Prediction of Motorcycle Seat Styling Based on Grey Modelling (1,1)

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Abstract. The process of motorcycle seat styling is a grey system with partially known and partially unknown information and is influenced by various factors. In this study, Grey Modelling (GM)(1,1) is used to predict the style of a motorcycle seat, and the shape features of the seat are extracted via morphological analysis and are parameterized. The process of shape evolution is established, and the modelling characteristics are predicted by GM(1,1). The kansei study is performed using five adjectives describing the seat styles to establish the equation of kansei regression analysis. The regression analysis is employed to modify predictive modelling. A certain brand of motorcycle seats is modelled to analyse and verify the feasibility and scientific applicability of adopting GM(1,1) in predicting motorcycle seat styling, which provided a feasible and effective reference for the motorcycle seat design.

Keywords: motorcycle seat, prediction, GM(1,1), regression analysis
DOI: https://doi.org/10.14733/cadaps.2019.789-802

1 INTRODUCTION

As the motorcycle is one of the popular modes of transport, research on its modelling research is expanding. Motorcycle styling is an important link in the motorcycle design and development. Motorcycle styling design is one of the applications of computer-aided design technology. The modelling design of a motorcycle is not purely aesthetic but is influenced and restricted by its functions, materials, crafts, in addition to human-machine environment. In motorcycle styling, the seat is one of the most important parts. The motorcycle seat affects the comfort and safety of the driver; therefore, it plays a key role in motorcycle styling. The side contour lines of a motorcycle include important information such as the type of the motorcycle and the overall style. They can be used as the personalised information to differentiate the visual images of different motorcycle models [3].

At present, the method of motorcycle seat modelling design is not adequate. Furthermore, there is a lack of predictive research into the future motorcycle seat styling. The development trend of the domestic motorcycle seats lacks quantitative prediction; hence, the grey system theory [6] is applied to the motorcycle seat modelling prediction research. A quantitative model for predicting the development trend of motorcycle seat modelling is attempted. Then the feasibility of the theoretical prediction is verified by a case study. Therefore, in this study, the side contour line of a motorcycle seat is considered as the research object. In order to extract the features of motorcycle seat modelling, the method of extracting the cross-sectional shape feature is adopted [11]. Therefore, the transformation of a kansei image into a rational image is achieved.

The predictive models have been employed with great effect in many areas in the social and natural sciences. A study proposed a simple and valid predictive model for acquiring external ischial tuberosity width (EITW) values to determine the seats for riders when bicycling [4]. According to Carneiro et al. [2], home care nurses often have high prevalence rates of musculoskeletal complaints, so the study developed a statistical model to predict lumbar complaints. Wu and Wada summarised many researches of several scholars, and reported that human performance modeling (HPM) provided a new set of methods to predict operator performance for improved productivity and safety [22].

The grey system theory is one of the most commonly used prediction model. The GM(1,1) is the most frequently used prediction model in the grey system. The GM(1,1) model has a very extensive scope, and it has achieved a good prediction accuracy. A "small sample" with "partially known and partially unknown information" and an uncertain system with "poor information" are the subjects investigated in the GM(1,1) model.

Wu et al. [23] summarised five aspects of GM(1,1) from the existing research. A study applied GM(1,1) to predict the number of end-of-life vehicles in Turkey [7]. The result demonstrated that the GM(1,1) model can be used in similar forecasting problems. Silva et al. [15] analysed the performance of two prediction methods, which are the linear regression and grey model. Statistical indicators were gathered to create a game theory payoff matrix. Dejamkhooy et al. [5] utilised the improved grey system theory to predict the time series. The results demonstrated that the modified grey models have high performances both in model fitting and forecasting. A hybrid optimised grey model was proposed to forecast the annual power load. The result indicated that the optimised GM(1,1) model can significantly improve the accuracy of the annual power load forecast by Zhao and Guo [27]. Bezuglov and Comert [1] used the grey system theory models to predict the short-term freeway traffic parameter. They observed that the grey model was simple and adaptable and had other advantages. Tabaszewski and Cempel [17] proposed three methods to counteract the errors in automated diagnostic systems based on the grey system theory and GM(1,1).

Evans [8] developed another method to estimate the unknown parameter of GM(1,1), which proved that this alternative method provides more reliable parameter estimation. A novel prediction-based data collection protocol was proposed by Wei et al. [21]. The result demonstrated that the proposed method improved the service life of wireless sensor networks significantly. Wang and Hung [20] used the systematic grey prediction for hole filling. The hole filling results were superior to other known methods. Tsaur [18] verified the reliability and validity of GM(1,1) and used two examples of the LCD TV demand to illustrate the proposed models. After two years, Tsaur [19] continued to investigate and derive the grey model. He successfully predicted the LCD TV demand by using this model.

The remainder of this paper is organized as follows. Section 2 introduces the procedure of parameterization, the arithmetic of GM(1,1) model and its evaluation. In Section 3, the prediction process based on GM(1,1) models is shown, including data acquisition, model simulation, prediction results and results analysis. Section 4 discusses the error analysis, predictive seat styling correction and its verification. Finally, the findings in this paper is summarized in Section 5.

2 MATERIALS AND METHODS

In this section, the parameterisation of seat styling is first summarized; then the idiographic arithmetic of the GM(1,1) model and its evaluation are introduced.

