

THE SELF-ADAPTABLE MODELING OF SOCIO-ECONOMIC COMPLEX SYSTEM BASED ON GENETIC ALGORITHM

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Economic system is a typical evolutionary complex system with uncertainty, which is usually complicated and dynamic. In spite of the advantage in dynamic behavior simulation of economic system, differential dynamic model has the drawback of low precision since it represents complex economic system using the rigid structure. Meanwhile, based on least squares method, parameter recognition could hardly satisfy the precision requirement. Based on genetic algorithm, this paper conducts evolutionary computing on structure parameter of system differential dynamic model by using time series sampled data. Such computing method makes it possible for dynamics model to represent system behavior dynamically and precisely. Furthermore, it also strengthens the self-adaptability of the model. In this sense, it is of great importance to the modeling, characteristic analyzing and trend prediction of the socio-economic complex system.

Keywords: Genetic algorithm, socio-economic complex system, differential dynamic model, self-adaptable

1. INTRODUCTION

In accompany with the development of socialization and globalization, the factors that impacts economy system development is increasingly complex. Therefore, people changed their research orientation from simple system to complex system. Macro economic system is a typical evolutionary complex system with uncertainty, which is both complicated and dynamic. Based on differential dynamic formula, this paper conducted modeling analyze on the complex macro economic system. Meanwhile, it carried out evolutionary computing on the structure parameter of system differential dynamic model based on time series sampled data, which make it possible for dynamics model to represent system behavior dynamically and precisely and strengthen the self-adaptability of the model.

2. ECONOMIC COMPLEX SYSTEM DIFFERENTIAL DYNAMIC MODEL

Consider the complex economic system with multiple input and output. It is frequently described as the following differential dynamic model:

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$$\frac{dx(t)}{dt} = f(x(t), u(t)) + g(x(t)),$$

in which $x(t)$ being the state vector in the economic system, $u(t)$ being the system controlling input variable, $f(x(t), u(t))$ being the function vector with both state vector and control vector. Here $x(t) = (x_1, \dots, x_h)^T$ is the h dimension state vector, while $u(t) = (u_1, u_2, \dots, u_p)^T$ is the p dimension controlling input vector. For non-linear systems, ordinary method is to linearize the non-linear system by approaching. Therefore, differential dynamic model could be built as follows:

$$\frac{dx(t)}{dt} = Ax(t) + Bx(t),$$

where A and B being suitable vector matrix, $A \in R^{h \times h}$, and $B \in R^{h \times p}$.

Owing to the multi-variate evolutionary behavior of economic system and the imperfection and uncertainty of information, for the prediction control of complex economic system, analysis is merely based on time series data obtained from observation, statistics or survey. It has become an important work to analyze macro economic system based on the "observed" time series data and constitute controlling strategy accordingly.

In an economic system, given the characteristic state vector being x , $x \in R^h$, the system controlling output vector being u , $u \in R^p$, by "observation" (generalized observation such as statistic and survey), p entries of time series inputs and h entries of time series outputs could be obtained as following:

$$\begin{aligned} x &= \{x_i(k)\}, k = 1, 2, \dots, n, i = 1, 2, \dots, h; \\ u &= \{u_s(k)\}, k = 1, 2, \dots, n, s = 1, 2, \dots, p. \end{aligned}$$

Considering the dynamic procedure of economic complex system in macro level, the lack of modeling information and the relationship ambiguity between control strategy and state output, based on the time series data observed, differential dynamic system model could be structured as following:

$$\begin{aligned} \dot{x}(t) &= Ax(t) + Bx(t) \\ (1) \end{aligned}$$

3. PARAMETER EVOLUTIONARY COMPUTING BASED ON GENETIC ALGORITHM

Differential dynamic model has its own advantage in simulating economic system dynamic behavior. However, there exists drawback like low precision in using rigid structure to represent complex economic system. Parameter recognition based on least squares method could hardly satisfy the precision requirement. By using genetic algorithm, this thesis conducted evolutionary computing on structure parameters of time series differentiate dynamic model, which made differential dynamic model more adaptable to the changing environment and more precisely represent system behavior dynamically.

