World Men's 200m performance development trend applied research based on residual correction gm (1, 1) model

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ABSTRACT

For competitive sports performance prediction problems possessed "poor data information", "small sample" and "dynamics" as well as other traditional statistical methods hard problems, grey model's application will more effective and accurate solve the problems. But meanwhile grey model's application in competitive sports prediction problems, it also appears lots of problems; traditional GM (1, 1) model cannot arrive at corresponding accuracy in lots of problems' prediction. The paper researches on residual correction-based GM (1, 1) grey model application in competitive sports. Take world men's 200m best performance from 2003 to 2013 as sample, it carries out residual correction GM (1, 1) grey model's modeling, its prediction accuracy arrives at first grade accuracy, and makes prediction and models on world men's 200m best performance in 2014 with solved model, it solves its prediction performance is 20.59s.

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INTRODUCTION

Since Professor Deng Ju-Long started grey mathematics, only above 30 years, grey mathematics application and its theoretical research has achieved fast development, modeling fields involved decision making, controlling, planning and predicting and others, its application field also involve medical, economy, education and sports as well as other fields. And in competitive field, grey model applied development is very fast. According to correlation thesis statistics, in recent five years, quantity of competitive sports thesis with grey model as research method will be increased at annual 9.81%~10.10% speed[1]. Grey model application's rapidly development in sports competitive performance prediction, it greatly improved competitive sports performance predicted research's scientific, which also greatly propels to grey mathematical theory's constant development. But meanwhile grey model also occurs abuse in sports, lots of problems that not fit for grey model or traditional GM (1, 1) grey prediction model have been applied into GM (1, 1) grey model to model, which will surely affect grey mathematical theoretical development and its development in competitive sports performance prediction.

For GM(1,1) grey prediction model application in competitive sports field, lots of scholars have already carried out lots of researches, stated their modeling basic thoughts, and made lots of improvements on traditional GM(1,1) grey prediction model. Among them: Liu

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Di(2002) from the perspective of sports application, it discusses grey model modeling advantages and features in sports problems, it stated grey modeling basic thoughts, basic methods[2]; Sun Qiang (2012) by establishing Olympic Games men's 400m competition performance same dimension gray recurrence GM(1,1) model, he solved grey model middle and long term competitive sports performance prediction[3]; He Xin, Chen Ya-Qing (2010) for Chinese recent years' civil aviation enterprise development, they applied Markov chain theory amended GM(1,1) grey prediction model, and predicted Chinese civil controllers' quantity[4]; Liu Jia-Jin(2006) analyzed the 14th to the 28th five sessions' Olympic Winter Games women's shot competitive performance development trend, he proposed GM(2,1) is more fit for sports competitive performance prediction grey model establishing that possessed slightly swing data sequence[5]; Ma Wei-Jun(2006) researched on products sale process fault products sales proportions, he proposed that adopted supply residual and weighted average method to improve GM(1,1) grey prediction model, and improved prediction accuracy[6].

Now, grey model researches application has already become one of most rapidly subjects in sports field applied development. The paper takes world men's 200m performance as an example, and makes research on grey model application in competitive sports performance prediction. By researching and analyzing, it finally defines residual correction GM (1, 1) prediction model's establishment. It provides reference for Chinese men's 200m sports, meanwhile it propels to competitive sports field grey model's application and development.

WORLD MEN'S 200M PREVIOUS CHAMPIONS' PERFORMANCE ANALYSIS

In order to predict world men's 200m performance development trend, the paper applies document literature, it counts world men's 200m annual best performance in 11 years from 2003 to 2013, and based on this, it makes residual GM (1, 1) grey prediction model. Its statistical data is as TABLE 1:

To sports competitive performance prediction, different development changing trends performance data, it needs to model on it with different corresponding grey models, its prediction results then can arrive at corresponding prediction accuracy. In order to establish high accuracy prediction model on world men's 200m annual best performance, it should first analyzes 2003~2013 world men's 200m annual best performance changing development trend so that define corresponding grey prediction model.