2.1 PARAMETERISATION OF SEAT STYLING

The procedure for extracting the side contours of a seat is shown in Fig. 1. In this process, the seat is reduced to 1/45 of the actual size and then the outline is extracted using a software named Rhinoceros (Rhino) [13]. By using the Curve instruction in Rhino, the seat contour line is parameterised by 41 control points as listed in Table 1. The 41 control points for the seat are determined by its styling. So as to avoid inaccurate prediction results caused by inappropriate number of control points, the motorcycle seat profile is able to be described appropriately by 41 points, including the appropriate curvature and turning point.

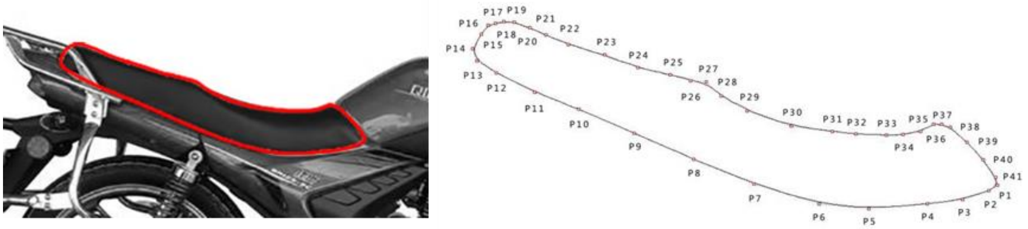

Figure 1: Extraction Process of Motorcycle Seat Profile: (a) The Seat Profile of Motorcycle, and (b) The Form Feature Points of Motorcycle Seat.

Control point	*Curve segment of seat side profile line*
P_1, P_2,..., P_{12}	Seat bottom curve section
P_{13} , P_{14} , P_{15}	Rear seat down left curve segment
P_{16}, P_{17},..., P_{19}	Rear seat up left curve segment
⋮	⋮
P_{38}, P_{39},..., P_{41}	Front seat down right curve section

Table 1: Relationship between seat profile curve and control point.

In order to carry out the parametric research, it is necessary to set the control points. Therefore, in this study, $P_1(20,5)$ (mm) is set.

Modelling using the Rhino is the reverse operation of motorcycle seat styling parameterisation [25]. As shown in Fig. 2, numbers $1,2,\cdots,n-1$ represent the existing styling of the product where n represents the new modelling. Then, the predictive modelling of the product is achieved by using the GM(1,1) model and Rhino.

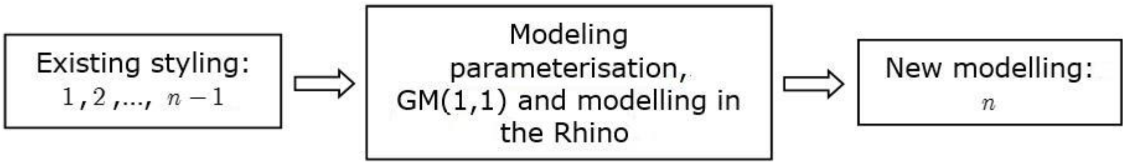

Figure 2: Predictive model.

2.2 PREDICTION MODEL OF SEAT STYLING

In this study, the GM(1,1) model is used to predict the future motorcycle seat styling. The GM(1,1) model is particularly suitable for the case of data scarcity—only four training data values are adequate to determine the parameters of the prediction model [26]. The idiographic arithmetic of the GM(1,1) model is as follows [9],[24],[28].

2.2.1 Generate accumulated data sequence

Definition: Assume that $X^{(0)}$ is an original data sequence

$$X^{(0)} = \ x_1^{(0)}, x_2^{(0)}, \cdots, x_n^{(0)} \tag{1}$$

Generate the first-order Accumulated Generating Operation (1-AGO) sequence as

$$X^{(1)} = \ x_1^{(1)}, x_2^{(1)}, \cdots, x_n^{(1)} \tag{2}$$

$$X^{(1)} = AGO(X^{(0)}) \tag{3}$$

Where, $X_k^{(1)} = \sum_{k=1}^{k} x_k^{(0)}, k = 1,2,\ldots,n$.

2.2.2 Generate mean generation

Assume the mean generation with consecutive neighbouring sequence is $Z^{(1)}$. $Z^{(1)}$ is defined as

$$Z^{(1)} = \ Z_2^{(1)}, Z_3^{(1)}, \cdots, Z_n^{(1)} \tag{4}$$

Of which, $Z_k^{(1)} = \dfrac{x_{k-1}^{(1)} + x_k^{(1)}}{2}, k = 2,3,\cdots,n$.

