

# The Development of Prediction Software Gm(1,1) and its Application in Marine Economy Field

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**Abstract.** Gm(1,1) model is the simplest and also the most widely used grey prediction model. However, the manual computation cost is so very large, and cooperation of related calculation software is relatively complicated, so the performability is not that high. In cases of utilizing Java language to compile Gm(1,1) model desktop and running the software, the installation is convenient and operation is simple, so that the manual computation cost is reduced, which makes Gm(1,1) more effectively applied in terms of research on development tendency of marine economy and other aspects.

A large number of factors affect the prediction of economic trend. There are either certainty factors or uncertainty factors (such as natural disasters) that cannot be carried out quantitative analysis directly. The grey system thought regards the development progress of marine economy as a grey system, and then predicts the economic trend. The existing software that could proceed grey prediction are Excel, Matlab, DPS, SAS etc. But all these software are complicated to operate, and performability is not high, so it is difficult for users who are not familiar with the software but in need of a quick Gm(1,1) prediction results. This paper uses Java language to compile Gm(1,1) model desktop software through detailed analysis of Gm(1,1) prediction principle, and realizes the quick installation and calculation function of Gm(1,1) prediction software. Furthermore, it verifies the operability and accuracy of the model, and the practicability of application by examples.

## Principle of Gm (1, 1) model

In 1982, Deng Julong, a Chinese famous scholar, created grey system theory aiming at uncertain system of small samples and poor information. Thereinto, grey methodology(Gm in short) did not require too much about data, and could weaken the randomness of system and elevate precision of prediction, which had become the widely used method in short-term prediction. And as the simplest grey prediction model, Gm(1,1) gained more popularity. Its basic principle is as following:

### (1) Data preprocessing

There are n numbers in the original non-negative series as following:  $X^{(0)} = [x^{(0)}(1), \dots, x^{(0)}(n)]$ .

Proceed the accumulative production processing to the original series for one time, generating 1-AGO series:  $X^{(1)} = [x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)]$ , thereinto,  $x^{(1)}(1) = x^{(0)}(1)$ ,  $x^{(1)}(t) = \sum_{i=1}^t x^{(0)}(i)$ ,  $t = 2, 3, \dots, n$ . Figure out the 1-AGO series and obtain the sequence of adjoining mean values:  $Z = [z(2), z(3), \dots, z(n)]$ , thereinto,  $z(t) = 0.5x^{(1)}(t) + 0.5x^{(1)}(t-1)$ .

### (2) Inspection of model applicability

The original series  $X^{(0)}$  is required to meet quasi-smoothness condition, namely  $\rho(t) = \frac{x^{(0)}(t)}{x^{(1)}(t-1)}$ ,

supposed  $m \in (1, 2, \dots, n)$ , when  $t > m$ ,  $\sigma(t) \in [1, 1.5]$ ,  $\delta = 0.5$ , then  $X^{(0)}$  meets quasi-smoothness condition;

1-AGO series  $X^{(1)}$  meets quasi-index law, namely  $\rho(t) = \frac{x^{(1)}(t)}{x^{(1)}(t-1)}$ , supposed  $m \in (1, 2, \dots, n)$ ,

when  $t > m$ ,  $\sigma(t) \in [1, 1.5]$ ,  $\delta = 0.5$ , then  $X^{(1)}$  meets quasi-index law.

Supposed above condition are both met, then it indicates that when the accumulation generation series trend is similar to index trend, then the grey Gm(1,1) model can be established.

### (3) Determination of model

Because model parameter can be figured out per least square method:  $(a, b)^T = (B^T B)^{-1} B^T X_n$ , thereinto  $a$  is the development coefficient,  $b$  is endogenous control grey,

$$X_n = \begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \dots \\ x^{(0)}(n) \end{pmatrix} \quad B = \begin{bmatrix} -z(2) & 1 \\ -z(3) & 1 \\ \dots & \dots \\ -z(n) & 1 \end{bmatrix}$$

Gm(1,1) prediction model is worked out:

$$\hat{x}^{(1)}(t+1) = \left[ x^{(1)}(1) - \frac{\hat{\mu}}{\hat{a}} \right] e^{-\hat{a}t} + \frac{\hat{\mu}}{\hat{a}} \quad t = 1, 2, \dots, n \quad (1)$$

### (4) Inspection of model precision

Utilize Gm(1,1) prediction model to work out the value of simulation of original series. And then figure out the residual error, relative error, average relative error, post-test odds and probability of small error can be obtained through the comparative verification of original series and simulative series. Thereinto, residual error at each time = value of simulation at each time - original value at each time, namely  $\varepsilon(t) = x^{(0)}(t) - \hat{x}^{(0)}(t) \quad t = 1, 2, \dots, n$ .