By Figure 1, it is clear that world men's 200m annual best performance change range is between 20.13~20.94s, from 2003 to 2006, its performance change overall performance is in declining trend, performance in 2007 has promotions and is higher relative to performances in 2006 and 2008 that is higher, performance in 2009 has no big changes by comparing

TABLE 1 : 2003~2013 previous women's pentathlon highest performance table[7]

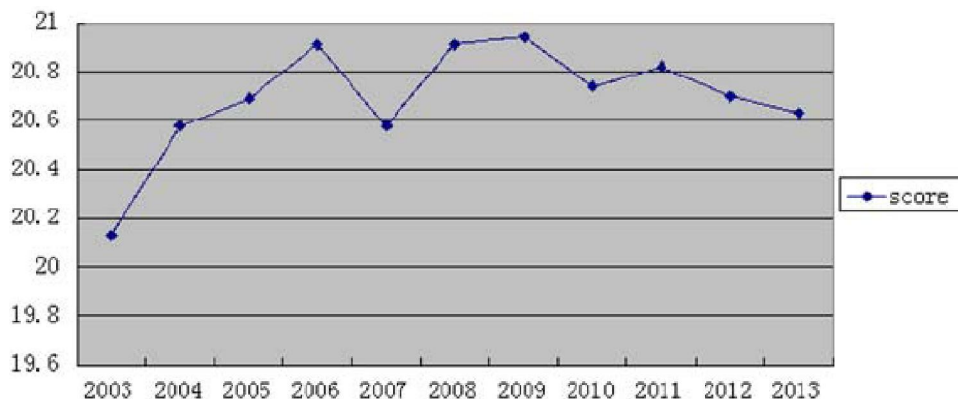| Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Performance	20.13	20.58	20.69	20.91	20.58	20.91	20.94	20.74	20.82	20.7	20.63

Figure 1: 2003~2013 men's 200m annual best performance change graph

with that in 2008. And from 2009 to 2013, its performance changes are also in rising trend. Due to its changes has volatilities, they go up and down, fluctuate, so irregular and data quantity is little, information quantity is little, meanwhile world men's 200m annual best performance development change is a dynamic process, traditional mathematical method is as regression analysis, interpolation fitting and so on, it has higher requirements on samples data that needs lots of data with certain change rules and develops static samples, which is difficult to analyze it and judge its change trend. By analyzing its development changes trend, the paper decides to apply GM (1, 1) grey prediction model to model on it, and makes prediction on world men's 200m in 2014.

WORLD MEN'S 200M BEST PERFORMANCE GM (1, 1) MODEL

In grey theory, grey prediction is one of main research directions; its method applying position in grey mathematical theory is only inferior to grey relational analysis. GM (1, 1) model method is simple, range of application is wide, accuracy is high, application in actual problems is strong, its application has already occupied 75.61% of grey prediction model's application, and its thesis quantities is increasing at annual 19.69%~21.08% speed. The paper by researching and analyzing world men's 200m annual best performance change trend, it applies GM (1, 1) model to predict on its development changes.

Data test

By data statistics, it carries out world men's 200m annual best performance grey model original data sequence generation from 2003 to 2013. Generated data sequence is as following:

$$\mathbf{x}^{(0)} = (\mathbf{x}^{(0)}(1), \mathbf{x}^{(0)}(2), \mathbf{x}^{(0)}(3), \cdots, \mathbf{x}^{(0)}(11))$$

In order to ensure GM (1, 1) grey prediction model's accuracy and it's precise, it needs to carry out test handling with modelling obtained original sequence data. It requires original sequence ultimate rate $\lambda(k)$ falls in the interval $(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+2}})$, otherwise it cannot proceed with grey prediction modeling on its data. If its ultimate

rate sequence doesn't fall in required interval, then it should handle with original sequence. Input $n = 11$ and it can get interval(0.8465,1.1663).

By sequence ultimate rate formula:

$$\lambda(\mathbf{k}) = \frac{\mathbf{x}^{(0)}(\mathbf{k} - 1)}{\mathbf{x}^{(0)}(\mathbf{k})}, \mathbf{k} = 2, 3, \cdots, 11$$

It can get that obtained ultimate rate sequence falls in interval(0.9781,1.0096),so it can use original sequence to directly model on prediction system.

GM (1, 1) model establishment

(1) Accumulating and mean handling with new data column

By accumulating operator $AG0$ carrying out accumulating with to new data sequence, weaken its randomness, it can get accumulating sequence:

$$\mathbf{x}^{(1)} = (\mathbf{x}^{(1)}(1), \mathbf{x}^{(1)}(2), \cdots, \mathbf{x}^{(1)}(13))$$

And by formula $z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k)$,it solves its average value generation sequence $z^{(1)}(k)$.

