Multi-objective optimisation method of human–computer interaction interface layout of music electronic products based on adaptive particle swarm optimisation

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Abstract: Aiming at the problems of poor optimisation effect in multi-objective optimisation of human-computer interface layout of music electronic products, a multi-objective optimisation method of human-computer interface layout of music electronic products based on adaptive particle swarm optimisation is designed. Analyse the characteristics of interface layout structure, and determine the component layout level, layout parallax and split screen ratio as the optimisation objectives. The fuzzy judgement results of multi-objective parameters are determined by fuzzy hierarchy, and the weight value is obtained. Analyse the basic principle of adaptive particle swarm optimisation, set the adaptive particle radius and adaptive value, constantly update the adaptive particle position, build a multi-objective optimisation model and solve the optimal solution of the model through the objective function to complete the layout multi-objective optimisation. The results show that the multi-objective optimisation accuracy of the proposed method is higher than 90%.

Keywords: adaptive particle swarm optimisation; music electronic products; human computer interaction interface; multi-objective optimisation; adaptive particle radius; fitness value.

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1 Introduction

With the continuous development of electronic information technology, a variety of electronic products are constantly updated, and a variety of intelligent electronic products are presented in the market. Among them, the types of music electronic products are increasing, and a variety of music electronic products emerge in endlessly (Huang et al., 2021). The interface function of music electronic products is constantly updated and changed with the needs of users. In the multi-objective arrangement of human-computer interaction interface layout of music electronic products, the interface layout includes the setting of key indicators such as interface functional components, use frequency and colour matching. Reasonably setting these key indicators in the human-computer interaction interface of music electronic products (Contento et al., 2020) can meet the needs of users. However, with the changing needs of users, the layout of human-computer interaction interface of music electronic products cannot meet the current needs. Therefore, how to improve the effect of human-computer interaction interface layout of music electronic products has become the focus of research in this intelligent field (Zhong et al., 2021).

Zhao et al. (2020) proposed a layout optimisation method of operation interface based on human factor driven ant colony algorithm. In view of the high complexity of the operation interface in the existing methods, a new ant colony algorithm is introduced to construct the objective function of the operation interface, calculate the coordinate position of the operation interface, then set the optimisation constraints through the feedback mechanism in the algorithm, and finally construct an optimisation function to complete the arrangement of the layout. This method has a good effect in setting interface constraints, but the number of target factors is small and there is a problem of generalising the optimisation results. Jin et al. (2020) proposed a virtual interactive interface layout optimisation method based on visual attention mechanism. This method first constructs a virtual optimisation model, then determines the colour of the interface layout according to the human visual mechanism and constructs the objective function by determining the attention factors. This method completes the research of the method by optimising the interface vision. The virtual interface constructed by this method meets the needs of users, but the goal is relatively single and the optimised results are different. Kang et al. (2021) proposed a multi-objective optimisation method for element layout of product operation interface. This method analyses the beauty principle of layout optimisation, determines the basic principle of optimisation, designs the optimisation mathematical model and applies genetic algorithm to layout optimisation. The operation process of this method is relatively simple, but the multi-objective consideration of layout is less and there are some limitations.

Aiming at the problems existing in the above methods, this paper proposes a multi-objective optimisation method for human-computer interface layout of music electronic products based on adaptive particle swarm optimisation. Firstly, the features of interface layout are extracted and pre-processed, and then the multi-objective optimisation model is constructed. Finally, the multi-objective optimisation model is solved by adaptive particle swarm optimisation algorithm to realise the multi-objective optimisation of human-computer interaction interface layout of music and electronic products. The technical route of this paper is as follows:

- *Step 1*: Analyse the layout structure characteristics of human-computer interaction interface of music electronic products, and determine the component layout level, layout parallax and split screen ratio as the optimisation objectives of human-computer interaction interface of music electronic products;

- *Step 2*: Determine the fuzzy judgment results of multi-objective parameters with the help of fuzzy analytic hierarchy process, and obtain the weight value of the optimisation objective of human-computer interface;
- *Step 3*: Analyse the basic principle of adaptive particle swarm optimisation, set the adaptive particle radius and adaptive value, constantly update the adaptive particle position, take the component layout level, layout parallax and split screen ratio as the objectives of human-computer interaction interface optimisation of music and electronic products as the basic parameters, build a multi-objective optimisation model and solve the optimal solution of the model through the objective function. The multi-objective optimisation of human-computer interaction interface layout of music electronic products is completed.