Relative error at each time = |(residual error at each time / original value at each time)| \* 100%, namely  $e(t) = \frac{|x^{(0)}(t) - \hat{x}^{(0)}(t)|}{x^{(0)}(t)} \times 100\% = \frac{|\varepsilon(t)|}{x^{(0)}(t)} \times 100\% \quad t = 1, 2, \dots, n$ .

Average relative error = averaging the relative error at each time, namely  $\bar{e}(t) = \sum_{t=1}^n e(t) / n$ .

Mean value and standard deviation of original series:  $\bar{X} = \frac{1}{n} \sum_{t=1}^n x^{(0)}(t)$ ,  $S_1 = \sqrt{\frac{1}{n} \sum_{t=1}^n [x^{(0)}(t) - \bar{X}]^2}$ .

Mean value and standard deviation of residual sequence:  $\bar{\varepsilon} = \frac{1}{n-1} \sum_{t=2}^n \varepsilon(t)$ ,  $S_2 = \sqrt{\frac{1}{n-1} \sum_{t=2}^n [\varepsilon(t) - \bar{\varepsilon}]^2}$ .

Post-test odds = standard deviation of original series / standard deviation of residual sequence, namely  $C = S_2 / S_1$ .

Probability of small error = { |residual error at each time mean value of residual sequence| < 0.6745 \* standard deviation of residual sequence }, namely  $P = P\{|\varepsilon(t) - \bar{\varepsilon}| < 0.6745 S_1\}$ .

When  $P > 0.95$  and  $C < 0.35$ , the model is reliable, so it's applicable to predict system behavior based on the model. Generally, when the probability of small error ( $P$ ) is the same, the smaller the post-test odds ( $C$ ) is, the more reliable the model is; while the larger the probability of small error ( $P$ ) is, the higher the prediction precision is.

As to the given  $e(t)_0 > 0$ ,  $P_0 > 0$ ,  $C_0 > 0$ , supposed the models meet the conditions at the same time  $e(t) < e(t)_0$ ,  $P > P_0$ ,  $C < C_0$ , the precision of models is qualified, or it's not qualified. The grade of final precision of model is shown as table 1.

### (5) Prediction

When the precision of model meets the standard, use Gm(1,1) to figure out the predicted value of future time point.

## Design and implementation of Gm(1,1) prediction software

### (1) Structure of Java program

Java is a program language that is object-oriented and cross-platform. It has the advantages of portability, robustness, safety and concurrency (multithreading) and supports editing of visual interface. Luo Shuren(2006) once utilized VB language to realize the prediction function of Gm(1,1), but VB language does not have the design as humanized as Java language, nor cross-platform.

Also, its extendibility is not as good as JAVA, so that the popularizing rate is low; Shi Zhenwei (2012) utilized C language to complete the compiling of Gm(1,1), and extended it to the prediction of building settlement. However, C language is primarily for the operation, so the development advantage over desktop program is not as obvious as Java, etc. In overall consideration, this paper uses Java language to compile Gm(1,1) prediction software. Realize the simulation of Gm(1,1) prediction software to original time sequence by means of Standard Widget Toolkit(SWT) software developer's kit of Eclipse software, and further figure out the residual error between original time sequence and simulative sequence, relative error and average relative error. What's more, based on the judgment of three index of average relative error, post-test odds, probability of small error, obtain the grade of model precision and value of prediction at future time point, so as to acquire the parameter of Gm(1,1) model quickly and conveniently, thus elevating working efficiency of users, and realizing the perfect integration of Gm(1,1) and computer.

Tab.1. Inspection of model precision table

Grade of model	$e(t)_0$	$P_0$	$C_0$	Conclusion	Grade of model	$e(t)_0$	$P_0$	$C_0$	Conclusion
Grade 1	1%	0.95	0.35	QP	Grade 4	20%	0.6	0.80	QP
Grade 2	2%	0.8	0.5	QP	Unqualified	Other	Other	Other	UQP
Grade 3	10%	0.7	0.65	QP					

Note: QP is Qualified for prediction; UQP is Unqualified for prediction

### (2) Implementation of Gm(1,1) prediction software

Step1: Use SWT to construct the software interface as shown in figure 2.

Step2: Run the program, and it reminds users to “input numbers of original data ( $\geq 4$ )”; after users complete inputting, a window pops-up to remind users to input numbers of original data. The default numbers of pop-up windows are the number of carriage returns after the system removes spacing automatically. If the numbers of original data that users input are less than 4, or input number contains illegal symbols, or the number users input manually is smaller than the value system automatically obtains after completing input, then it will pops-up “reminder: numbers of value in original sequence is incorrect. Please input correct value and numbers!”.