2.2.3 Develop the differential equation

The grey differential equation is

$$x_k^{(0)} + a z_k^{(1)} = b, k = 2,3,\cdots,n \tag{5}$$

The corresponding albinism differential equation is

$$\frac{dx^{(1)}}{dt} + a x_t^{(1)} = b \tag{6}$$

Definition:

$$u = [a,b]^T \text{ , } Y = [x_2^{(0)}, x_3^{(0)}, \cdots, x_n^{(0)}]^T \text{ , } B = \begin{bmatrix} -Z_2^{(1)} & 1 \\ -Z_3^{(1)} & 1 \\ \vdots & \vdots \\ -Z_n^{(1)} & 1 \end{bmatrix} = \begin{bmatrix} -(x_1^{(1)} + x_2^{(1)})/2 & 1 \\ -(x_2^{(1)} + x_3^{(1)})/2 & 1 \\ \vdots & \vdots \\ -(x_{n-1}^{(1)} + x_n^{(1)})/2 & 1 \end{bmatrix} \tag{7}$$

The estimated value of u for which $J(u) = (Y - Bu)^T (Y - Bu)$ is minimised is obtained by the least squares method.

$$\hat{u} = [\hat{a}, \hat{b}]^T = (B^T B)^{-1} B^T Y \tag{8}$$

Then by solving equation (6), the prediction value is obtained

$$\hat{x}_{k+1}^{(1)} = (x_1^{(0)} - \frac{\hat{b}}{\hat{a}}) e^{-\hat{a}k} + \frac{\hat{b}}{\hat{a}}, k = 0,1,\cdots,n-1,\cdots \tag{9}$$

2.3 EVALUATION AND CORRECTION OF PREDICTIVE MODELLING

In order to further improve the prediction results, in this study, a linear regression analysis was adopted to evaluate and correct the prediction results, taking the control point coordinate of the sample profile curve as an independent variable and the kansei score of the sample as the dependent variable. Then the SPSS Statistics [16] was used for linear regression analysis, and the regression equation was established as follows:

$$\hat{y} = \hat{b}x + \hat{a} \tag{10}$$

In the equation, x - independent variables (control point coordinates),

$\hat{y}$ - dependent variable (kansei score of sample),

$\hat{b}$ - coefficient of linear regression equation and

$\hat{a}$ - constant quantity.

In this study, the concept of prototype seat modelling is referenced to predict the seat modelling accurately. The prototype seat is a theoretical seat model, which is obtained by the averaging calculation with sixteen samples that are parameterized. The predicted seat results are evaluated and analysed based on the prototype seat to correct the predicted modelling of the seat.

There are generally three methods to test the grey model: residual test, correlation test and posterior error test [12]. This study mainly adopts the residual test and the posterior error test.

2.3.1 Residual test

$\delta(k)$ represents the relative error between the actual values, ${x_{(k)}}^{(0)}$, and the predictive values, ${\hat{x}_{(k)}}^{(0)}$.

$$\delta(k) = \frac{\left|{x_k}^{(0)} - {\hat{x}_k}^{(0)}\right|}{{x_k}^{(0)}}, k = 1, 2, \cdots, n \tag{11}$$

$\delta(k)$ is the qualified residual that is less than 0.20 [14].

2.3.2 Posterior error test

Let the raw data sequence be $X^{(0)}$, variance S_1^2, residuals sequence e and variance S_2^2, then

$$S_1^2 = \frac{1}{n}\sum_{k=1}^{n}({x_k}^{(0)} - \overline{x}^{(0)})^2 \tag{12}$$

Where, $\begin{cases} \overline{x}^{(0)} = \frac{1}{n}\sum_{k=1}^{n} {x_k}^{(0)} \\ S_2^2 = \frac{1}{n}\sum_{k=1}^{n}(e_{(k)} - \overline{e})^2 \\ \overline{e} = \frac{1}{n}\sum_{k=1}^{n} e_{(k)} \\ e(k) = {x_k}^{(0)} - {\hat{x}_k}^{(0)}, k = 1, 2, \cdots, n \end{cases}$.

The calculated posterior error ratio is C:

$$C = S_2 / S_1 \tag{13}$$

The calculated small error P.

$$P = p\{| e(k) - \overline{e} | < 0.6745 S_1\} \tag{14}$$

The prediction model can be used only if it passes the accuracy test. The quality of the model can be evaluated by using the model accuracy grade [10], which is listed in Table 2.

Indicators of the accuracy test	Grade of prediction model accuracy			
	Excellent	Qualified	Reluctantly qualified	Unqualified
Relative error/ δ	0.01	0.05	0.10	0.20
The mean variance ratio/ C	0.35	0.50	0.65	0.80
Small error probability/ P	0.95	0.80	0.70	0.60

Table 2: Critical value of residual test and posterior error test.

3 CASE STUDY

A case study is conducted by considering a certain brand of motorcycles as an example and selecting a certain series of cross-riding motorcycle seats for the case analysis. According to the seat of a certain series, the grey prediction model is used to forecast the future seat styling.

3.1 PARAMETERISATION OF MOTORCYCLE SEAT

The side profiles of ten seat models of a certain series of a certain brand of motorcycles (marked: Model 1, Model 2, and Model 10) were extracted, and the seat modelling is parameterised by morphological analysis as shown in Table 3. In Table 3, the values are in mm, based of 1/45 scaling of the actual seat size.

Control point	Coordinate						
	Model 1		Model 2		⋯	Model 10	
	x	y	x	y	⋯	x	y
P_1	20.00	5.00	20.00	5.00	⋯	20.00	5.00
P_2	20.06	4.78	19.54	4.95	⋯	19.71	4.8
P_3	19.27	3.51	18.45	5.03	⋯	18.84	4.49
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
P_{41}	19.95	5.28	20.28	5.46	⋯	19.93	5.26

Table 3: Seat modelling parameters of a certain series of motorcycles (mm).