2 Electronic multi-computer interface multi-objective layout

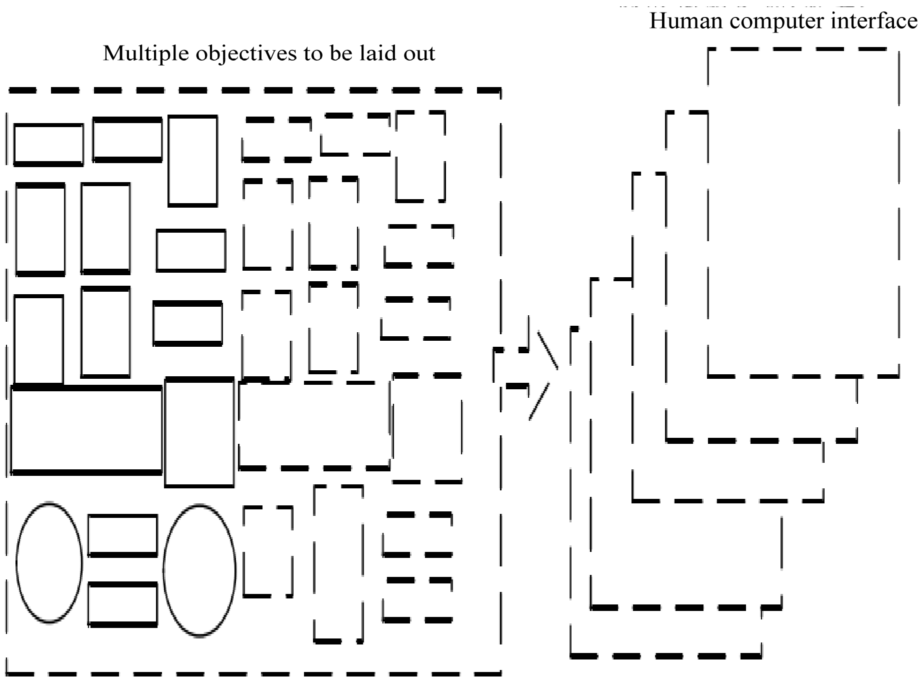
2.1 Layout characteristics analysis and multi-objective determination of human-computer interaction interface of music electronic products

2.1.1 Analysis on layout characteristics of human-computer interaction interface of music electronic products

The layout optimisation of human-computer interaction interface of music electronic products is complex, which is mainly composed of the spatial dimension of human-computer interaction layout of music electronic products. The higher the spatial dimension of human-computer interaction layout of music electronic products, the higher the optimisation degree of human-computer interaction layout of music electronic products. Therefore, in order to improve the effectiveness of layout optimisation, first analyse its high-latitude layout characteristics, and then optimise it into a two-dimensional spatial layout problem. In the analysis of the layout characteristics of the human-computer interaction interface of music electronic products, the spatial layout characteristics of the human-computer interaction interface of music electronic products are regarded as two-dimensional spatial characteristics, the sequence of layout feature points is determined in this space, the proportion of colours in each area of the human-computer interaction interface of music electronic products is calculated, and the layout characteristics of the human-computer interaction interface of music electronic products are analysed.

Assuming that the number of components to be arranged in the human-computer interaction interface space dimension of music electronic products is n, it can be considered that multiple functional components in the human-computer interaction interface of music electronic products are arranged in the interface space (Jiang et al., 2021), and the spatial layout is shown in Figure 1.

Figure 1 Layout of human-computer interaction interface space of music electronic products



As can be seen from Figure 1, in the spatial layout of human-computer interaction interface of music and electronic products, the components of the layout are evenly arranged in two-dimensional space. Therefore, the layout features in the two-dimensional space are extracted (Yang et al., 2020).

Suppose the two-dimensional coordinate point of the layout space of music electronics is *o*, set its coordinate system to (oxy). Assuming that the components required to be arranged in the HMI layout of the music electronics are *N*, *i* components are waiting to be scheduled, of which, $i \in N$. Assuming that human-computer interaction is *M*, set its number to μ , $\mu \in M$, the location of the human-computer interaction interface layout is H_i, At this time, the characteristic points in the two-dimensional space of the human-computer interaction interface layout of music electronic products are as follows:

$$H_i = (x_i, y_i, \mu_i)\_ \tag{1}$$

In formula, (x_i, y_i) represents the coordinate origin in the interactive interface of music electronics, μ_i represents the functional settings in the HMI interface for music electronics.