Step3: Click “modeling calculation” button, and obtain the following according to principle of grey Gm(1,1) model: 1. parameter a, b; 2. time response function; 3. value of simulation; 4. residual error; 5. relative error; 6. average relative error E; 7. post-test odds C; 8. probability of small error P; 9. figure out grade of model precision based on the judgment of size of value E, C, P.

Step4: If the model precision meets the standard, then click “prediction” button. It will remind users to input numbers of prediction required(numbers of time points in time sequence must be integers, if users input decimals, the system will pop-up error tooltip), and the prediction value at future time point will be worked out; otherwise Gm(1,1) cannot be used for prediction, and it will remind users that “this time sequence cannot use Gm(1,1) model for prediction, correction on Gm(1,1) or other prediction model is required for prediction!”.

The flow chart of specific program is shown in figure 1.

### (3) Verification of Gm(1,1) prediction software

For the purpose of verifying the liability of Gm(1,1) prediction software, we choose the grain output during 1988 to 2004 in literature [5] as the input for Gm(1,1) prediction software, and proceed prediction for the data of 6 years during 2005 to 2012. The result of prediction(as shown in figure 2) is in full accord with the value of prediction, error and average relative error in the literature, which indicates that this software is liable. However, the Gm(1,1) prediction software

indicates that the precision of Gm(1,1) model established in literature [5] fails to meet the standard, namely it's not applicable to use Gm(1,1) to predict the grain output during 1988 to 2004. The model requires residual correction, or other prediction models shall be used instead. Unnecessary details will not be given here.

