Study on spatial layout evaluation of game UI interface based on grey interval clustering

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Abstract: In order to overcome the problems of time-consuming and low accuracy of traditional evaluation methods, a new evaluation method of game UI spatial layout based on grey interval clustering is proposed. This paper analyses the relevant content of the game UI interface, integrates the interval grey degree and grey theory, and designs the grey interval whitening weight function and grey interval clustering process. On this basis, according to the grey interval category of the index sample to be evaluated, combined with its grey interval category, the spatial layout of the game UI interface is evaluated. The experimental results show that the time-consuming of the evaluation result generation process varies from 0.60 min to 0.79 min, the accuracy of the evaluation result varies from 92.5% to 94.6%, and it has stronger adaptive ability, which proves the effectiveness of the method.

Keywords: game UI interface; interface spatial layout; grey interval clustering; spatial layout evaluation.

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1 Introduction

With the rapid development of computer technology, the optimisation speed of Web Games has been improved. Users do not need to download or install the client when playing web games. The process of machine configuration is relatively simple, and the operation of entering or closing the game is very convenient, so it is welcomed by many users. With the increasing audience of web games, users also put forward higher requirements. Among them, the layout design of game UI interface is an important one (Li and Wang, 2017; Ji et al., 2020). Game UI design refers to the design of interface beauty, operation procedure and interpersonal interaction process of web game. In the game UI interface, users can exchange information with devices. An efficient game UI interface is easy to understand, easy to operate, visually comfortable and beautiful, so as to improve the use efficiency of the interface (Meng, 2020; Chen, 2017).

In Lyu et al. (2019), an evaluation method of information interface layout based on cognitive characteristics is designed. This method fully considers the principle of visual attention, clarifies the relationship between layout and cognition in the information interface by improving the visual information processing process, and determines the mapping relationship between them. On this basis, combined with the design concept of the quality evaluation model, the relevant evaluation indexes are designed, and the evaluation process of information interface layout is established. Combined with the analytic hierarchy process, the weight of evaluation indexes is set, so as to complete the comprehensive evaluation of information interface layout. However, in practical application, it is found that this method has the disadvantage of time-consuming in the process of generating evaluation results. In Zhao et al. (2019), an evaluation method of human-computer interface spatial layout based on multi factor fusion is designed. In this method, the evaluation formula is constructed by using semantic difference method to comprehensively evaluate the image style, layout rationality and operation performance of human-computer interface. On this basis, fuzzy analytic hierarchy process (FAHP) is used to complete the optimal evaluation decision of human-computer interface spatial layout under multi-objective intention. However, in practical application, it is found that this method has the disadvantage of low accuracy. In Zhou et al. (2020), a comprehensive evaluation method of interface layout based on index moderate standardisation is designed. According to the characteristics of different evaluation indexes, this method designs multiple samples to be evaluated, and then obtains the score values of different indexes by using Likert scale method, and then uses the least square method to carry out curve fitting between the weight value of each index and the survey value, and completes the index standardisation according to the relationship between them. On this basis, the comprehensive evaluation model is constructed by using the sorting method of approximate ideal solution and the correlation weighting method. However, in practical application, it is found that this method has the disadvantage of poor adaptive ability.

In order to solve the problems of the traditional methods, this paper proposes a game UI spatial layout evaluation method based on grey interval clustering

1 Based on the analysis of the relevant content of the game UI interface, the gray interval whitening weight function is designed by fusing the interval gray degree and gray theory. Then, the gray interval clustering coefficient is calculated combined with the clustering weight, and the category of the sample value is judged to complete the gray interval clustering.

2 On this basis, according to the gray interval category of the index sample to be evaluated, combined with its gray interval category, the spatial layout of the game UI interface is evaluated.

3 Experimental verification: the proposed method is compared with the traditional method by taking the time-consuming of the evaluation result generation process, the fitness of the evaluation result and the accuracy of the evaluation result as the experimental comparison indexes.