(2) Construct data matrix B and data vector Y:

$$\mathbf{B} = \begin{bmatrix} -\mathbf{z}^{(1)}(2) & 1 \\ -\mathbf{z}^{(1)}(3) & 1 \\ \vdots & \vdots \\ -\mathbf{z}^{(1)}(11) & 1 \end{bmatrix}, \mathbf{Y} = \begin{bmatrix} \mathbf{x}^{(0)}(2) \\ \mathbf{x}^{(0)}(3) \\ \vdots \\ \mathbf{x}^{(0)}(11) \end{bmatrix}$$

$$\overset{\wedge}{\mathbf{u}} = (\mathbf{a}, \mathbf{b})^{\mathbf{T}} = (\mathbf{B}^{\mathbf{T}}\mathbf{B})^{-1}\mathbf{B}^{\mathbf{T}}\mathbf{Y} = \begin{pmatrix} -0.0002 \\ 20.7291 \end{pmatrix}$$

(3) Calculate $\hat{u}$:

$$\frac{\mathbf{dx}^{(1)}}{\mathbf{dt}} - 0.0002\mathbf{x}^{(1)} = 20.7291$$

(4) Model establishment:
It can solve:

$$\mathbf{x}^{(1)}(\mathbf{k} + 1) = 122821\mathbf{e}^{-0.000168803\mathbf{k}} - 122801$$

Solved grey model prediction value is:

$$\overset{\wedge}{\mathbf{x}}^{(0)}(\mathbf{k}) = \mathbf{x}^{(1)}(\mathbf{k}) - \mathbf{x}^{(1)}(\mathbf{k} - 1)$$

Among them, $k = 2, 3, \cdots, 13$, then it can solve 2003~2013 men's 200m best performance prediction value is as following TABLE 2.

GM (1, 1) model test

Model each item test indicator is as following

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TABLE 3 show:

By TABLE 3, it can get prediction model relative error maximum value is 0.9%, maximum ultimate deviation is 0.0217.

Residual qualified model

Relative error sequence is:

$$\Delta = (\Delta_1, \Delta_1, \cdots, \Delta_1)$$

Then it can solve average relative error is:

$$\overline{\Delta} = \frac{1}{n}\sum \Delta_k = 0.0051$$

Correlation degree qualified model:

Absolute correlation degree g is original sequence $x^{(0)}$ and corresponding grey prediction sequence $\overset{\wedge(0)}{x}$ absolute correlation degree, it solves:

$$g = 0.9947$$

(3) Mean square error ratio qualified model

S_1^2 and S_2^2 are respectively original sequence $x^{(0)}$ and residual sequence $\varepsilon(k)$ variances, it can solve mean square error ratio value:

$$C = S_2 / S_1 = 0.5710$$

By TABLE 3 data, it can solve model precise test data as following TABLE 4:

By TABLE 4, it is clear that directly uses traditional GM(1,1) grey model to predict world men's 200m performance, its relative error is 0.0051 that is first grade precise, absolute correlation degree is 0.9947 that is first grade precise, mean square error ratio is 0.5710 that is three grade precise; on a whole, model prediction precise is better. To ensure established prediction model precise, here takes three indicators lowest precise indicator's precise as prediction model's precise. And by TABLE 4, it is clear that GM (1, 1) grey prediction model predicted precise is third grade.

RESIDUAL SEQUENCE GM(1,1) MODEL ESTABLISHMENT

One of very important problems in grey model application is prediction model's precise. In practical ap-

TABLE 2 : 2003~2013 men's 200m best performance prediction table

Year	2003	2004	2005	2006	2007	2008
Performance	20.1300	20.7342	20.7388	20.7412	20.7447	20.7482
Year	2009	2010	2011	2012	2013	
Performance	20.7517	20.7553	20.7588	20.7623	20.7658	

TABLE 3 : GM (1, 1) model test table

Year	Original value	Model value	Residual	Relative error	Ultimate rate deviation
2003	20.13	21.3000	0	0	
2004	20.58	20.7342	-0.1542	0.0075	0.0217
2005	20.69	20.7377	-0.0477	0.0023	0.0051
2006	20.91	20.7412	0.1688	0.0081	0.0104
2007	20.58	20.7447	-0.1647	0.0080	-0.0162
2008	20.91	20.7482	0.1618	0.0077	0.0156
2009	20.94	20.7517	0.1883	0.0090	0.0013
2010	20.74	20.7553	-0.0153	0.0007	-0.0098
2011	20.82	20.7588	0.0612	0.0029	0.0037
2012	20.70	20.7623	-0.0623	0.0030	-0.0060
2013	20.63	20.7658	-0.1358	0.0066	-0.0036