According to the determined human-computer interaction interface layout of music electronic products, the feature points in the two-dimensional space are regarded as a whole. At this time, the feature point sequence (Han et al., 2019) in the two-dimensional space can be expressed as:

$$H = \{h_1, h_2, ..., h_n\} \tag{2}$$

$$h_k = \{h | h \in M, 1 < H_i < M, K = 1, 2...N\} \tag{3}$$

In the formula, h_k represents the human-computer interaction interface feature point layout sequence of music electronics , represents the music electronic human-computer interactive interface feature point optimisation vector.

According to the obtained human-computer interaction interface feature points and layout feature points of music electronic products, determining the interface colour characteristics is also a key link. The extraction of colour features in the layout of human-computer interaction interface of music electronic products is the process of determining the layout colour features according to the colour partition (Tao et al., 2020). Determine the proportion of colours in each area in the human-computer interaction interface of music electronic products, namely:

$$S_j = \frac{pv_i}{\sum_{i=1}^{n} piv_i} \tag{4}$$

In the formula, S_j represents the specific proportion of colours in different regions, p represents the interactive interface colour pixels, v_i represents the colour amplitude.

According to the determination of colour proportion in different areas of human-computer interaction interface of music and electronic products, the area and proportion occupied by interface colour have changed accordingly according to different colour distribution positions. Therefore, it is necessary to consider the changes in interface colour layout and determine different colour schemes according to different changes, namely:

$$Q = \{C1, S_j 1\}\{C2, S_j 2\}\ldots\{CM, S_j M\} \tag{5}$$

In the formula, Q represents the boundary face value, C indicates different locations of interface colours.

On this basis, the colour features in the human-computer interaction interface layout of music electronic products are extracted. In this paper, the colour features in the interface layout are extracted through the colour information probability function, and the following results are obtained:

$$R = ULOG \frac{1}{S_j} P(X) \tag{6}$$

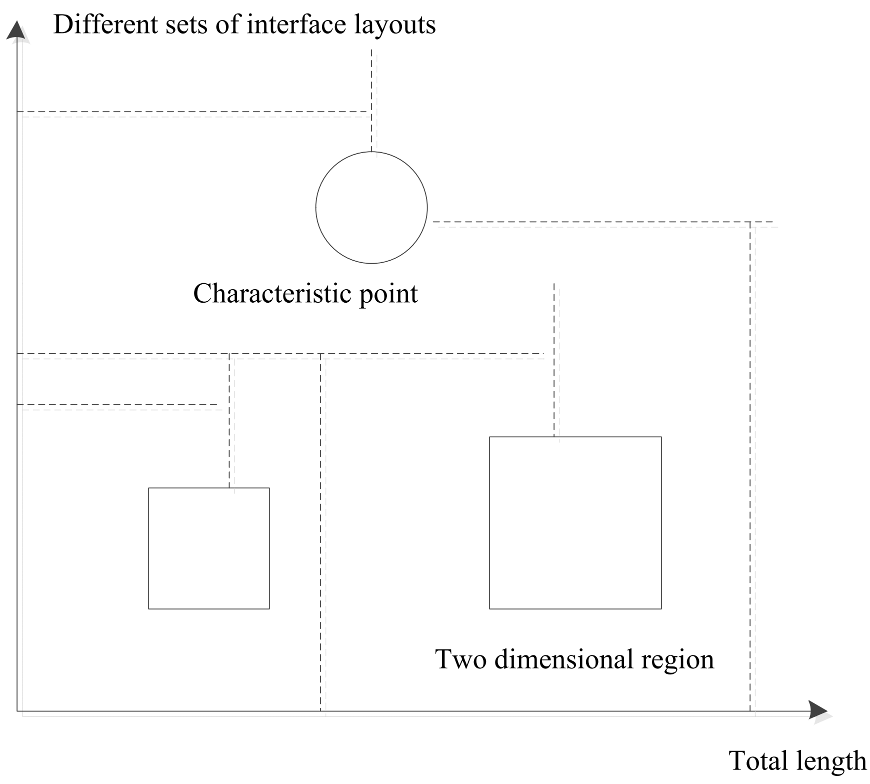
In the formula, R represents the amount of colour information for the interface layout, U represents the characteristic point of the colour information quantity distribution, $P(X)$ represents the probability function.