3.2 MODEL SIMULATION AND EVALUATION

In this study, the accuracy of the prediction model was determined by simulation. The specific measures are as follows: the latest seat of a certain series is predicted by using the other nine seat models. If the results show that the relative error of the latest motorcycle seat is within the acceptable range, the prediction model is applied to a motorcycle seat.

The predictive value of the tenth seat is obtained by using the GM(1,1) model. From Table 4, the values of $\delta(k)$ are less than 0.10, which are treated as the qualified residual. Based on the formula of $C = S_2 / S_1$, the value $C = S_2 / S_1 = 0.27499657$ is obtained. $P = p\{| e(k) - \bar{e} |< 0.6745 S_1\} = p\{| e(k) - \bar{e} |< 3.27852828\} = 1 - 0.16622282 = 0.8337772$; therefore, $C \leq 0.35, P \geq 0.80$. The model has a good accuracy.

In summary, the consequences were tested and verified satisfactorily by conducting the residual and posterior error tests. Therefore, this model can be applied to the motorcycle seat prediction of a certain series of a certain brand of motorcycles in this study. The result is listed in Table 4.

Control point	Coordinate				Discrepancy		Relative error/ δ	
	Real date of Model 10		Predictive date of Model 10					
	x	y	x	y	x	y	x	y
P_1	20.00	5.00	20.00	5.00	0	0	0	0
P_2	19.71	4.8	19.58	4.70	0.13	0.10	0.0066	0.0216
P_3	18.84	4.49	18.51	4.28	0.33	0.21	0.0176	0.0467
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
P_{41}	19.93	5.26	19.76	5.31	0.17	-0.05	0.0084	0.0092

Table 4: The result of model evaluation (mm).

3.3 PREDICTIVE SEAT MODELLING BY USING GM(1,1) MODEL

Insert the abscissa, P_{ix}, and the ordinate value, $P_{iy}(i=1,2,\cdots,41)$, of each control point of the side profile of the seat of a certain series into the GM(1,1) model. The coordinate parameters of the control points for predicting the seat modelling are calculated as shown in Table 5.

According to the coordinates listed in Table 5, the profile of a cross-riding motorcycle seat of a certain series was predicted by using the Curve instruction in Rhino as shown in Fig. 3.

Control point	Coordinate	
	x	y
P_1	20.00	5.00
P_2	19.53	4.8
P_3	18.4	4.69
$\vdots$	$\vdots$	$\vdots$
P_{41}	19.99	5.38

Table 5: Predictive seat modelling parameters of a certain series of motorcycles (mm).

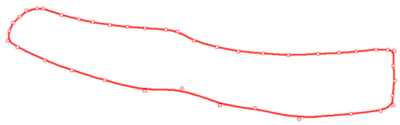

Figure 3: Predictive side profile of seat of certain series of motorcycles.

3.4 EXTRACTION OF PROTOTYPE SEAT

In order to predict the motorcycle seat by linear regression analysis, the prototype seat should be considered as the reference seat. The prototype seat is the modelling extracted from the samples after parameterization, which is based on the averaging calculation. In order to eliminate the interference factors of the original motorcycle seats of a certain series, sixteen similar cross-riding motorcycle seats of other brands are selected as the samples for an accurate reference. The side profiles of the 16 seat samples (marked: Model A, Model B, and Model P) are illustrated in Fig. 4, and each sample was processed with the grayscale. The seats of the 16 sample models were parameterized, and the corresponding coordinates were averaged to obtain the control coordinates of the prototype seat. Based on the characteristic parameter reverse generation principle, the side profile of the prototype seat was modelled by using the Rhino as shown in Fig. 5.

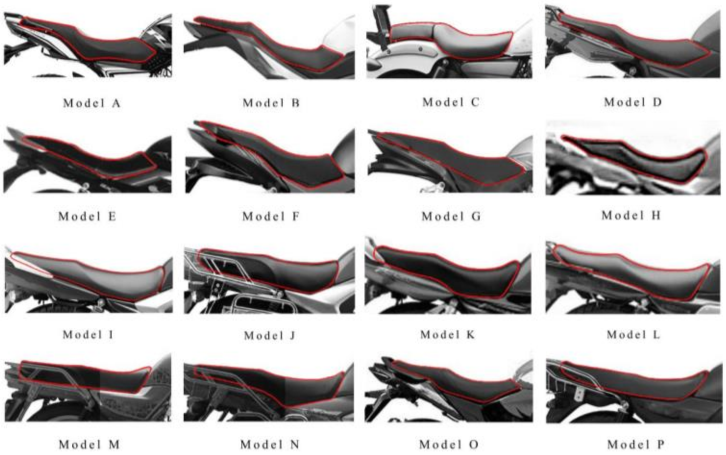

Figure 4: 16 Side profiles of 16 sample seats.

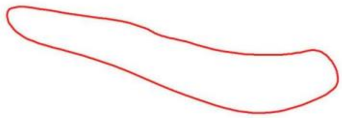

Figure 5: Side profile modelling of prototype seat.