TABLE 4 : GM (1, 1) prediction model precise table

Precise grade	Relative error	Absolute correlation degree	Mean square error ratio value
Three grades	0.0051	0.9947	0.5710

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plication, due to data itself change development features and model application, problem solvers' self knowledge as well as other limits, it lets grey model prediction model precise cannot arrive at corresponding requirement, and competitive sports performance model has no exception. How to solve grey model predicted precise problem, how to implement effective improvement and handling with grey model, it is one of major problems in grey model development. By above calculation results, it is clear that for world men's 200m annual best performance grey model's modeling, its mean square error ratio test indicator is 0.5289 precise is third grade, prediction model's predicted precise is lower. To how to improve grey model's predicted precise such problems, there are lots of performance methods and theories, which mostly is whitening differential equation handling with sample data and selecting grey model. To improve world men's 200m annual best performance predicted precise, the paper carries out residual sequence grey prediction on the model to correct GM (1, 1) grey prediction model.

Residual sequence GM (1, 1) prediction model's establishment

Residual refers to grey prediction model's predicted value and actual value's difference, residual sequence grey prediction model refers to take residual sequence as grey prediction model's original sequence to carry out GM (1, 1) modeling, it gets its prediction model, and makes use of its residual prediction model to correct previous modeled GM (1, 1) grey prediction model, so as to improve prediction model's precise. By above calculation, world men's 200m annual best performance residual is as TABLE 5 show.

Take year 2007~2013 residual to proceed with world men's 200m best performance residual sequence generation:

$$\varepsilon_0 = (\varepsilon_0(1), \varepsilon_0(2), \cdots, \varepsilon_0(7))$$

By TABLE 5, it is clear that partial residual value is negative value, it cannot direct use it to carry out GM (1, 1) grey modeling. Meanwhile, if it needs to carry out grey prediction modeling, its sequence ultimate ra-

TABLE 5 : 2003~2013 Men's 200m best performance prediction model residual

Year	2003	2004	2005	2006	2007	2008
Performance	0	-0.1542	-0.0477	0.1688	-0.1647	0.1618
Year	**2009**	**2010**	**2011**	**2012**	**2013**	
Performance	0.1883	-0.0153	0.0612	-0.0623	-0.1358	

tio $\lambda(k)$ drops in the interval $(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+2}})$, otherwise it cannot use its data to proceed with grey prediction modeling. Among them, $n = 7$, input it and can get interval(0.7788,1.2488).

In order to model on GM(1,1) grey prediction model, it should handle with residual sequence and get new sequence that meets grey model establishment conditions. In the paper, do translation transformation with residual sequence ε_0, that is to take a proper positive number c, let $\varepsilon_1^{(0)}(k) = \varepsilon_0(k) + c$, the paper her takes $c = 15$, and can get transformation sequence as TABLE 6 show.

By ultimate testing, it can get new generated residual sequence ultimate rate value range is [0.9785,1.0136], it meets GM(1,1) grey prediction model established conditions. That can model on it ac-

cording to above GM (1, 1) grey prediction model's modeling steps.

Residual sequence GM (1, 1) model result and test

To new generated residual sequence, it makes GM(1,1) modeling, set its accumulating sequence to be $\varepsilon_1^{(1)}$, it can get its whiten differential equation solution as:

$$\hat{\varepsilon}_1^{(1)}(k+1) = 3718.11 - 3703.27\exp(-.00410962k)$$

To solve predicted value and original value, it makes

TABLE 6 : New generated residual sequence value

Year	2007	2008	2009	2010
Performance	-0.1647	0.1618	0.1883	-0.0153
Year	**2011**	**2012**	**2013**	
Performance	0.0612	-0.0623	-0.1358	

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comparative analysis and test, and gets model error values TABLE as following TABLE 7:

Utilize TABLE 7 solved model error value and residual value, it calculates on GM(1,1)model, solves each item test indicator to calculate and obtained result is as TABLE 8:

By TABLE 8, it is clear that model relative error is 0.0023, its precise grade is first grade, absolute correlation degree is 0.9978, precise grade is first grade, mean square error rate value is 0.3272, and precise grade is first grade. Residual GM (1, 1) grey system goes ahead with grey prediction modeling; its precise is very high and can apply it to predict on its residual.