2.1.2 Multi-objective determination of human-computer interaction interface layout of music electronic products

Based on the above analysis of the layout characteristics of human-computer interaction interface of music electronic products, in order to realise the multi-objective optimisation of human-computer interaction interface layout of music electronic products, the component layout level, layout parallax and split screen ratio are determined as the optimisation objectives of human-computer interaction interface of music electronic products. At this time, the optimisation goal of human-computer interaction interface of music electronic products is to determine the component layout level, layout parallax and split screen ratio; And set the constraints of human-computer interaction interface layout of music electronic products in two-dimensional space to realise multi-objective pre-processing of human-computer interaction interface layout of music electronic products. It provides a basis for later multi-objective optimisation.

The total length of the feature space of the layout is assumed *L*, its lateral length is *K*. All the feature points in this interface are n, L_a and K_a both represent the different set sizes of the interface layout, (z_i, z_j) represents the central location of the feature point in the interface with a schematic diagram as shown in Figure 2.

Figure 2 Layout characteristics of human-computer interaction interface of music electronic products



In order to avoid large-area overlap in the layout characteristics of human-computer interaction interface of music electronic products, set the constraints of human-computer interaction interface layout of music electronic products in two-dimensional space (Croonenbroeck and Hennecke, 2020), that is:

$$s.t\begin{cases} \dfrac{L_a + K_a}{2}\left|z_i, z_j\right| < 0 \\ \dfrac{K_a}{2}\left|z_i, z_j\right| > 0 \end{cases} \tag{7}$$

According to the constraints determined above, it is necessary to delete the overlapping points with high degree of overlap in the layout features of human-computer interaction interface of music electronic products. Firstly, the feature overlapping points are extracted to obtain:

$$C(x,y) = v\sum_{a=1}^{n} \frac{\varepsilon^{a}}{\sum_{a=1}^{n} \varepsilon^{a}} \times \sum_{b=1}^{n} \frac{h_j \times h_{nj}}{|h_j| \times |h_{nj}|} \tag{8}$$

In the formula, $C(x,y)$ represents the degree of similarity to the HMI interface layout feature data of music electronics, n represents the number of features. h_j represents similar weights of HMI layout feature data for music electronics, h_{nj} represents similar weights for layer *i*, ε^{a} represents a data sequence of similar feature points, v represents the degree of overlap.

According to the overlapping degree of feature points obtained above, delete the data with high overlapping degree in the feature points and remove them to obtain the final layout feature points of human-computer interaction interface of music electronic products, namely:

$$S = k(x) + \frac{n\sqrt{2\ln k(x)}}{r^{2} \cdot u_m} \tag{9}$$

In the formula, $k(x)$ represents similar weights for the layout feature data, u_m represents the music electronics feature data scale coefficient.

2.2 Construction of multi-objective optimisation model for human-computer interface layout of music electronic products

On the basis of determining the layout characteristics of human-computer interaction interface of music electronic products, in order to realise the multi-objective optimisation of human-computer interaction interface layout of music electronic products, a multi-objective optimisation model of human-computer interaction interface layout of music electronic products is constructed. Take the layout characteristic data of human-computer interaction interface of music electronic products as the input data of the model (He et al., 2019), so as to realise the multi-objective optimisation of human-computer interaction interface layout of music electronic products.

Firstly, the multi-objective factors in the human-computer interaction interface layout of music electronic products are compared with the help of fuzzy analytic hierarchy process, and the fuzzy judgment results of multi-objective factors are as follows:

$$J = \left(A_{ij}\right)_{mn} \tag{10}$$

In formula, A_{ij} represents the importance of multi-objective factors in the HMI interface layout of music electronics.

Since the importance of multi-objective factors in the human-computer interaction interface layout of any music electronic product is different, it is necessary to complement the importance of different multi-objective factors by fuzzy degree, and complete the complementarity of different multi-objective factors by constructing fuzzy complementarity judgment matrix (Wang et al., 2019), that is:

$$D(a,b) = \frac{1}{n}\sum_{a=1}^{n}\sum_{b=1}^{n} A_{ij} + B_{ij} \tag{11}$$

In formula, $D(a,b)$ represents the number of multi-objective factors in the HMI interface layout of music electronics, B_{ij} represents the judgment factor.