3.5 KANSEI SCORE AND REGRESSION ANALYSIS OF PREDICTIVE SEAT

Based on the focus group method and the literature, the kansei words were collected, which depict the seat, and then used the subjective evaluation and KJ method to exclude inappropriate or near-term words. The KJ method was proposed by Tokyo humanist, Kawakita Jiro. Finally, five kansei words that describe the seat were obtained: dynamic, modern, streamlined, stylish and comfortable. Then the five kansei words were used to describe the 16 sample seats, prototype seat and predictive seat using the 7-order Semantic Differential (SD) scale method to conduct a kansei questionnaire. The respondents rated the kansei image of 18 motorcycle seat stylings. The higher the styling score means the higher compatibility mapping kansei image of seat styling to kansei words. The kansei scores provided by 50 respondents (of which 26 people have a design background and 24 people do not) were recorded as follows. The dynamic image scores are listed in Table 6.

In order to verify the accuracy from the perspective of kansei image, linear regression analysis is used to study the relationship between seat styling and kansei image. Taking the word "dynamic" as an example to analyse the images. In this study, the relative coordinate value of the control points of each type of seat is an independent variable, and the average score of the dynamic image is a dependent variable. The relative coordinates of the control points are obtained from the difference between the coordinates of the control points of the sample seats and that of the prototype seat. The regression coefficients are obtained by linear regression analysis by inputting the relative coordinates of the side profile control points of the 16 sample models and the mean value of the "dynamic" kansei word into the SPSS. In the linear regression equation, because the term whose regression coefficient is less than 0.1 has little effect on the overall result, it can be ignored in the calculation. The linear regression equation is

$$y_{dynamic} = 3.435 - 0.448x_2 - 1.145y_2 - 0.241x_3 - 0.727y_3 + 0.292x_{14} - 0.264x_{17} - 0.103x_{20} + 0.876y_{38} - 4.120y_{41} \quad (15)$$

The relative coordinate parameters of the predicted seat of a certain series of cross-riding motorcycles are substituted into the dynamic image regression equation. The relative coordinates are the difference between the control-point coordinates of the predictive seat and that of the prototype seat as summarised in Table 7. The theoretical score for calculating the dynamic image is 2.70. Similarly, the theoretical values corresponding to the modern, streamlined, stylish and comfortable images are 3.40, 4.27, 2.26 and 3.61, respectively.

Number	Name	Scores of 50 questionnaires					Average
		1	2	3	⋯	50	
1	Model A	5	5	5	⋯	5	4.30
2	Model B	4	6	3	⋯	6	3.98
3	Model C	5	1	1	⋯	3	3.06
⋮	⋮	⋮	⋮	⋮	⋯	⋮	⋮
16	Model P	2	2	2	⋯	2	2.82
17	Prototype seat	4	4	4	⋯	3	3.98
18	Predictive seat	2	2	2	⋯	3	2.94

Table 6: Dynamic image scores.

Control point	Relative coordinate	
	x	y
P_1	0.00	0.00
P_2	0.07	0.29
P_3	-0.11	0.52
⋮	⋮	⋮
P_{41}	0.18	0.11

Table 7: Relative coordinate parameter of predictive seat of certain series of cross-riding motorcycles (mm).

4 RESULTS AND DISCUSSION

4.1 ERROR ANALYSIS AND RESIDUAL TEST RESULTS

The error is the difference between the theoretical and real values. In this study, the theoretical value required for the error analysis is the regression analysis value of the predicted seat, and the real value is the mean value of the kansei imagery score.

According to Eq. 11, $x_{(k)}^{(0)}$ means real value (the kansei score of the questionnaire survey), and $\hat{x}_k^{(0)}$ represents theoretical value (the kansei score of linear regression analysis).

The relative error of the kansei score of the word "dynamic" is 0.0806. The error value is small, which indicates that the predictive modelling of the motorcycle seat according to the GM(1,1) model is feasible for the "dynamic" image prediction. The error values of the kansei score of the words "modern" and "streamlined" are relatively small, 0.0561 and 0.0675, respectively. The relative error corresponding to the word "stylish" is 0.0174, which is very small. It shows that the GM(1,1) model for the prediction of the "stylish" image is excellent. The relative error corresponding to the word "comfortable" is 0.0919. The relative errors of the kansei scores of all the five words are less than 0.010, indicating that they are qualified.

4.2 PREDICTIVE MODELLING CORRECTION

The theoretical values of "dynamic" and "comfortable" images are excessively lower than their corresponding real values; therefore, the theoretical values need to be increased. In addition, the theoretical values of "modern" and "streamlined" images are higher than their corresponding real values; therefore, the theoretical values need to be reduced. In the image regression equation, adjusting the parameter values has a corrective effect on the five image scores, which are -4.120, -0.2115, +0.751, -3.089 and -1.408, according to the coefficients of P_{41y}. In the image regression equations corresponding to the words "dynamic", "stylish" and "comfortable", the coefficient is negative. In order to increase their theoretical values, the value of P_{41y} is reduced. The predicted value of 5.38 is reduced to 5.28. In other words, in the view of motorcycle seat modelling, point P_{41y} is moved along the y-axis by 0.10 mm downward. After correction, the results are as follows: the scores corresponding to "dynamic", "modern", "streamlined", "stylish" and "comfortable" are 3.11, 3.42, 4.20, 2.40 and 3.76, respectively. The relative errors corresponding to "dynamic", "modern", "streamlined", "stylish" and "comfortable" are 0.0596, 0.0621, 0.0500, 0.0435 and 0.0553, respectively. In these five errors, only two errors are less than 0.0500, which indicates that they are excellent, and the remaining three are qualified. All the results are within the allowable range of error.

