Application of Grey Prediction Model in Rural Informatization Construction

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Abstract. Grey system theory has been widely applied to many domains such as economy, biology, agriculture, control and so on. Based on the theory of grey system, this paper established GM(1,1) grey predict modeI for the first time to forecast Chinese every hundred rural households owned computers and every hundred rural households owned mobile phone. The predicting results are almost close to the actual values, and this shows that the model is reliable. Finally ,these models are used to forecast the two factors in the future years. The research provides a new seientific method for predicting rural informatization development.

1. Introduction

Agriculture and rural informatization is an important component of the national economy informatization. Setting up prediction model is very significant for the social and economic systems. Because rural informatization is a society-economy-nature complex system, there are many kinds of factors afflecting rural informatization level, and it is difficult to confirm all influencing factors. Besides, some factors are indefinite, some are definite but difficult to be described quantitively and some are quantified but they may have randomness. Therefore, we can think that rural informatization is a gery system.

Since grey system analysis method has fine adaptability to actual situation when information is incomplete, rural informatization system can be studied using grey theory, among which single sequence one order GM(1,1) model can be applied. The following work will introduce the principle of grey topologicaI forecast and a grey

predicting model is set up. This model can be fully processed at a quantity level on the basis of history data to realize a scientific prediction[1].

2.   The basis of grey prediction method

2.1. Grey system theory

The grey theory, developed originally by Deng (1987), is a multidisciplinary and generic theory that deals with systems that lack adequate information and/or have only poor information. The fields covered by the grey theory include systems analysis, data processing, modeling, prediction, decision making and contro1. The grey theory mainly conducts systems analysis with poor, inadequate or uncertain messages. Grey prediction models have been extensively used in many applications[2]. In contrast to statistical methods, the weight of the original series in the time series grey model, called GM(1,1), has been proven to be more than four. This model is a time series forecasting mode1, encompassing a group of differential equations adapted for parameter variance, rather than a first order differential equation. Its difference equations have structures that vary with time rather than being general difference equations. In addition assumptions regarding the statistical distribution of data are not necessary when the grey theory is applied. The accumulated generation operation (AGO) is one of the most important characteristics of the grey theory, and its main purpose is to reduce the randomness of data. In fact, functions derived from AGO formulations of the original series are always well fired to exponential functions[3-5].

2.2.   Grey GM (1,1) prection model

The GM(1,1) model is one of the most frequently used grey forecasting models. This model is a time series forecasting model, encompassing a group of differential equations adapted to parameter variance, rather than a first-order differential equation. Its difference equations have structures that vary with time rather than being general difference equations. Although it is not necessary to employ all the data from the original series to construct the GM(1,1) model, the weight of the series must be more than four. In addition, the data must be taken at equal intervals and in aconsecutive order without by passing any data. The GM(1,1) model constructing process is described below[4]:

Denote the original data sequence by

$$X^{(0)} = (X^{(0)}(1), X^{(0)}(2), \cdots, X^{(0)}(n)) \tag{1}$$

The AGO formation of $X^{(0)}$ is defined as:

$$X^{(1)} = (X^{(1)}(1), X^{(1)}(2), \cdots, X^{(1)}(n)) \tag{2}$$

Where

$$X^{(1)}(1) = X^{(0)}(1) \text{ and } X^{(1)}(k) = \sum_{m=1}^{k} X^{(0)}(m), \quad k = 1, 2, \cdots, n \tag{3}$$

The GM(1,1) model can be constructed by establishing a first-order differential equation for $X^{(1)}$ as:

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = \mu \tag{4}$$

Where, α is the grey coefficient, μ is the grey control parameter.
If the estimating parameter vector 5 is defined as:

$$\hat{\alpha} = \begin{bmatrix} a \\ \mu \end{bmatrix} \tag{5}$$

And it use the least square method,

$$\hat{\alpha} = \begin{bmatrix} B^T B \end{bmatrix}^{-1} B^T Y_n \tag{6}$$

Then, the solution of Eq.(4) can be obtained by using the least square method. That is,

$$\hat{X}^{(1)}(k+1) = (X^{(0)}(1) - \frac{\hat{\mu}}{\hat{\alpha}})e^{-\hat{\alpha}k} + \frac{\hat{\mu}}{\hat{\alpha}}, k = 1, 2, \cdots, n \tag{7}$$

Where

$$\hat{\alpha} = \begin{bmatrix} \hat{\alpha}, \hat{\mu} \end{bmatrix}^T = \begin{bmatrix} B^T B \end{bmatrix}^{-1} B^T Y_n \tag{8}$$

And

$$B = \begin{bmatrix} -\frac{1}{2}\begin{bmatrix} X^{(1)}(1)+X^{(1)}(2) \end{bmatrix} & 1 \\ -\frac{1}{2}\begin{bmatrix} X^{(1)}(2)+X^{(1)}(3) \end{bmatrix} & 1 \\ \vdots & \vdots \\ -\frac{1}{2}\begin{bmatrix} X^{(1)}(n-1)+X^{(1)}(n) \end{bmatrix} & 1 \end{bmatrix} \tag{9}$$

And

$$Y_n = \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(n) \end{bmatrix} \tag{10}$$

$\hat{X}^{(1)}$ is obtained from Eq.(7). Let $\hat{X}^{(0)}$ be the fitted and predicted series,

$$\hat{X}^{(0)} = (\hat{X}^{(0)}(1), \hat{X}^{(0)}(2), \cdots, \hat{X}^{(0)}(n)) \tag{11}$$

Where

$$\hat{X}^{(0)} = X^{(0)}(1) \tag{12}$$

Applying the inverse AGO, then have

$$\hat{X}^{(0)}(k+1) = (\hat{X}^{(1)}(k+1) - \hat{X}^{(1)}(k) \tag{13}$$

$$= (1 - e^{\alpha})\left[(X^{(0)}(1) - \mu/\alpha)\right]e^{-\alpha k}$$

Where $\hat{X}^{(0)}(1), \hat{X}^{(0)}(2), \cdots, \hat{X}^{(0)}(n)$ are called the GM(1,1) fitted sequence, while $\hat{X}^{(0)}(n+1), \hat{X}^{(0)}(n+2), \cdots,$ are called the GM(1,1) prediction values.