Let parameter pop_size , P_c and P_m being population scale, crossing probability and mutation probability respectively. Based on genetic algorithm, the parameter evolutionary computing steps are as follows:

3.1 Initialization

Encode using elements in parameter matrix $[A:B]$ as the chromosome of genetic algorithm, where $A = (a_{ij})_{h \times h}$, $B = (b_{ij})_{h \times p}$. Frequently used encoding scheme include binary encoding and real number encoding. Because of the strongest searching ability and efficient crossover and mutation operation of binary encoding, binary encoding is used here. Meanwhile, we use Gray code here in case the superior individual is damaged during the crossover operation. Each chromosome includes $(h \times h + h \times p)$ gene chain, each of which represents one-dimensional data. The numeric area difference among each attribute in original data make it necessary to conduct row transformation to data in order to unify gene chain length. There are two ways available:

- (1) Scanning the whole data set and determining the numeric area of each data dimension. Unify them into the same order of magnitude. On the basis of keeping certain significant digits, calculate necessary gene chain length dynamically according to the significant digits.
- (2) Normalizing data, which means to transform each dimension of data into the same span. $[0, 1000]$ for example, it could be calculated that the gene change length is 10, since $2^{10} = 1024 > 1000$.

The stable gene chain length and the high utilization rate of code-element in the second method could avoid the generation of null and void code which saved running time. Therefore, this algorithm makes use of this transformation method.

3.2 Evaluation Function

According to the sampling control system theory, the state output determined in model (1) at time k could be represented as:

$$\hat{x}(k) = e^A x(k-1) + \left[\int_0^1 e^{At} dt \right] B u(k-1)$$

(time span here is given as 1). Suppose the parameters matrix obtained in the l th evolution computation are A_l and B_l , then the tracking error at time k is:

$$e^l(k) = x(k) - \hat{x}(k) = x(k) - [e^{A_l} x(k-1) + \left[\int_0^1 e^{A_l t} dt \right] B_l u(k-1)]$$

Evaluation function of genetic algorithm could be represented as the count backward of sum of the squares of errors of model forecasting output vector \hat{x} and actual state output vector.

3.3 Genetic Operation

Choose operation is conducted using optimal reservation tournament method with the tournament scale being 2, which means to randomly select two individuals and compare their fitness values, the bigger is reserved as father individual. Optimal individual in each generation is reserved to the next generation. The crossover operation is generally done by single point crossover or multi-point crossover. Single point crossover results better on experiment so it is used here. Meanwhile, crossover operation should be carried out to each individual to guarantee enough search space and efficient result. Mutation operation generally uses basic bit mutation method.

3.4 Termination condition of the algorithm

Genetic algorithm terminates in the following two conditions:

- (1) Model optimizing has reached the given precision.
- (2) Genetic operation has reach given maximize generation number.

4. APPLICATION CHALLENGE

For an economic system, analysis is usually carried out by the use of statistic or time series data obtained from observation. From the system and control aspect, economic growth rate, employment rate, imports and exports trade, consumer price index, energy consumption all represent stable state. However, management and controlling policy such as fix asset investment, total wage expenditures on workers and staff represent as controlling. The establishment of time series differential dynamic system model is of great importance to the relevant analysis, prediction and controlling countermeasures.

5. CONCLUSIONS

In the domain of differential dynamic model, system parameter recognition usually resorts to least squares method. However, being a dynamic complex system, social economic system has dynamic parameter representing system construction. Based on genetic algorithm, this paper conducted evolutionary computing on construction parameter matrix, by using time series data. It also enabled system dynamic model represent system behavior dynamically and precisely, which made the model self-adaptable. Therefore, it is of great importance to the social economic system attribute analyze and development trend prediction.

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