2 Analysis of game UI interface

Game UI is the main medium for users to complete interpersonal interaction in the process of playing web games. From the perspective of visual characteristics, the content of web games needs to be reflected by images, animation, text and other elements, while users need to get these information through the UI interface. Therefore, the game UI interface can play a good role as a bridge between the user and the game program (Li et al., 2017; Lu, 2019; Ren and Xue, 2018). In order to improve the operability of game UI interface, the related structure of game UI interface is analysed to improve the rationality of page layout.

The following is a detailed analysis of the spatial layout and functions of the game UI interface.

1 *Basic information module*. The module will display the user's name, avatar, game level, status and other information, which changes according to the user's own changes. The UI interface of the basic information module in the web game is shown in Figure 1.

2 *Function selection module*. This module will display the operation method, task information, reward and punishment rules and other functional information of the web game, which is generally in the more prominent area of the interface, so that the game program users can quickly find and find, and also save the interface space to a certain extent. After completing the task corresponding to the motor, the player can get the upgrade qualification. The UI interface of the function selection module in the web game is shown in Figure 2.

3 *Discussion and chat module*. In this module, users of different game programs can communicate with each other. Different channels are set in this module, and game program users can open or close the chat channel according to their own needs (Xia et al., 2020; Shen, 2018).

4 *Map guide module*. In this module, the users of the game program can view their own position, and can also view the positions of other game players. Through the geographic index, game players can also query the location of any place. The UI interface of map guide module in web game is shown in Figure 3.

Figure 1 UI interface of the basic information module in a web game

Figure 2 UI interface of function selection module in web game

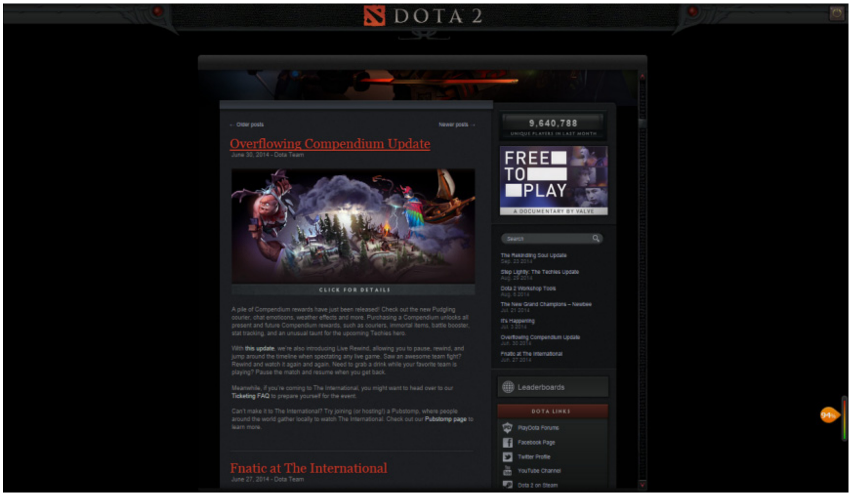


Figure 3 UI interface of the map guide module in a web game

With the development of computer technology, the design of game UI interface becomes more and more strict. Only by continuous reform and innovation, can we meet the comprehensive needs of users from more angles, can we attract users more effectively. In order to further enhance the beauty and practicality of the game UI interface, it is necessary to carry out effective evaluation on its spatial layout, and constantly optimise and improve its spatial layout according to the evaluation results. Next, based on the results of grey interval clustering, this study will effectively evaluate the spatial layout of game UI interface.

3 Grey interval clustering process design and game UI spatial layout evaluation

3.1 Design of grey interval whitening weight function

Grey interval clustering is a multi-dimensional grey evaluation process constructed by designing whiteness function. Among them, the whiteness function is mostly generated based on the gray number. According to different clustering indexes, the process divides and summarises the whiteness number of objects to be clustered according to gray level categories, then judges the gray level categories of the objects to be clustered, thus completing the effective evaluation of uncertain information (Dang et al., 2017; Qian et al., 2016; Wei, 2019).