Then, the weight of the complementary results of the importance of multi-objective factors in the human-computer interaction interface layout of music electronic products is calculated, and the following results are obtained:

$$\omega = g\frac{\sum_{i=1}^{n} A_{ij} + \frac{n}{2}}{n(n-1)} \tag{12}$$

In formula, n represents the number of rows of the judgment matrix, g represents the multi-objective weight factor in the human-computer interaction interface layout of music electronics.

According to the determined weight value, a multi-objective optimisation model of music electronic human-computer interaction interface layout is obtained:

$$F(x, y = u\sum_{i=1}^{n} LN(D - \omega) \tag{13}$$

In formula, u represents the constant. LN represents the importance objective function of multi-objective interface layout for music electronics, D represents the multi-objective evaluation index weight factor.

In the construction of multi-objective optimisation model for human-computer interface layout of music electronic products, the fuzzy judgment results of multi-objective factors of human-computer interface layout of music electronic products are determined with the help of fuzzy analytic hierarchy process, and the fuzzy complementary judgment matrix is constructed to complete the complementarity of different multi-objective factors according to the determined weight value. The multi-objective optimisation model of human-computer interface layout of music electronic products is constructed.

2.3 Solution of multi-objective optimisation model based on adaptive particle swarm optimisation

Owing the above multi-objective optimisation model of human-computer interaction interface layout of music electronic products, there is a certain optimisation deviation in the multi-objective optimisation of interface layout, which is easy to lead to the optimisation of human-computer interaction interface layout of music electronic products into local optimisation, with good results, and too much consideration of global factors. Therefore, in order to avoid this result. In this paper, the multi-objective optimisation model of human-computer interface layout of music electronic products is solved by using adaptive particle swarm optimisation algorithm. Adaptive particle swarm optimisation is a kind of algorithm that makes the individual optimal solution evenly dispersed in the global with the help of the idea of appropriate distribution, which can reduce the influence of individual on the whole and make the optimal solution of the model most stable. On the basis of setting the radius and value of the adaptive particle in this study, the position of the adaptive particle is continuously updated, the optimisation model is constructed, and it is solved through the objective function to complete the multi-objective optimisation of the layout of the human-computer interface of music and electronic products,

In this paper, the solution of multi-objective optimisation model for human-computer interface layout of music electronic products mainly includes the calculation of adaptation radius and adaptation value, and completes the solution of the model to achieve the best layout optimisation (An et al., 2020). The choice of fitting radius in model solution affects the quality of solution value. Therefore, effective calculation of this value is required.

Suppose $F: X \in R \to R^d$, $d = 2$, $\overrightarrow{x_1}$ and $\overrightarrow{x_2}$ is the optimal solution representing the objective function. At this point, the human-computer interaction interface layout is:

$$R = \frac{\sqrt{\left(F\overrightarrow{x_1}\right) - \left(F\overrightarrow{x_2}\right)}}{B} \tag{14}$$

In formula, *R* represents the number of existence in external memory lift and *B* represents the radius value of the adapter value.

In the solution of this paper, the adaptation value is equivalent to evenly dividing the multi-objective layout of human-computer interaction interface of music electronic products, and then reducing the adaptation value of each individual. At this time, the adaptation value of multi-objective layout of human-computer interaction interface of music electronic products is:

$$SS = \frac{R}{\sum_{i=1}^{n} SS'} \tag{15}$$

In formula, SS represents the European distance between multi-target individuals.

After setting the adaptation radius and adaptation value, initialise all variables in the multi-objective optimisation model of music and electronic products human-computer interface layout, set the particles in the adaptive particle swarm in the current space and determine the running speed of the particles in the multi-objective optimisation model of music and electronic products human-computer interface layout, that is:

$$V_i = \omega\left[v_1\right], \omega\left[v_2\right], \ldots, \omega\left[v_n\right] p(i) \tag{16}$$

In formula, $\omega\left[v_1\right]$ represents the operating speed of the particle, $\omega\left[v_n\right]$ represents the current particle phase velocity.

