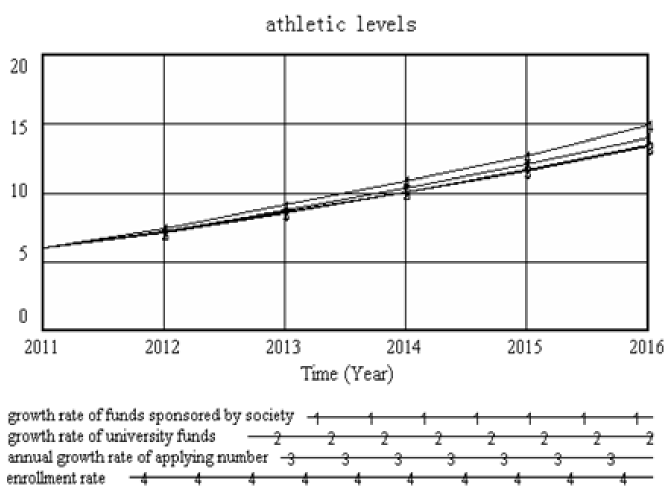

Fig. 2 Influential degrees of different variables to “athletic levels” in normal state

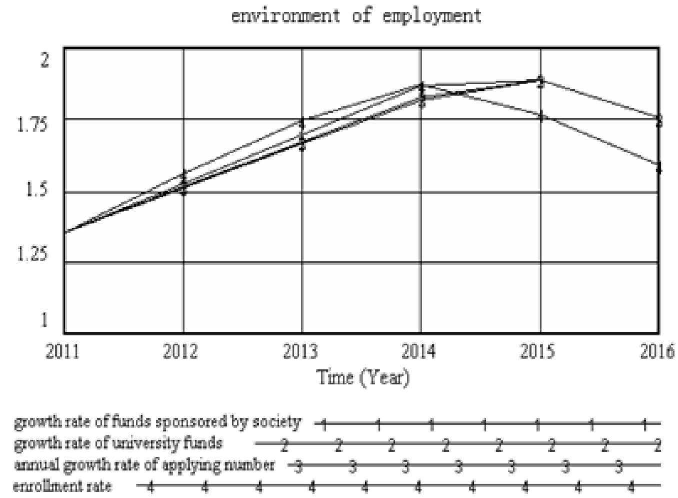

Fig. 3 Influential degrees of different variables to “environment of employment” in normal state

The results show, in the same conditions there is biggest enhancement of the “enrollment rate” to the “athletic levels” (i.e. the smallest relative difficulty), the second biggest is the “rate of funds sponsored by society”. However, there is biggest negative influence of the “enrollment rate” to the “environment of employment” (i.e. the biggest relative difficulty), with the inflexion appearing earliest and declining rate biggest. Moreover, in the process of system simulation, with no concern of the factor of employment, there is smallest difficulty in the enhancement of “enrollment rate” to the “athletic levels”; while if the factor of employment is taken into consideration, the “rate of funds sponsored by society” becomes the rate variable that shows the smallest difficulty in the enhancement.

2) Selection of the Range of Changing the Rate Variables in System Dynamics

In the selection of the decision-making range of the rate variables, we take the changing of “enrollment rate” as the example, and construct several GM (1, 1) models with “enrollment” in different dimensions.

Six-dimensional model:

$$\hat{x}^{(1)}(t+1)=58.300000\,e^{0.110540t}–54.300000$$

Check:

$$C=0.2648,\ P=1.0000$$

Obtain:

$$\hat{x}^{(0)}(t+1)=11.84258;\ \hat{x}^{(0)}(t+2)=13.22675$$

In a similar way:

Five-dimensional model: “enrollment”= 0.07677

Three-dimensional model: “enrollment”= 0.05215

Thus, the estimated grey interval of “enrollment” is [0.05215, 0.11688].

Although in the changing of the decision-making “enrollment” may be beyond this interval, but we can not anticipate whether the bigger or smaller changing values of the rate variables are reliable. So at least in this interval, the reliability and feasibility of the decision-making changing is guaranteed. Thus the changing results of the system dynamics model are as follows:

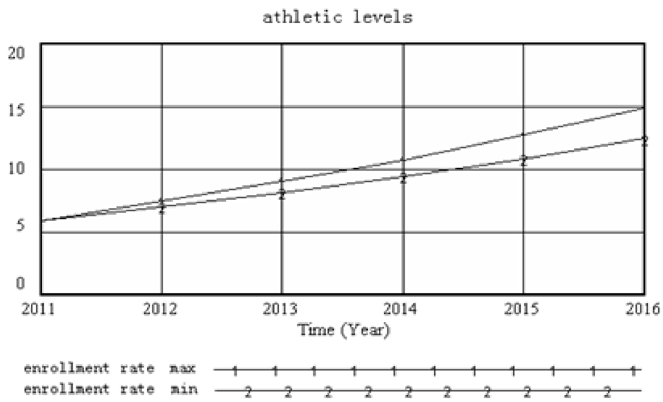

Fig. 4 Influence of grey interval of "enrollment rate" to "athletic levels"

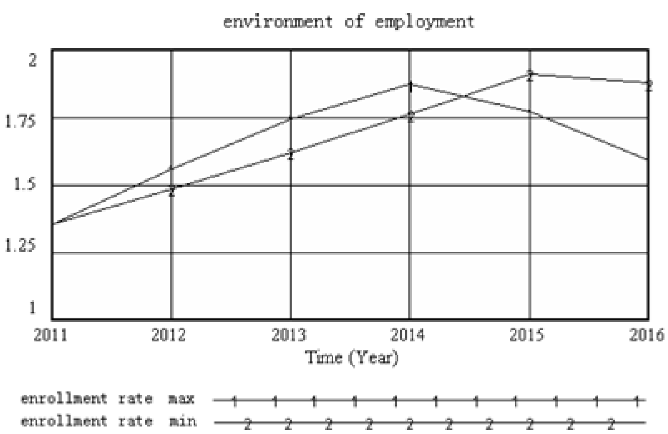

Fig. 5 Influence of grey interval of "enrollment rate" to "environment of employment"

From above, we can see that to develop with the lower limit of the "enrollment rate" will lead to relatively slow enhancement of "athletic levels", though; it will keep a relatively high level of "environment of employment" for a long period of time and get a relatively ideal decision-making program.

4. Conclusions

The system dynamics and the grey system are two different theory systems. However, there are similarities of the two in the construction of the equations. The system dynamics can be applied together with the grey theory in many processes such as the construction of models, the establishing of equations and the simulation analysis, etc.

There are serious defects in system dynamics in the process of simulation analysis. The researchers find difficulties in the decision-making difficulty and the changeable range of the decision-making, which leads to relatively serious blindness in decision-making. The application of GM (1, 1) model to the regulation of rate variables in system dynamics can be a solution to the problem in certain extent.

There are two aspects of the grey model in the regulation to the rate variables in system dynamics. First is to predict the influential degrees of the rate variables to the model in the same conditions and find out certain rate variables as the regulation focus; second is to estimate the grey interval of the rate variables to define the possible changing range of the decision-making and avoid losing the reliability of the decision-making.

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