Residual test results are satisfactory, and if the posterior error test also qualified, indicating that the GM(1,1) model applies to motorcycle seat modelling predictions.

Based on the formula of the posterior error test, $C = S_2 / S_1 = 0.24644933$ was obtained, where $P = p\{| e(k) - \bar{e} | < 0.6745 S_1\} = p\{| e(k) - \bar{e} | < 0.43584184\} = 1 - 0.1335031 = 0.8664969$; therefore, $C \leq 0.35, P \geq 0.80$. The model has a good accuracy.

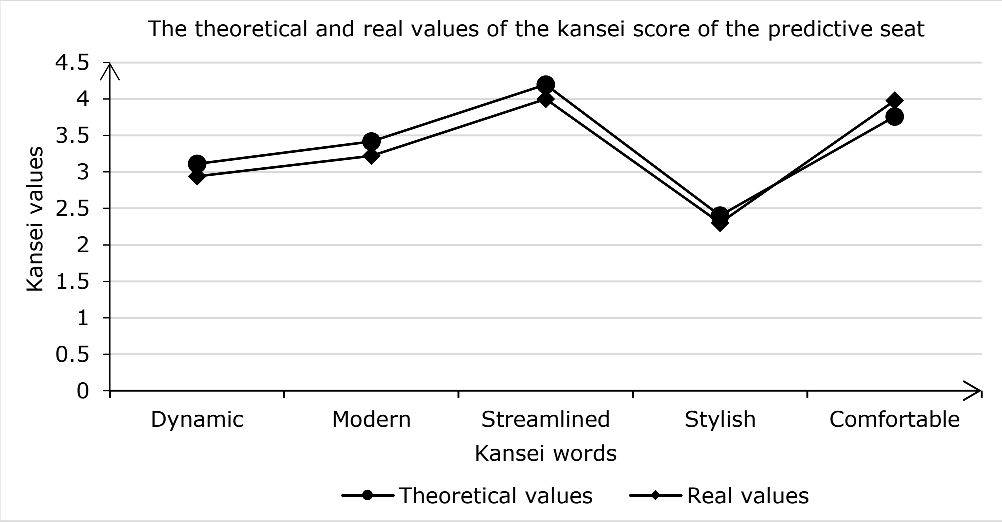

Figure 6: Theoretical and real values of kansei score of predictive seat.

From the residual test and posterior error test, it can be observed that the model has high precision, which shows that GM(1,1) is suitable for the prediction of the shape of motorcycle seats. The final distribution of the theoretical and real values of the kansei score, which is adopted to describe the predictive seat, is shown in Fig. 6. The predictive profile of the motorcycle seat after final correction is illustrated in Fig. 7.

Figure 7: Corrected profile of predictive motorcycle seat.

This modified predictive seat styling meets the safety requirements of the seat. First, it gives a sense of flexibility and comfort. Second, the rear end of the seat is upturned, preventing the occupants from skidding when the motorcycle accelerates sharply. Third, the middle part of the seat is protruded, which is designed to prevent the rider from skidding on the body during rapid acceleration of the motorcycle, affecting the operation and safety of the motorcycle. Finally, the seated area under the sciatic bone is approximately horizontal to avoid discomfort caused by excessive compression of the femur. Fig. 8 is a comparison between the pre- and post-revisions of the predicted seat styling. The red line is the original predictive seat styling, and the black line represents the modified predictive seat styling. When compared with the original predicted seat, the modified seat has only a slight change in the lower right side of the seat. However, because of this little change, the seat, in theory, is more in line with the requirements of higher accuracy.

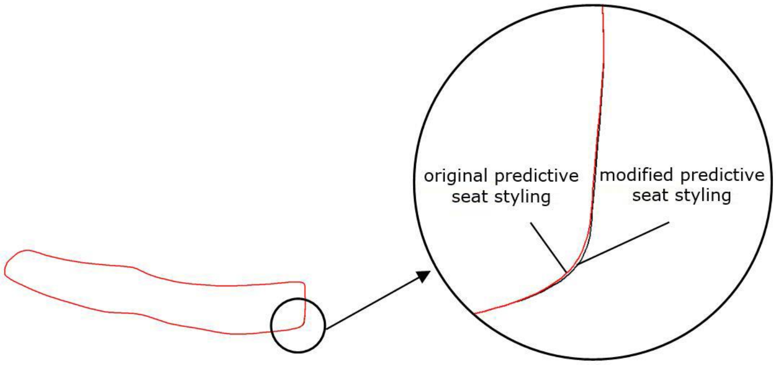

Figure 8: Comparison between pre-and post-revisions of predicted seat styling.

