

Product Packaging Design Innovation based on Visual Communication in Digital Perspective

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Objectives: This paper chose the front section of the assembly line of the explosive packaging machine as the design object, and studied the application of the interactive genetic model in the packaging machinery. **Methods:** Through the research on the product characteristics and the development trend of the packaging machinery, the main points of the design of the packaging machinery were summarized. The application models of two interactive genetic algorithms based on the compound fitness allocation strategy (HFAS) and the graded fitness allocation strategy were established in this paper. **Results:** The parameter setting of the compound fitness distribution strategy was analyzed, and the better scheme was selected for the case of the packaging machine design. **Conclusion:** In this paper, a specific case of the application of interactive genetic algorithm in the design of packaging machinery products—the design of the front section of the explosive packing machine was discussed. The total arrangement method and fuzzy evaluation method were used to evaluate the design results. Two methods were used to evaluate the design results.

Keywords: visual communication; product packaging; HFAS method

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Industrial design is more and more important in changing the way of life, culture, energy and environment. Conceptual design is the key link in product design. It is considered the most important phase of the human intelligence and the important phase of the decision¹. Conceptual design will decisively affect the follow-up product detailed design, product production and development, product market development and the realization of enterprise management strategic objectives. Once the conceptual design is determined, the 60%-70% of the product design is determined. For mechanical products with complex structure, their product system is not only fuzzy, complex and multi-faceted, but also requires in-depth research on theoretical development and

application of conceptual design methodology². It is an important research direction in the field of product design to study the design method of large mechanical product conceptual design phase. Introducing advanced theories and methods such as computational intelligence theory and optimization design method into the research of product design method, and combining with existing product design concepts, we can broaden the concept of design. The process of product conceptual design is structured, systematized and visualized (i.e. parameterized). It improves the efficiency of conceptual design and is able to assist in innovation³. The application of genetic algorithm in the conceptual design of packaging machinery product is a kind of auxiliary design method which combines product design and

computational intelligence. The purpose of this study is to explore the feasibility of the application of a new method for calculating the conceptual design of intelligent auxiliary products.

Computational intelligence (Computational Intelligence) is a cross discipline that began in 1980s to express and simulate intelligent behavior in digital form. Computational intelligence takes data as the basis and uses computation as a way to establish functional connections (models), so as to solve problems, so as to realize the simulation and cognition of intelligence. Its research contents include artificial neural networks, genetic algorithms, fuzzy logic and so on⁴. The main application fields of computational intelligence include pattern recognition, optimization calculation, economic prediction, intelligent control, robotics, and data mining and so on. Since 1990s, the application of Computational Intelligence in the field of mechanical design has been gradually deepened. For example, the study of genetic algorithms is in mechanical optimization design. At the same time, the research of computing intelligence in the field of industrial design has been gradually expanded. For example: Hunan University, 2002 published several research papers based on the knowledge of NC machine tools form⁵. The theoretical research on the application of computational intelligence to product design engineering abroad has developed rapidly in recent years, and the theoretical framework of the system has been gradually established. The product characteristics and technological development trend of packaging machinery have an important influence on the design of packaging machinery. Meanwhile, the product styling design of packaging machinery is also affected by the mainstream trend of product design. For example, green design, contracted design and other design concepts may become an important concept of product modeling design for packaging machinery⁶. Some scholars have proposed a programming knowledge acquisition model based on the design problem and a program based knowledge retrieval algorithm based

on similarity calculation. The practice and verification is obtained in the construction of numerical control machine modeling system⁷.

METHODS

An Assignment Algorithm for the Fitness of an Interactive Genetic Algorithm

The compound fitness allocation strategy is that the user first selects a favorite individual and assigns 1 to its fitness. The allocation of the fitness of other individuals is the value calculated based on the fuzzy inference method based on the relationship between the selected individual and the other individual. From the point of view of the user, the compound fitness allocation strategy is better than the scoring algorithm. Because the user's task is lighter and the process is faster. In practical applications, however, users do not necessarily want to reduce the burden. Because sometimes the user faces two individuals that are similar to the target image, or do not appear to be similar to the target. At this point, it is a difficult decision to select only one individual for the user⁸. In these cases, the user will want to select some individuals and give the similarity of the individual to the target image. Considering the requirements of conceptual design of packaging machine, and in order to create a more natural interaction process, the composite fitness assignment strategy adopted in this paper allows users to select some individuals and evaluate their similarity with target images, that is, the degree of satisfaction. The fitness of all individuals is calculated on the basis of the base distance between the selected individual and the other individuals. In addition, the degree of similarity is reflected in the exponential calculation of fitness. It is pointed out that, according to the results simulation, under certain constraints, the fitness of two individuals selected by each generation is better than that of each generation. This particular condition is that the degree of similarity between each individual and the target individual is not very large. And the degree of similarity difference between the individual and the two target individuals is relatively small. This composite strategy helps to achieve a more natural