Compared with other commonly used evaluation methods, grey interval clustering process can not only avoid a large number of calculations, avoid problems such as incompatibility between evaluation results and qualitative analysis results, but also avoid the objective influence of evaluation indexes, thus making the evaluation results more reliable.

Therefore, before the formal implementation of grey interval clustering, this study first designed the grey interval whitening weight function.

Suppose that the evaluation scheme set of game UI interface spatial layout is $A=\{A_1,A_2,\cdots,A_i\}$, and the evaluation index set of game UI interface spatial layout is $B=\{B_1,B_2,\cdots,B_j\}$, and the gray scale category of the evaluation result is *h*. Then, the weight of the *n* evaluation index in the *m* set of schemes is ω_{mn}, and the whitening weight function of the *n* evaluation index in the *m* set of schemes, belonging to the *h* gray level category is $g_{mn}^h(\omega)$. If $g_{mn}^h(1),g_{mn}^h(2),g_{mn}^h(3)$ can represent the turning point of $g_{mn}^h(\omega)$, then the whitening weight function can be expressed by formula (1):

$$g_{mn}^h(\omega)=\begin{cases} 0, & \omega\notin\left[g_{mn}^h(1)\right] \\ \dfrac{\omega-g_{mn}^h(1)}{g_{mn}^h(2)-g_{mn}^h(1)}, & \omega\in\left[g_{mn}^h(1),g_{mn}^h(2)\right] \\ 1, & \omega\in\left[g_{mn}^h(2),g_{mn}^h(3)\right] \end{cases} \tag{1}$$

If the whitening weight function does not have the first two turning points, it can be regarded as the lower limit measure whitening weight function. If the albino weight function has no third turning point, it can be regarded as the upper bound measure albino weight function.

In order to more clearly describe the uncertainty information related to the spatial layout of the game UI interface, the weight of the *n* evaluation index in the *m*-set scheme was reflected by the interval gray level, and it was denoted as $\omega_{mn}(\oplus)$, and $\omega_{mn}(\oplus)=\left[\omega_{mn}^P,\omega_{mn}^Q\right]$. In general, if the interval gray level is too small or too large, it is almost meaningless to the final evaluation result, then there is a relation as shown in formula (2):

$$\omega_{mn}^Q-\omega_{mn}^P>\left[\min\omega_{mn}(3)-\omega_{mn}(2)-\omega_{mn}(1)\right] \tag{2}$$

When the information satisfying the relation shown in formula (2) is eliminated, the whitening weight function of interval gray, etc., can be expressed as: $g_{mn}^{h}\left(\omega(\oplus)\right)$.

3.2 Grey interval clustering process design

On the basis of the above design whitening weight function, the grey interval clustering process is designed. The steps are as follows:

Step (1): The whitening weight function $g_{mn}^{h}\left(\omega(\oplus)\right)=1$ of the h gray subclass of n index is given;

Step (2): Determine the clustering weight ω_n of n evaluation indexes on the basis of qualitative analysis;

Step (3): Combined with the whitening weight function $g_{mn}^{h}\left(\omega(\oplus)\right)=1$ obtained above and the clustering weight ω_n, it is assumed that the sample value of the object m with respect to the index n is X_{mn}, and then the grey interval clustering coefficient γ_{mn}^{h} is calculated, the process is as follows:

$$\gamma_{mn}^{h}=\sum_{i=1}^{n} g_{mn}^{h}\left(X_{mn}\right)\times\omega_n \tag{3}$$

Step (4): The category h of sample value X_{mn} is judged according to the grey interval clustering coefficient, so as to complete the grey interval clustering.