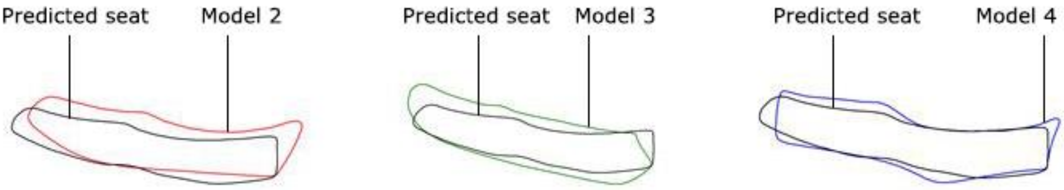

Figure 9: Comparison between predicted seat styling and existing seat of certain series: (a) Predicted seat & Model 2, (b) Predicted seat & Model 3, and (c) Predicted seat & Model 4.

The predictive seat and the existing motorcycle seats of a certain series were compared. In this study, three representative groups are selected. Fig. 9 is the comparison between the predicted seat styling and the existing seats of a certain series. It can be observed from Fig. 9 that the predicted seat and the existing seats are the same in some details, such as the approximate level of the seat surface, the upturned seat back, and the protruded middle part of the seat. The predicted seat is consistent with the existing seats, and the prediction results are satisfactory.

4.3 VERIFY PREDICTED RESULTS

In addition, an electronic questionnaire was developed to gather the information for the study to verify the predicted results. There are four questions in the questionnaire, as follows:

(1) The gender of the respondents.

(2) Whether the respondents have a design background.

(3) Whether the respondents have experience of riding motorcycles.

(4) Compare the predicted motorcycle seat styling with the existing ten seats of certain series. Then rate the degree of serialisation of the predicted seating styling. The degree of serialisation is graded with five scores. The higher the score is, the higher the degree of serialisation of the predicted seat is.

110 valid questionnaires were received. Respondents including 44 males and 66 females; 40 people have a design background, while 70 people do not; 69 people have experience of riding motorcycles, while 41 people do not. The results of the degree of serialisation of the predicted seating styling is shown in Fig. 10. According to Fig. 10, there are 24, 40, 35, 10, and 1 people who have selected Level "5", "4", "3", "2", and "1", respectively.

Options	Subtotal	The proportion
5	24	21.82%
4	40	36.36%
3	35	31.82%
2	10	9.09%
1	1	0.91%
The number of valid fill in this question	110	

Figure 10: The questionnaire results of serialisation degree of the predicted seat styling.

According to the survey results, the majority of respondents believed that the predicted seat styling and the original ten seats are highly serialized. This result proves the feasibility of using GM(1,1) model to predict the motorcycle seat styling and the validity of prediction results.

5 CONCLUSIONS

In this study, the GM(1,1) model is used to predict the motorcycle seat styling of a certain series of a certain brand of motorcycles. The results and contributions are as follows:

(1) The grey model prediction method provides the theoretical basis for the development of the motorcycle seat modelling. Through the case analysis, the kansei word regression equation was established with the score of the kansei words questionnaire, and the predictive modelling of the seat was tested and corrected.

(2) The process verifies the feasibility and rationality of the grey prediction theory in predicting the modelling method of motorcycle seats and provides an effective reference and evaluation method for the motorcycle seat styling design.

(3) The proposed framework, as demonstrated by the case study, can be applied to a range of conditions for the motorcycle seat styling design. It provides a relatively easy methodology for establishing the motorcycle seat model and enhances the decision-making process in the motorcycle seat styling design with limited data, especially at the project level. In the future design and production of motorcycle, this would provide references and assistance for motorcycle designers in the series design of motorcycle.

ACKNOWLEDGEMENT

This work was supported by the National Science Foundation of China (grant number 51675289) and a Project of Shandong Province Higher Educational Science and Technology Program (grant number J17KA029).

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REFERENCES

[1] Bezuglov, A.; Comert, G.: Short-term freeway traffic parameter prediction: Application of grey system theory models, Expert Systems with Applications, 62, 2016, 284-292. https://doi.org/10.1016/j.eswa.2016.06.032.

[2] Carneiro, P.; Braga, A.-C.; Barroso, M.: Work-related musculoskeletal disorders in home care nurses: Study of the main risk factors, International Journal of Industrial Ergonomics, 61, 2017, 22-28. https://doi.org/10.1016/j.ergon.2017.05.002.

[3] Chen, H.-Y.: A study on the relationship of automobile contour of image feature and discrimination feature, M.S. Thesis, National Cheng Kung University, Tainan, TW, 2001.

[4] Chen, Y.-L.: Predicting external ischial tuberosity width for both sexes to determine their bicycle-seat sizes, International Journal of Industrial Ergonomics, 64, 2018, 118-121. https://doi.org/10.1016/j.ergon.2018.01.008.

[5] Dejamkhooy, A.; Dastfan, A.; Ahmadyfard, A.: Modeling and Forecasting Nonstationary Voltage Fluctuation Based on Grey System Theory, IEEE Transactions on Power Delivery, 32(3), 2017, 1212-1219. https://doi.org/10.1109/TPWRD.2014.2386696.

[6] Deng, J.-L.: Control problems of grey systems, Systems & Control Letters, 1(5), 1982, 288-294. https://doi.org/10.1016/S0167-6911(82)80025-X.

[7] Ene, S.; Öztürk, N.: Grey modeling-based forecasting system for return flow of end-of-life vehicles, Technological Forecasting & Social Change, 115, 2017, 155-166. https://doi.org/10.1016/j.techfore.2016.09.030.