After the above model is generated and developed, further tests are necessary to underst and the error of forecasted value, as compared to the actual value. To demonstrate the efficiency of the proposed forecasting model, we adopted the residual error test method to compare the actual value and the forecasted value.

Here, Equations (14) and (15) are used to compute the residual error of the Grey forecasting.

$$\text{Error} = \left| \frac{X(k) - \hat{X}(k)}{X(k)} \right| \tag{14}$$

$$\text{Average error} = \frac{1}{k} \sum_{k=1}^{n} \left| \frac{X(k) - \hat{X}(k)}{X(k)} \right| \tag{15}$$

Grey prediction of rural informatization infrastructure

Based on the characteristics of rural informatization, this paper choose two factors to be predicted, one is every hundred rural households owned computers, the other is every hundred rural households owned mobile phones[6].

Between 2000 and 2008, the every hundred rural households owned computers，the every hundred rural households owned mobile phones in China are listed in Table1.

Table 1. Annual values of the two rural informatization factor between 2000-2008

Time	Every hundred rural households owned computers	Every hundred rural households owned mobile phones
2000	0.5	4.3
2001	0.7	8.1
2002	1.1	13.7
2003	1.4	23.7
2004	1.9	34.7
2005	2.1	50.2
2006	2.7	62
2007	3.68	77.84
2008	5.3578	96.13

Based on the data in Table1 and the above principle of grey forecasting, we can get the coefficients in the model through calculation. And then we get grey forecasting model GM(1,1) of every hundred rural households owned computers and every hundred rural households owned mobile phones.

By using DPS9.05, The predicted values obtained by the proposed GM(1,1) model and their respective errors are shown in Table2 and Table3.

Table2. Model operation results of every hundred rural households owned computers

Model parameter				
a=0.006531		b=0.156794		
$X(k+1)= -23.680009\exp(-0.006531k)+24.006336$				
No.	Actual value	Predicted value	Error	%
2001	0.7	0.792	-0.022	-3.3033
2002	1.1	1.2313	-0.0812	-7.5411
2003	1.4	1.5064	-0.1066	-8.4386
2004	1.9	1.8782	0.11	5.7485
2005	2.1	1.9008	0.2217	10.859
2006	2.7	2.7173	0.1202	4.6554
2007	3.68	3.989	-0.1551	-4.3817
2008	5.3578	5.8581	-0.0911	-1.7495

The evaluation of the model	
C=0.0816	Very good
p=1.0000	Very good

Table3. Model operation results of every hundred rural households owned mobile phones

Model parameter				
a=0.152491			b=29.303635	
X(k+1)=-160.819281exp(-0.152491k)+192.166756				
No.	Actual value	Predicted value	Error	%
2001	8.1	7.4016	1.3424	16.7172
2002	13.7	17.1468	-2.2686	-16.3302
2003	23.7	28.3539	-2.4442	-10.3129
2004	34.7	36.5123	-0.6278	-1.7376
2005	50.2	48.8886	5.3954	10.6858
2006	62	56.7101	4.0001	6.5668
2007	77.84	78.187	1.9737	2.6764
2008	96.13	112.1695	-8.1425	-8.8905
The evaluation of the model				
C=0.1273	Very good			
p=1.0000	Very good			

We can test the grey model by using the second errors, the average values of absolute values of relative errors respectively are being 0.0816 and 0.1273, which show that the established grey model have a good accuracy. It can be seen that the simulation results from 2001 to 2008 have a good degree of fitting. This shows that the forecasting model possesses the better forecasting precision and the forecasting resu1ts are believable. Based on these forecasting values, we can ca1cu1ateted annual every hundred rural households owned computers and every hundred rural households owned mobile phones values in China between 2010 and 2013 which is listed in Table4.

Table4. Predicted values of the two rural informatization factor between 2009-2013

Time	Every hundred rural households owned computers	Every hundred rural households owned mobile phones
2009	7.36	115.58
2010	9.69	159.20
2011	12.74	217.13
2012	16.75	293.86
2013	22.01	395.29

4. Conclusion and Recommendations

Based on the grey system theory, two predicting model of rural informatization infrastructure factors have been set up. From the predicting results, its forecasting precision is higher. And the model needs fewer indexes, and thus is simple and convenient to calculate in practical application.

The research results show that when the grey forecasting technology is used in the middle and short-term prediction, this method has higher confidence and can be as a quantitative forecasting method of rural informatization infrastructure factors.

The study of this paper offers a new method and approach to predict for rural informatization development. But the establishment of grey predicts system is not once and for all. The accuracy of predict result is based on the amount and reliability of information we have had. We think it is essentially accurate and reliable for predicting the next period after a new grey prediction system has been estab1ished[7]. We should modify grey parameters in time and establish new prediction model based on the risk of new information we have got. Then the credibility of prediction result can be greatly improved with the new model.

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