3.3 Evaluate the layout of the game UI interface

Combined with the above grey interval clustering process, the grey interval category of the index sample to be evaluated can be known. Combined with its grey interval category, the evaluation model of the spatial layout of the game UI interface is constructed, the process is as follows:

If the m-set scheme belongs to the h-set grey interval category, then its evaluation value is defined as follows:

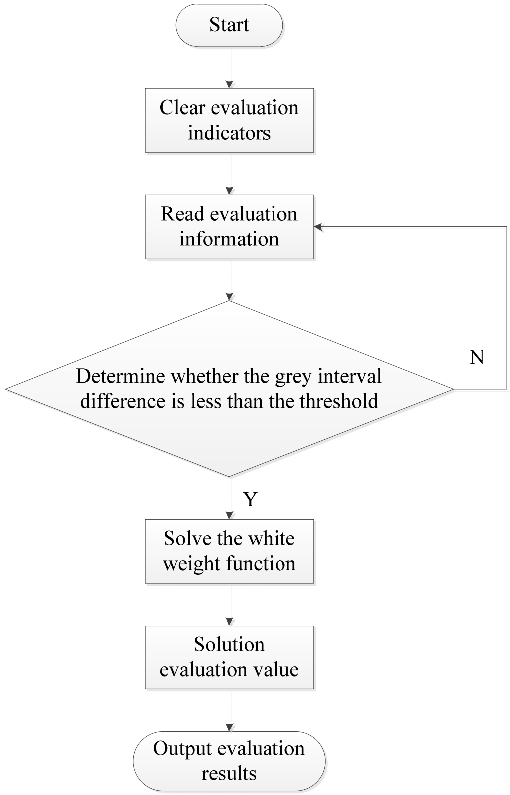
$$\delta_{m}^{h}=\sum_{j=1}^{m} g_{mn}^{h}\left(X_{mn}(\oplus)\right)\times\omega_{mn} \tag{4}$$

In equation (4), ω_{mn} represents the weight of the n evaluation index in the m set of schemes, and $g_{mn}^{h}\left(X_{mn}(\oplus)\right)$ represents the white weight function of the n evaluation index in the m set of schemes belonging to the h grey interval category. On this basis, according to the calculation method of interval grey number, the magnitude of δ_{m}^{h} is compared. If equation (5) holds, it is said that the m-th evaluation scheme belongs to the gray level category h^*.

$$\delta_{m}^{h*}=\max_{1\le h\le s}\left\{\delta_{m}^{h}\right\} \tag{5}$$

To sum up, the evaluation process of game UI spatial layout based on grey interval clustering is shown in Figure 4.

Figure 4 Schematic diagram of spatial layout evaluation process of game UI interface based on grey interval clustering



Through the calculation of the above process, interval clustering method is used to evaluate the spatial layout of game UI interface theoretically. In order to further verify the effectiveness of the evaluation method, a comparative verification experiment will be carried out next.

4 Simulation experiment and result analysis

4.1 Experimental design

In order to verify the practical application performance of the evaluation method of spatial layout of game UI interface based on grey interval clustering designed above, the following simulation experiments are designed.

The experimental environment setting results are shown as follows: the experimental host processor I9-9900XE (the memory is 256TB), and the experimental background operating system is Windows 10. In order to ensure the uniqueness of the experimental environment, the number of experiments was set to 100 times.

The data used in the experiment are all from the Game UI Database website, and the layout information of the Game UI interface is obtained from the website Database. Based on the obtained data and information, a virtual simulation environment is built by using MATLAB software, so as to effectively evaluate the spatial layout of the Game UI interface.

In order to effectively solve the problem of the unity of experimental results, the overall experimental plan is set as follows: the time-consuming process of evaluation results generation, the fitness of evaluation results and the accuracy of evaluation results are used as the experimental comparison indicators, and the traditional information interface layout evaluation method based on cognitive characteristics is used. Lyu et al. (2019) method and a comprehensive evaluation method of interface layout based on moderate standardisation of indicators (Zhou et al., 2020 method) are used as comparison methods to complete the performance test together with the method in this paper.

4.2 Design of experimental indicators

1 *Time consuming in the process of generating evaluation results*: the time consuming in the process of generating evaluation results can reflect the evaluation efficiency of different methods. The less time it takes to generate the evaluation results, the higher the evaluation efficiency of the method. On the contrary, the longer the response time is, the lower the evaluation efficiency of the method is.