interaction process in the actual operation. All the individuals of each generation correspond to a point in the space. This point is composed of various parameters describing the individual image. This space is called the parameter space in this paper. The coordinates of the individual i are expressed as follows:

$$P_i = (p_{i1}, p_{i2}, p_{i3}, \dots, p_{in}), p_{\min} \leq p_{ij} \leq p_{\max} \quad (1)$$

In this, p_{\min} and p_{\max} refer to the maximum and minimum of p_{ij} . n is the number of parameters or the dimensions of the space. The formula for calculating the distance between individual i and j in the parameter space are as follows:

$$distance = \sqrt{\sum_{k=1}^n (p_{ik} - p_{jk})^2} \quad (2)$$

Because each parameter has a different degree of influence on the similarity between individuals. The distance relation described in formula (2) can be further expressed as the following weighted form,

$$distance = \sqrt{\sum_{k=1}^n w_k (p_{ik} - p_{jk})^2} \quad (3)$$

Here, w_k is the weight of the k parameter. In this study, a weighted search method is not simulated. Therefore, the formula (1) will be used, and the distance is calculated by unweighted method. In the compound allocation strategy, users can select arbitrary number of individuals from each generation, and specify the level according to the similarity between each selected individual and the target. The fitness of the selected individual is designated as the maximum value of 1. The fitness of other individuals is calculated according to the distance between the selected individual and the other individual in the parameter space. When an individual is selected, the fitness of the i individual is calculated by the next formula f_i .

$$f_i = \left(\frac{d_{\max} - d_{i-s}}{d_{\max}} \right)^a \quad (4)$$

In the formula, d_{\max} is the maximum of the distance in the parameter space, and the a is a constant

When the degree of adaptation and the linear proportion of d_{i-s} are proportional, the constant a is 1.0. In order to reflect the similarity level g in calculating the fitness, the index method is usually used. The equation is as follows:

$$f_i = \left(\frac{d_{\max} - d_{i-s}}{d_{\max}} \right)^{3.0g} \quad (5)$$

The similarity level g reflects the degree of similarity between the selected individual and the target image, usually between 0.0 and 1.0. If the user selects two individuals A and B, their similarity levels are $g(A)$ and $g(B)$, respectively. An individual I has two different degrees of fitness, and $f_i(A)$ and $f_i(B)$ are calculated by the formula (6). Then the fitness of the individual i is defined by the fitness of the weighted average with the similar level:

$$f_i(Com) = \frac{g(A)f_i(A) + g(B)f_i(B)}{g(A) + g(B)} \quad (6)$$

Finally, this paper uses the standard values calculated by $f_i(Com)$ and $f_{\max}(Com)$ as the fitness value of the individual i .

$$f = \frac{f_i(Com)}{f_{\max}(Com)} \quad (7)$$

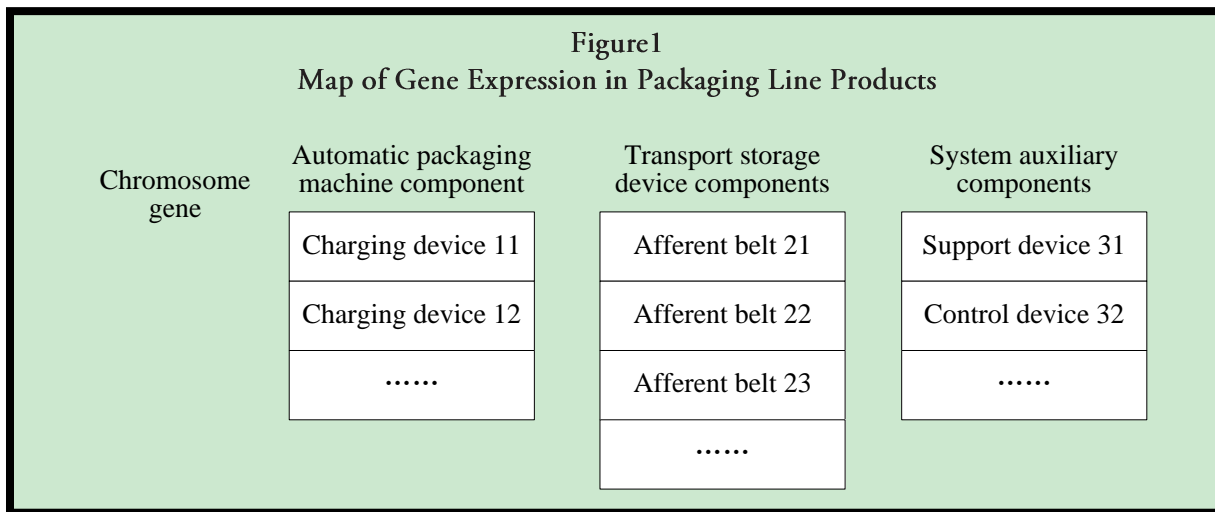
Interactive Genetic Algorithm Gene Coding for Product Conceptual Design