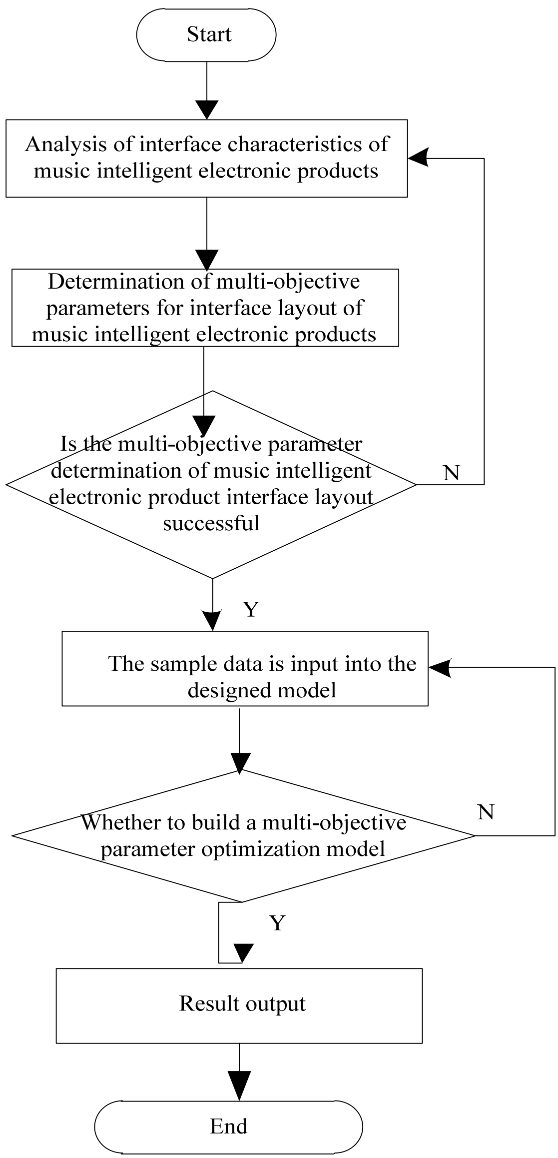
Update the current position of particles in the multi-objective optimisation model of human-computer interface layout of music electronic products, complete the final solution of the multi-objective optimisation model of human-computer interface layout of music electronic products and obtain:

$$p(i) = \omega\left[v_n\right] + \frac{R}{\sum_{i=1}^{n} SS'} \tag{17}$$

In the formula, $p(i)$ represents the current position of the particle.

In solving the multi-objective optimisation model of human-computer interface layout of music electronic products, the basic principle of adaptive particle swarm optimisation is analysed. Based on setting the radius and value of adaptive particles, the position of adaptive particles is continuously updated, the optimal solution of the model is determined and the multi-objective optimisation of human-computer interface layout of music electronic products is completed. The implementation process is shown in Figure 3.

Figure 3 Multi-objective optimisation process of human-computer interface layout of music electronic products



3 Experimental analysis

3.1 Experimental scheme

In the experiment, the QQ music in the tablet is taken as the research object, the music electronic software is taken as the research object and the multi-objective optimisation of the layout of the interface is studied. The music software is the latest version and supports the current music playing requirements. The interface reflection speed is about 0.01 s, which meets the requirements of the experiment. Ideally set the layout of the human-computer interaction interface of the music electronic product, and the noise value in the layout is set to [–2, 2] dB. After many iterations in the experiment, the effectiveness of the proposed method is verified.

3.2 Experimental index

The experimental indicators set in the experiment are the accuracy and time cost of multi-objective optimisation of human-computer interface layout of music and electronic products. In order to highlight the effectiveness of the proposed method, the experiment highlights the effectiveness of different methods by comparing the proposed method, Jin et al. (2020) method and Kang et al. (2021) method.