2 *Self-fitness of evaluation results*: Self-fitness refers to the ability to automatically assign index weights, adjust the order of evaluation importance, and process evaluation parameters and constraint conditions according to the characteristics of processed information in the evaluation process, so as to make the evaluation results obtained adapt to the characteristics of processed information. The higher the self-fitness of the evaluation results, the stronger the efficient evaluation ability of the evaluation method.

3 *Accuracy of evaluation results*: this index can directly reflect the effectiveness and reliability of different evaluation methods. The higher the accuracy of the evaluation results, the higher the effectiveness and reliability of the method. On the contrary, the lower the accuracy of the evaluation results, the lower the effectiveness and reliability of the method.

On the basis of the experimental environment and indexes designed above, the application performance of different methods is compared and verified. In order to ensure the validity and reliability of the results obtained and to avoid the influence of environmental factors and errors on the experimental results as much as possible, the experiment will be repeated several times.

4.3 Experimental results and comparative analysis

4.3.1 Comparison of the time spent in the generation process of evaluation results

First, the time consuming of the evaluation result generation process of different evaluation methods was counted, and the results were shown in Table 1.

Table 1 Statistical results of time consuming in the generation process of evaluation results of different evaluation methods (min)

Number of experiments/time	*Method of Lyu et al. (2019)*	*Method of Zhou et al. (2020)*	*Method in this paper*
20	1.83	1.91	0.68
40	2.05	1.82	0.60
60	1.64	1.75	0.79
80	1.82	2.31	0.76
100	1.84	2.43	0.77

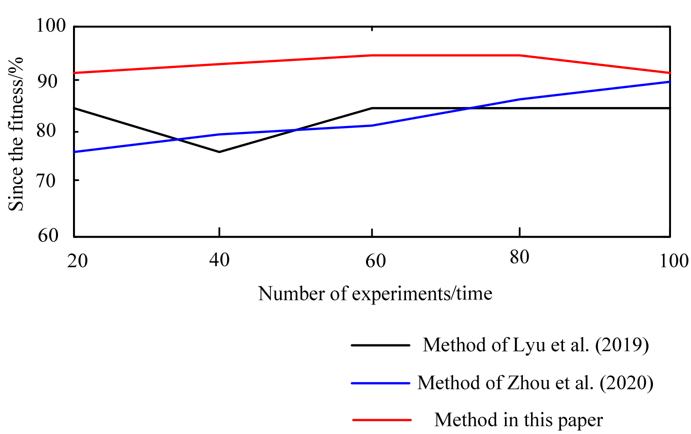
By comparing the results in Table 1, it can be seen that after the application of method of Lyu et al. (2019), with the continuous increase in the number of tests, the time spent in the generation of evaluation results varies between 1.64 min and 2.05 min. After the application of method of Zhou et al. (2020), with the continuous increase of the number of tests, the time of generating evaluation results varies between 1.75 min and 2.43 min. However, with the application of method in this paper, with the continuous increase of the number of tests, the time of the evaluation result generation process changes between 0.60–0.79 min, and shows a slight increase trend.

Through the above comparison, it can be seen that the evaluation result generation process of method in this paper takes less time, indicating that the evaluation efficiency of this method is higher.

4.3.2 Self-fitness comparison of evaluation results

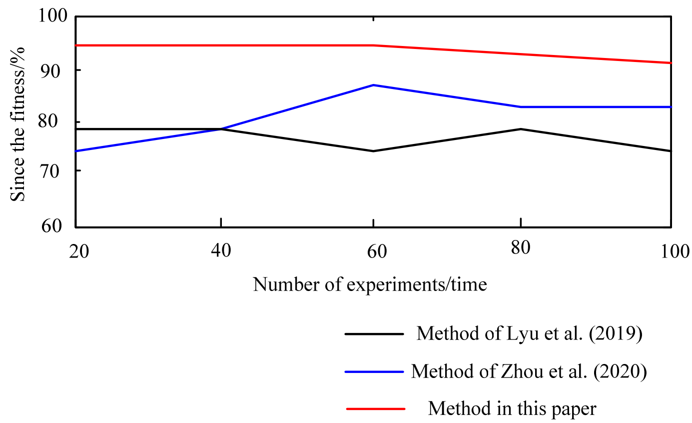
In order to verify the evaluation ability of different evaluation methods, the self-fitness of evaluation results was used as the index to carry out performance tests for different methods, and the results were shown in Figure 5.