The interactive genetic algorithm is simple in form and has good global search ability. The control parameters of the interactive genetic algorithm have an important influence on the performance of the interactive genetic algorithm. How to set effective control parameters of an effective interactive genetic algorithm is the key to determine the success of interactive genetic computing. There are three main control parameters of the main interactive genetic algorithm, namely, population size, cross probability and mutation probability. For population size (n): population size refers to the number of all individuals in the search group. The size of the population directly affects the computational efficiency of the interactive genetic algorithm and the quality of the obtained

solution. The population size is too small, easy to appear premature convergence and fall into local optimization. The size of the population is too large and the amount of calculation will increase too much, so that the calculation time is too long. In this study, the population size was 8, and the search algebra was 10. Each search involves 88 individuals. For cross probability (P_c): cross probability determines the number of individuals cross operating in each generation. For example, when the population size $n=100$, $P_c=0.8$, there will be 80 individuals cross operation. The cross probability affects the survival probability and the variation probability of the individual. In this study, $P_c=0.6$ was taken. For the mutation probability (P_m): the mutation probability determines the number of variations of each gene in each individual of the population. If the encoding length of an individual is L , there is an average $P_c \times L$ bit variation in each individual. Mutation operation

is beneficial to maintain the diversity of the population. Mutation probability affects the performance of mutation operation. P_m is too big to make a genetic algorithm a random search, and P_m is too small to restore the allele that is lacking in the genetic algorithm population.

All human bodies can be described by about 30000 genes expressed by four letters, A, C, G and T, or if they are willing to use binary expression, they consist of only a series of 0 and 1. Any two people, regardless of the phenotypic difference (i.e. appearance), are significant, and their difference is only from a very small percentage of genetic differences. For mechanical products, genes can also be used to express their appearance. Figure 1 shows a sketch map of the gene expression of a packaging line product. In the picture, the parts are expressed by genes, and the chromosomes represent the parts. By linking the gene to the product features, the product can be clearly delamination.



In the genetic algorithm, there are two data conversion processes. That is, the coding operation and decoding operation. The encoding operation is the transformation of the phenotype to the genotype, which converts the product appearance to the chromosomes or genes in the genetic space. The decoding operation is the transformation of the genotype to the expressive type, that is, the opposite process of the coding operation.

The common coding form of genetic algorithm is binary encoding. The subsequent discussion, if not specifically pointed out, is explained in binary code. The appearance features of the packaging machinery can be regarded as the expressive type of the interactive genetic algorithm. After determining the range and accuracy of each parameter, the features of each module can be coded. That is, each module feature corresponds to a bit string, and the length of the string depends on the length of the interval