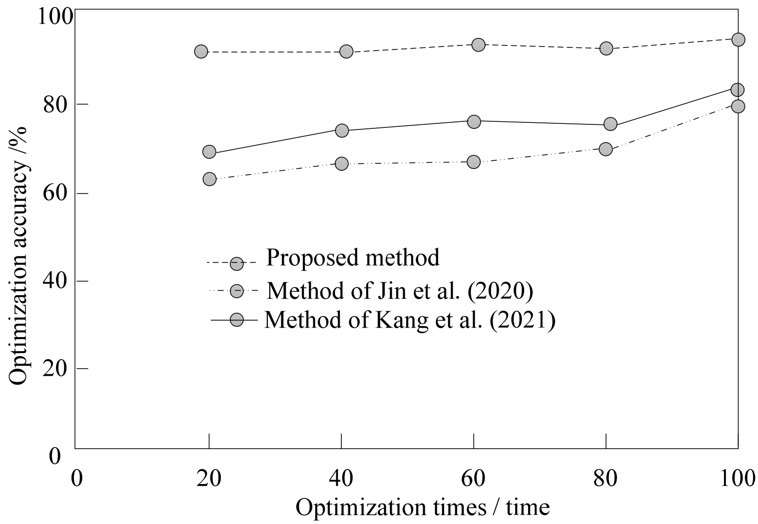
3.3 Analysis of experimental results

3.3.1 Accuracy of multi-objective optimisation of human-computer interface layout of music electronic products

There are many objectives in the layout of human-computer interaction interface of music electronic products. The accuracy of optimising these objectives is the key to measure the effectiveness of the method. Therefore, the accuracy of multi-objective optimisation of human-computer interface layout of sample music electronic products by the proposed method, Jin et al. (2020) method and Kang et al. (2021) method is tested experimentally. The results are shown in Figure 4.

By analysing the experimental results in Figure 4, it can be seen that the optimisation accuracy of the proposed method is better than the other two methods in the multi-objective optimisation of the human-computer interface layout of the sample music electronic products. The optimisation accuracy of the proposed method is higher than 90%, while the optimisation accuracy of the other two methods is lower than that of the proposed method. This is because this method sets the adaptation distance and adaptation value with the help of adaptive particle swarm optimisation algorithm, which improves the accuracy of model output and verifies the effectiveness of this method.

Figure 4 Accuracy results of multi-objective optimisation of human-computer interface layout of music electronic products



3.3.2 Time cost of multi-objective optimisation of human-computer interface layout of music electronic products

On the basis of ensuring the optimisation accuracy, the time cost is also the key to ensure the optimisation efficiency. In the experimental test, the time cost of multi-objective optimisation of human-computer interface layout of sample music electronic products by the proposed method, Jin et al. (2020) method and Kang et al. (2021) method is tested. The results are shown in Table 1:

Table 1 Time over of electronic MI interface layout (min)

Optimisation times / times	*The proposed method*	*Document (Jin et al., 2020) method*	*Document (Kang et al., 2021) method*
10	1.2	2.3	2.8
20	1.2	2.5	2.9
30	1.3	2.5	2.8
40	1.2	2.6	2.8
50	1.2	2.8	2.7
60	1.1	3.0	2.6
70	1.2	2.8	2.9
80	1.3	2.9	3.0
90	1.3	3.0	3.2
100	1.2	3.1	3.2

By analysing the experimental data in Table 1, it can be seen that there are certain changes in the time cost of multi-objective optimisation of human-computer interface layout of sample music electronic products by using three methods. Among them, the method with small optimisation time cost is the proposed method, and the fluctuation range of optimisation change is small and relatively stable. Although the optimisation time cost of the other two methods is also within the controllable range, there are certain fluctuations and higher than the proposed method. This is because this method preprocesses the corresponding objectives during multi-objective optimisation, reduces the processing time overhead, improves the speed of the proposed method, and verifies its advantageous performance.

4 Conclusions

In this paper, a multi-objective optimisation method of music electronic products human-computer interaction interface layout based on adaptive particle swarm optimisation is proposed. The component layout level, layout parallax and split screen ratio are determined as the optimisation objectives of music electronic products human-computer interaction interface; By setting the adaptive particle radius and adaptive value, constantly updating the adaptive particle position, building a multi-objective optimisation model according to the adaptive particle position and coding, solving the optimal solution of the model through the objective function, completing the multi-objective optimisation of the human-computer interface layout of music and electronic products, realising the multi-objective optimisation of the human-computer interface layout and improving the optimisation performance. Through comparison, it is concluded that this method has the following advantages:

1) Using the proposed method, the multi-objective optimisation accuracy of human-computer interaction interface layout of music electronic products is higher than 90%, which has a certain reliability;
2) The proposed method has the lowest time cost and certain work efficiency for multi-objective optimisation of human-computer interaction interface layout of music electronic products.

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