Restore residual sequence, set 2003~2006 years

residual predicted value is 0 and can get prediction residual value as TABLE 9:

Residual correction-based GM(1,1) grey prediction model's establishment

By above research calculation, it is clear that new generated residual sequence whiten differential equation solution is:

$$\hat{\varepsilon}_1^{(1)}(k) = 3718.11 - 3703.27\exp(-.00410962k)$$

And the whiten differential equation solution is the solution that is got by year 2007~2013 residual sequence value carries out GM(1,1) grey prediction model, in order to combine it with year 2003^ÿ2013 world men's 200m annual best performance sequence

TABLE 8 : Residual GM (1, 1) prediction model precise table

Precise grade	Relative error	Absolute correlation degree	Mean square error rate value
First grade	0.0023	0.9978	0.3272

TABLE 9 : Year 2003~2013 men's 200m best performance residual predicted value

Year	2003	2004	2005	2006	2007	2008
Performance	0	0	0	0	-0.1647	0.1878
Year	**2009**	**2010**	**2011**	**2012**	**2013**	
Performance	0.1255	0.0635	0.0017	-0.0598	-0.1211	

TABLE 10 : Grey prediction sequence GM (1, 1) model error value

Year	Original value	Model value	Residual	Relative error
2003	20.13	21.3000	0	0
2004	20.58	20.7342	-0.1542	0.0075
2005	20.69	20.7377	-0.0477	0.0023
2006	20.91	20.7412	0.1688	0.0081
2007	20.58	20.5800	0	0
2008	20.91	20.9360	-0.0260	0.0012
2009	20.94	20.8772	0.0628	0.0030
2010	20.74	20.8188	-0.0788	0.0038
2011	20.82	20.7605	0.0595	0.0029
2012	20.70	20.7025	-0.0025	0.0001
2013	20.63	20.6447	-0.0147	0.0007

carried out GM(1,1)grey prediction model result, it needs to handle with it. Set:

$$\varepsilon_2^{(1)}(k) = \begin{cases} 0 & k \le 4 \\ \varepsilon_1^{(1)}(k-4) & k > 4 \end{cases}$$

Set $y^{(0)}(k)$ is residual correction-based GM(1,1)

grey prediction model predicted value, from which $k = 1,2,\cdots,13$. Then $y^{(1)}(k)$ is residual grey prediction model predicted value's accumulating sequence. That can solve:

$$y^{(1)}(k) = \hat{x}^{(1)}(k) + \varepsilon_2^{(1)}(k-4)$$

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TABLE 11 : Residual correction-based GM (1, 1) prediction model precise table

Precise grade	Relative error	Absolute correlation degree	Mean square error rate value
First grade	0.0027	0.9980	0.3328

By accumulating sequence $y^{(1)}(k)$ solved prediction sequence $y^{(0)}(k)$ by restoring, it can solve predicted value and its error value as TABLE 9:

Utilize TABLE 9 solved model error value and residual value, calculate based on residual correction GM(1,1) grey prediction model, it solves each item testing indicators to calculate and solved result is as TABLE 10:

By TABLE 10, it is clear that model relative error is 0.0027, its precise grade is first grade, absolute correlation degree is 0.9980, precise grade is first grade, mean square error rate value is 0.3328, and precise grade is first grade. That solved residual correction-based GM (1, 1) grey prediction model's predicted precise grade is first grade; it can make accurate prediction on world men's 200m annual best performance.

Based on solved model, it can predict on world men's 200m annual best performance in 2014, by formula:

$$\hat{x}^{(1)}(k+1) = 122821e^{-0.000168803k} - 122801$$

It can solve when $k=10$, $k=11$,

$$\hat{x}^{(1)}(11) = 227.5006, \quad \hat{x}^{(1)}(12) = 248.2699 \cdot$$

That can solve GM (1, 1) grey prediction model predicted value in 2014 is: $\hat{x}^{(0)}(12) = 20.7639 \cdot$

Similarly, it can solve residual predicted value in 2014 is $\hat{\varepsilon}_2(8) = -0.1821$. Then it can solves world men's 200m best performance value is 20.59s based on residual correction GM(1,1) model.

CONCLUSIONS

The paper carries out grey prediction modeling with world men's 200m annual best performance, it predicts its performance in 2014, meanwhile discusses grey model applied methods in competitive sports performance prediction that propels to grey model application in competitive sports. GM (1, 1) grey model adapts sample data distribution modeling process with exponential changes, the paper by modeling analysis on statistical data, it expands grey prediction model, applies residual-based GM(1,1) grey prediction model to predict world men's 200m annual best performance, and carries out comparative analysis of it with GM(1,1) grey model. By results, it can find out that residual GM (1, 1) grey prediction model complex degree is low, predicted precise is high that adapts competitive sports performance prediction.

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