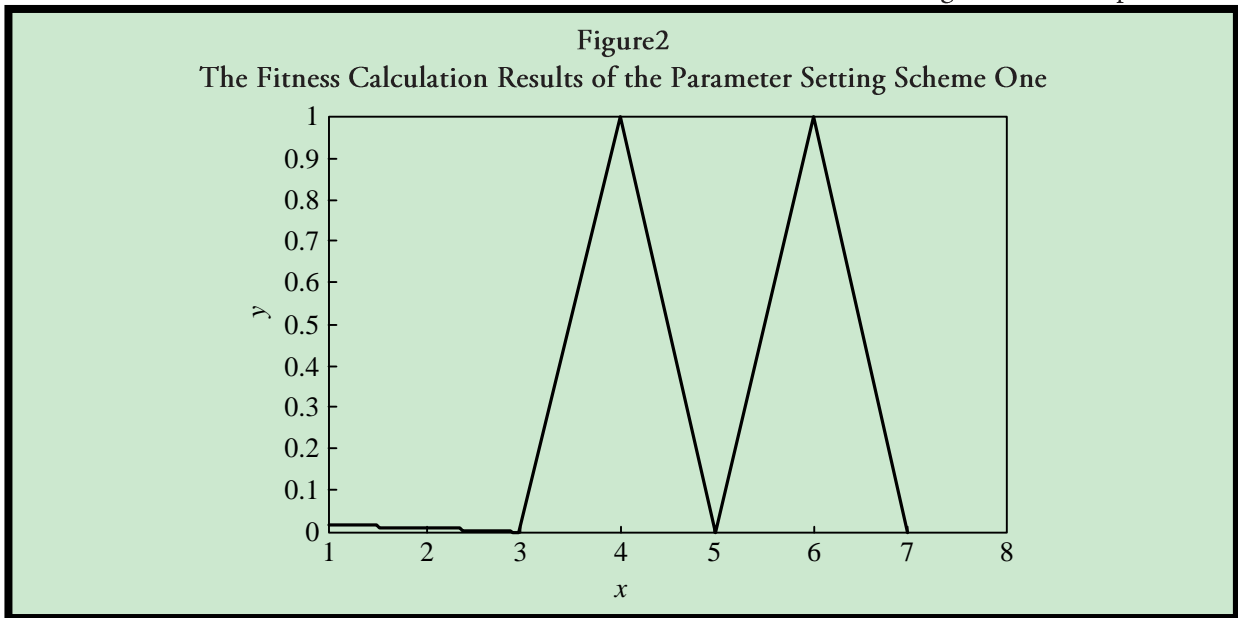
and the complexity of the module features. The string of all module features (one solution of the problem) is combined to become a chromosome coded string. By encoding, a solution (phenotype) of the problem is mapped into a binary chromosome coded string (genotyping).

RESULTS

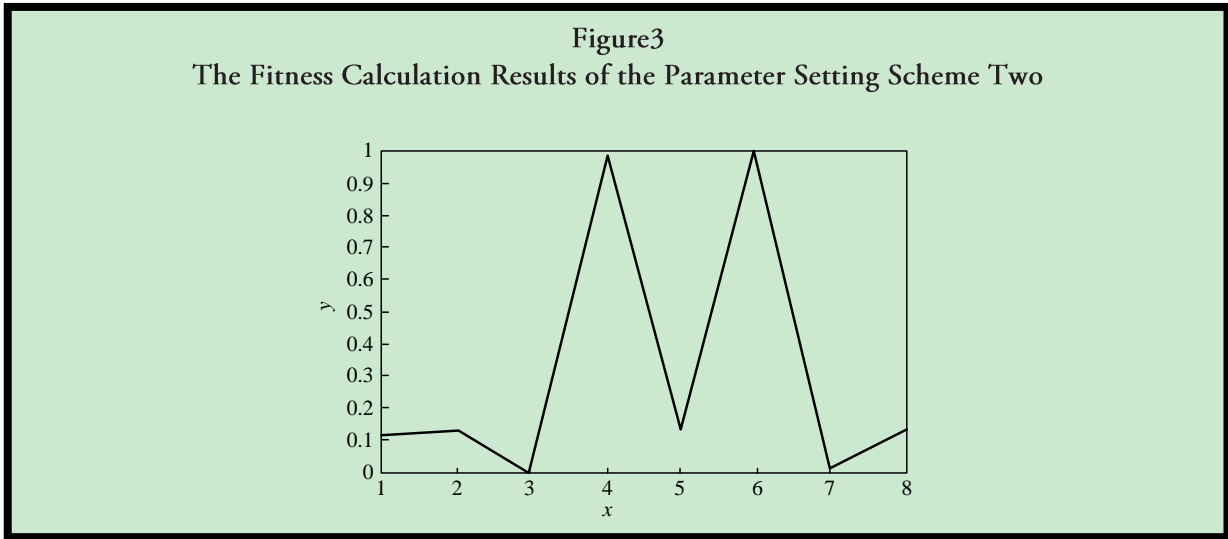
Comparison of Fitness Calculation Results of Fitness Assignment Strategy With Different Parameters