[8] Evans, M.: An alternative approach to estimating the parameters of a generalised Grey Verhulst model: An application to steel intensity of use in the UK, Expert Systems with Application, 41(4), 2014, 1236-1244. https://doi.org/10.1016/j.eswa.2013.08.006.

[9] Hou, S.-Q.: Forecasting of Water Resource of China based on Grey Prediction Model, Advance Journal of Food Science and Technology, 9(5), 2015, 389-392. https://doi.org/10.19026/ajfst.9.1921.

[10] Jiang, C.-F.; Hou, K.-P.; Sun, H.-F.: Prediction and analysis of safety production accident in mining based on the GM(1,1), Advanced Materials Research, 989-994, 2014, 3443-3446. https://doi.org/10.4028/www.scientific.net/AMR.989-994.3443.
[11] Jing, C.-H.; Zhao J.-H.: The Prototype Characteristics of Automobile Styling, Packaging Engineering, 36(2), 2015, 50-54.
[12] Liu, X.-Y.; Peng, H.-Q.; Bai, Y.; Zhu, Y.-J.; Liao, L.-L.: Tourism Flows Prediction Based on an Improved Grey GM(1,1) Model, Procedia - Social and Behavioral Sciences, 138, 2014, 767-775. https://doi.org/10.1016/j.sbspro.2014.07.256.
[13] Rhinoceros, Version 5.0, https://www.rhino3d.com/, Robert McNeel & Assoc.
[14] Si, S.-K.; Sun, Z.-L.: Mathematical Modeling Algorithms and Applications, National Defense Industry Press, Beijing, BJ, 2015.
[15] Silva, A.; Zhou, F.; Pontes, E.; Simplicio, M.-A.; Aguiar, R.; Guelfi, A.; Kofuji, S.: Energy-efficient node position identification through payoff matrix and variability analysis, Telecommunication Systems, 65(3), 2017, 459-477. https://doi.org/10.1007/s11235-016-0245-4.
[16] SPSS Statistics, Version 21.0, https://www.ibm.com/analytics/spss-statistics-software, IBM.
[17] Tabaszewski, M.; Cempel, C.: Using a set of GM(1,1) models to predict values of diagnostic symptoms, Mechanical Systems and Signal Processing, 52-53, 2015, 416-425. https://doi.org/10.1016/j.ymssp.2014.08.013.
[18] Tsaur, R.-C.: Forecasting analysis by using fuzzy grey regression model for solving limited time series data, Soft Computing, 12(11), 2008, 1105-1113. https://doi.org/10.1007/s00500-008-0278-z.
[19] Tsaur, R.-C.: The development of an interval grey regression model for limited time series forecasting, Expert Systems with Applications, 37(2), 2010, 1200-1206. https://doi.org/10.1016/j.eswa.2009.06.021.
[20] Wang, L.-C.; Hung, Y.-C.: Hole filling of triangular mesh segments using systematic grey prediction, Computer-Aided Design, 44(12), 2012, 1182-1189. https://doi.org/10.1016/j.cad.2012.07.007.
[21] Wei, G.-Y.; Ling, Y.; Guo, B.-F.; Xiao, B.; Vasilakos, A.-V.: Prediction-based data aggregation in wireless sensor networks: Combining grey model and Kalman Filter, Computer Communications, 34(6), 2011, 793-802. https://doi.org/10.1016/j.comcom.2010.10.003.
[22] Wu, C.-X.; Wada, T.: Introduction of the special issue of human performance modeling: Prediction of human performance to improve productivity and safety, International Journal of Industrial Ergonomics, 63, 2018, 1-2. https://doi.org/10.1016/j.ergon.2018.01.001.
[23] Wu, L.-F.; Gao, X.-H.; Fu, B.; Long, Q.-H.; Wen, Z.-X.: Advance in grey GM(1,1) model research, Mathematics in Practice and Theory, 47(15), 2017, 227-233.
[24] Xu, J.; Jing, G.-X.; Xu, Y.-Y.: Prediction of the maximum water inflow in Pingdingshan No.8 mine based on grey system theory, Journal of Coal Science and Engineering (China), 18(1), 2012, 55-59. https://doi.org/10.1007/s12404-012-0110-3.
[25] Xu, J.; Wang, X.-Y.; Huang, P.; Wang, Y.; Chu, Y.-T.: Research on prediction methods of automobile styling based on the grey correlation theory, Journal of Machine Design, 33(2), 2016, 114-117.
[26] Xu, Q.-Y.; Yang, M.-L.; Liu, W.-D.; Liu, C.-J.; Yan, H.-M.: Product form feature evolution forecasting based on IGMBPM model, Computer-Aided Design and Applications, 13(4), 2016, 431-439. https://doi.org/10.1080/16864360.2015.1131531.
[27] Zhao, H.-R.; Guo, S.: An optimized grey model for annual power load forecasting, Energy, 107, 2016, 272-286. https://doi.org/10.1016/j.energy.2016.04.009.
[28] Zhou, L.; Ni, F.-J.; Zhao, Y.-J.: Prediction method of highway pavement rutting based on the grey theory, Journal of southeast university (English Edition), (3), 2015, 396-400. https://doi.org/10. 3969/j.issn.1003 —7985.2015.03.017