Based on the Gray GM (1, 1) Prediction Model of Pig Disease

Yanying Ma^{1, a*}, Xiuzhen Li¹ and Xue Wang²

¹Jilin Engineering Normal University .Changchun; China;

²College of Mathematics and Computation Science Fuyang Teachers' college. Fuyang; China;

^aarnold0110@sina.com

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Abstract. With the growth of social economy, more and more high to the requirement of animal husbandry. With the brisk development of pig raising production, we have realized that how to improve the effectiveness of pig raising, disease warning and prevention is of great significance. In this research, by applying GM (1, 1) model of gray system theory, we try to forecast the pig disease based on the mortality rate of pig disease in a Jilin Provincial village. From the results, we can see the error between predicted values and measured values is very small and the fitting effect is excellent, which indicate that the method to predict pig disease is feasible, meanwhile, it will play a great role in health epidemic and disease prevention.

The Theory and Method of Modeling Gray GM (1, 1) [1] [8]

Date Processing. Let the sequence of primary data are nonnegative and discrete, $x(t) = \{x(1), x(2), \dots, x(n)\}$, add the elements in which for once, we get the data:

$$Y(t) = \sum_{i=1}^t x(i), t = 1, 2, \dots, n \quad (1)$$

Then finding the mean value of the data $Y(t)$ can we generate the following:

$$Z(t) = \frac{1}{2} [Y(t) + Y(t-1)], t = 2, 3, \dots, n \quad (2)$$

The Building of Model GM (1, 1). Formulating the first order differential equation of $Y(t)$:

$$\frac{dY(t)}{dt} + aY(t) = u \quad (3)$$

In which, u and a satisfying:

$$Y(t) = (x(1) - \frac{u}{a})e^{-a(t-1)} + \frac{u}{a} \quad (4)$$

Estimate the vectors of parameters u and a by least square technique, and the expressions of them obtained by matrix operations are the followings :

$$a = \frac{1}{D} \left\{ (n-1) \left[- \sum_{t=2}^n X(t)Z(t) \right] + \left[\sum_{t=2}^n Z(t) \right] \left[\sum_{t=2}^n X(t) \right] \right\} \quad (5)$$

$$u = \frac{1}{D} \left\{ \left[\sum_{t=2}^n Z(t) \right] \left[- \sum_{t=2}^n X(t)Z(t) \right] + \left[\sum_{t=2}^n Z^2(t) \right] \left[\sum_{t=2}^n X(t) \right] \right\} \quad (6)$$

$$D = (n-1) \left[\sum_{t=2}^n Z^2(t) \right] - \left[\sum_{t=2}^n Z(t) \right]^2 \quad (7)$$

Take them into the differential equation with separable variable we can get the estimated values of $Y(t)$ and $X(t)$ as follows:

$$\hat{Y}(t) = (X(1) - \frac{u}{a})e^{-a(t-1)} + \frac{u}{a} \quad (8)$$

$$\hat{X}(t) = \hat{Y}(t) - \hat{Y}(t-1), t = 2, 3, \dots, n \quad (9)$$

Check the Fitting Effect of Sequences $\hat{X}(t)$ and $X(t)$.If the fitting accuracy of the two is good, it can be used to extrapolate prediction; otherwise, it can't be used to extrapolate prediction directly unless being modified. To determine the reliability, we can use average relative error, posterior error ratio and minor error probability to check.

The average relative error is:

$$\bar{e} = \frac{\sum_{t=2}^n |\hat{X}(t) - X(t)|}{\sum_{t=2}^n X(t)} \times 100\% \quad (10)$$

Let the error $\varepsilon(t)$ be:

$$\varepsilon(t) = X(t) - \hat{X}(t), t = 2, 3, \dots, n. \quad (11)$$

Calculate the posterior error ratio C and minor error probability P as:

$$C = \frac{S_2}{S_1}, \quad (12)$$

$$P = P\{|\varepsilon(t) - \bar{\varepsilon}| < 0.685S_1\}, \quad (13)$$

Where

$$S_1^2 = \frac{1}{n} \sum_{t=1}^n [X(t) - \bar{X}]^2 \quad (14)$$

$$\bar{X} = \frac{1}{n} \sum_{t=1}^n X(t) \quad (15)$$

$$S_2^2 = \frac{1}{n} \sum_{t=1}^n [\varepsilon(t) - \bar{\varepsilon}]^2 \quad (16)$$

$$\bar{\varepsilon} = \frac{1}{n} \sum_{t=1}^n \varepsilon(t) \quad (17)$$

Judge the fitting degree of gray sequence according to the reference table on accuracy-checking grade.

Table 1 Judge the fitting degree of the prediction model GM (1, 1)

Accuracy Grade of the model	P value	C value
Good	>0.95	<0.35
Qualification	>0.80	<0.50
Reluctance	>0.70	<0.65
Disqualification	≤ 0.70	≥ 0.65

Extrapolate Prediction. A good fitting degree means the effect of the prediction model is feasible, so we can do extrapolate prediction by the following formula:

$$\hat{X}(t) = \hat{Y}(t) - \hat{Y}(t-1), t = n+1, n+2, \dots, n+k \quad (18)$$

Examples

Resource of Data Information.

Table 2 Pig disease mortality rate (1%) in a Jilin Provincial village (2009-2015)

order	1	2	3	4	5	6	7
year	2009	2010	2011	2012	2013	2014	2015
Real disease death rate (%)	2.88	2.36	2.62	2.24	2.14	2.06	2.03
Predicted disease death rate (%)	2.88	2.5073	2.3972	2.2926	2.1924	2.0962	2.0023

By using the real disease death rate from 2009 to 2015 in a Jilin Provincial village in table 2 and applying the GM (1, 1) model, we build the corresponding prediction model. From the formulas (5), (6), (7), we find that $\hat{a} = 0.0448$, $\hat{u} = 2.6699$ and $D = 522.7839$. Take the above-mentioned values on formula (8), the prediction equation will be acquired as follows:

$$\hat{Y}(t) = -57.1247e^{-0.0448(t-1)} + 59.54 \quad (19)$$

Discussion

Gray system theory is an interdisciplinary subject for researching indetermination and it has made much success in many practical fields since it appeared in 1982, there is no exception in disease monitoring and warning. The model of gray prediction is simple and convenient to calculate with less concerning influence factors. Depending on systematical known information to accumulate irregular data to generate a relatively more regular generating sequence by gray modular, then we can build differential dynamic time sequence model, process the gray information and improve the Whitening degree of gray model by a certain rule, accordingly, we will reach the goal of further prediction on the

base of disclosing the internal features and regularities of matters, Compared with traditional model of mathematical statistics, the model, can be used as an effective tool, has many good qualities in predicting diseases, such as, it needs less amount of samples, no typical probability distribution and less calculations. From the results, we can see the error between predicted values and measured values is very small and the fitting effect is excellent, which indicate that the method to predict pig foot and mouth disease is feasible, meanwhile, it will play a great role in preventing disease.

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