Figure 5 Comparison of self-fitness of evaluation results of different monitoring methods



(a) The first half of the evaluation process

Figure 5 Comparison of self-fitness of evaluation results of different monitoring methods (cont.)



(b) The second half of the evaluation process

It can be seen from the comprehensive analysis of the results shown in Figure 5 that, no matter in the first half of the evaluation process or in the second half of the evaluation process, the self-fitness of the evaluation results of method in this paper varies within a small range, but its value remains above 90%, higher than that of the two traditional methods. The self-fitness curve of the evaluation results of method of Lyu et al. (2019) and method of Zhou et al. (2020) is below method in this paper, and the variation range is larger than that of method in this paper. Therefore, it can be concluded that method in this paper has a stronger ability to automatically assign index weights, adjust the order of evaluation importance, and process evaluation parameters and constraint conditions according to the characteristics of processed information. The application of this method can make the evaluation results obtained adapt to the characteristics of processed information, so the more efficient evaluation ability of method in this paper is.

4.3.3 Accuracy comparison of evaluation results

Finally, the application performance of method in this paper, method of Lyu et al. (2019) and method of Zhou et al. (2020) is compared and tested with the accuracy of evaluation results as an index. The results are shown in Table 2.

Table 2 Statistical results of accuracy of evaluation results of different evaluation methods (%)

Number of experiments/time	*Method of Lyu et al. (2019)*	*Method of Zhou et al. (2020)*	*Method in this paper*
20	85.5	86.8	92.7
40	85.7	85.7	94.6
60	87.3	87.5	92.5
80	88.5	88.2	94.2
100	90.6	87.4	93.4

By comparing the results in Table 2, we can see that after the application of method of Lyu et al. (2019), the accuracy of its evaluation results varies between 85.5% and 90.6% with the increasing number of tests. After the application of method of Zhou et al. (2020), the accuracy of its evaluation results varies between 85.7% and 88.2% with the increasing of the number of tests. However, with the application of method in this paper, the accuracy of evaluation results varies between 92.5% and 94.6% with the increasing number of tests. Through the above comparison, it can be seen that the evaluation result of method in this paper is more accurate, indicating that the method is more effective and reliable.

To sum up, through the contrast experiment, the design of this study is based on the game UI layout grey interval clustering evaluation method of the evaluation results generated process takes between 0.60 min and 0.79 min, the accuracy of the evaluation results in the change from 92.5% to 94.6%, which proves that the method in this paper, the evaluation of higher efficiency and reliability evaluation results, and it has better adaptive ability, can make the evaluation results and the characteristics of processing information. It can be concluded that the evaluation method of spatial layout of game UI interface based on grey interval clustering has more application advantages.

5 Conclusion

Aiming at the problems of the traditional evaluation methods of UI spatial layout, such as time-consuming, low accuracy and poor adaptability, this paper designs a new evaluation method of UI spatial layout based on gray interval clustering results. The method combines interval grey degree and grey theory to design grey interval whitening weight function. Then the gray interval clustering coefficient is calculated by combining with the clustering weight, and the gray interval clustering is realised by judging the category of the sample value, so as to complete the evaluation of the spatial layout of the game UI interface. In addition, the simulation results show that the generation time of the evaluation results varies from 0.60 min to 0.79 min, the accuracy of the evaluation results varies from 92.5% to 94.6%, and it has stronger adaptive ability, which proves that the application results obtained by this method not only have higher reliability, but also have higher accuracy, and the evaluation results are more suitable to the characteristics of the processed information, which shows that the research results of this paper have a wide application prospect. In the future research work, we should further improve the accuracy of the evaluation, in order to achieve a more reasonable game interface layout.

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