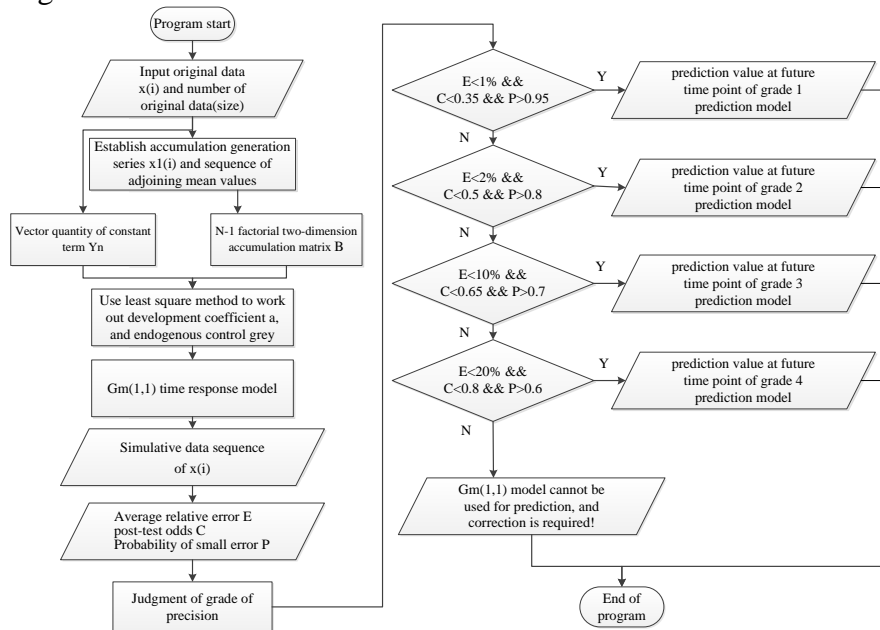


Fig.1. The flow chart of program

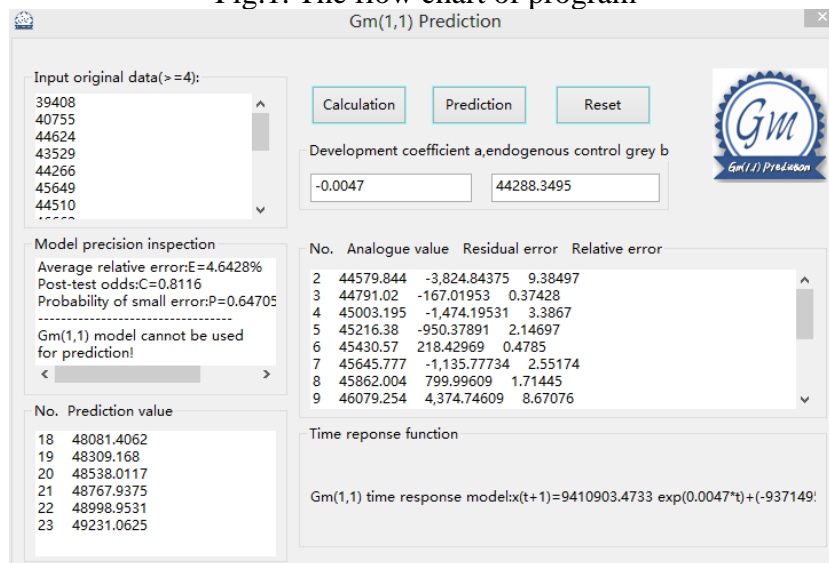


Fig.2. Verification result of Gm(1,1) prediction software

### Application example of Gm(1,1) prediction software in marine economic filed in Jiangmen

Benefited by sea area within 2886 square meters baseline of territorial sea, 420 kilometers coastline(one-tenth of the whole province), 561 islands(ranking the second among the whole province), Jiangmen has become the ocean city with the longest mainland coastline, largest number of island and maximum mud flat among the 7 coastal cities of Pearl River Delta. The hinderland for the development of marine economy is broaden. In 2003, the gross ocean production of Jiangmen is 29.5 billion yuan, which occupies 14.75% of gross regional production, increasing by 1.67 times than that in 2006. The status of marine economy being the important component and growth point of Jiangmen's economy has taken shape. However, related development plans and policies for marine economy have not been made and put into implementation. Consequently, the correct prediction of economic trend of Jiangmen is the key for related working staff of government or marine economic enterprises to make scientific decisions.

This paper adopts gross ocean production of Jiangmen as the overall measurement index of Jiangmen marine economic trend, and chooses original data of gross ocean production of Jiangmen during 2006 to 2013 as the research object(table 2). In addition, it uses the data of 2013 as the comparative inspection of the model to further predict the gross ocean production of Jiangmen in the future 5 years during 2014 to 2018.

Tab.2. Original data of GOP of Jiangmen during 2006 to 2013

Year	2006	2007	2008	2009	2010	2011	2012	2013
No.	1	2	3	4	5	6	7	8
GOP	52.45	53.28	62.35	85.12	105	134.72	249.58	295

Tab.3. Prediction value of GOP of Jiangmen

2014	2015	2016	2017
9	10	11	13
413.24	586.6	832.67	1181.96

Utilize Gm(1,1) prediction software to work out the result as shown in figure 3.

In the figure 3, the average relative error of the model is 16%, post-test odds  $C=0.246$ , probability of small error  $P=1.0$ , and the precision of model is “4”; this software predicts that the gross ocean production of Jiangmen in 2003 is 29.112 billion yuan, and the error is only 1.32% compared to the 29.5 billion published by the official, which is credible. In general, the precision of Gm(1,1) this software establishes is qualified, and could be used for short-term prediction.

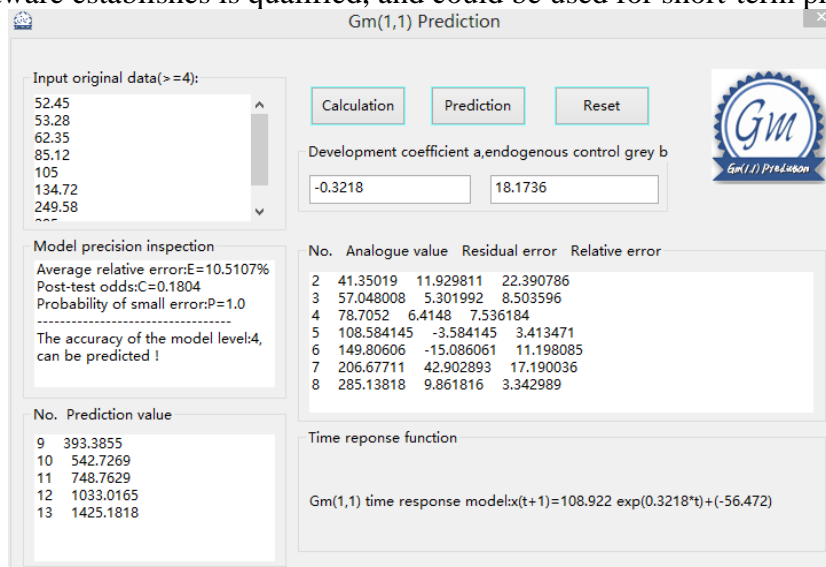


Fig.3. Result of Gm(1,1) prediction software

The gross ocean production of Jiangmen during 2014 to 2018 is shown in table 3.

It can be seen from the table 3 that, without the influence of other factors, the future gross ocean production of Jiangmen will present the tendency of rapid growth, namely the prospect of marine economic development is promising, and has a great upside potential.

## Conclusion

The Gm(1,1) desktop software utilizing Java language to compile realizes the integration of Java language and Gm(1,1) model in a good way, and simplifies the manual computation process that uses Gm(1,1) model for prediction, or the complicated installation and operation process of related software, so that it accomplishes the goals of predicting unknown data with the quick use of known data, and realizes the accurate and quick process of data, as well as saves a lot of manpower and material resources.

The application of Gm(1,1) prediction software in the prediction of marine economic trend of Jiangmen proves that Gm(1,1) has a extended application space in the field of marine economy prediction, and improves the prediction efficiency in marine economy field.

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