This paper then tests the algorithm. The computation method of composite fitness allocation strategy is rather complex. Its two main parameters: the similarity level g and the

individual distance d_i -S set directly affect the results of interactive genetic computation. In this paper, three groups of similarity level g and individual distance d_i -S are selected to compare the experiment. According to the formula (1) - (6) calculation results, the fitness distribution curve is drawn respectively. In the parameter setting one, the similarity degree [5, 3, 1] correspond to the distance [0, 3, 5], respectively. This is a uniform equidistance correspondence. Similarity level $g=1$. 8 samples of the parent are taken as an example to calculate the fitness value. $Fit=[0.0107, 0.0088, 0, 0.9976, 0.0154, 1, 0.0003, 0.0088]$. Draw the fitness distribution curve as Figure 2. The longitudinal axis is the fitness value after the return. The transverse axis is the 8 parent product case selected in the design test of this parameter.

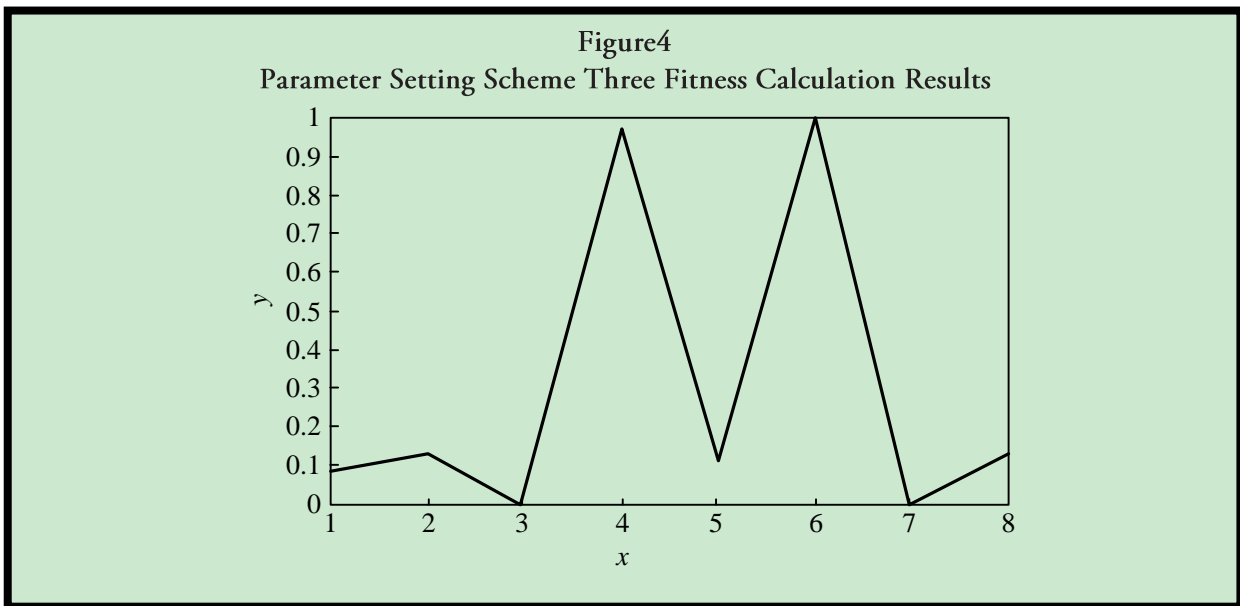


In parameter setting II, the similarity degree [5, 3, 1] correspond to distance [0, 3, 5], respectively. This is a kind of uniform equidistance correspondence. Similarity level $g=0.5$. Take 8 samples of the father's generation as an example. Calculation of fitness values: $fit=[0.1122, 0.1248, 0, 0.9761, 0.1222, 1, 0.0170, 0.1248]$. Draw the fitness distribution curve as Figure 3. The longitudinal axis is the fitness value after the return. The transverse axis is the 8 parent product case selected in the design test of this parameter.



In the parameter setting scheme III, the similarity degree [5, 3, 1] correspond to the distance [0, 0.1, 1] respectively, which is a non-uniform equidistance correspondence. Similarity level $g=0.5$. 8 samples of the parent are taken as an example to calculate the fitness value.

Fit=[0.0939, 0.1312, 0, 0.9672, 0.1138, 1, 0.0190, 0.1312]. Draw the fitness distribution curve as Figure 4. The longitudinal axis is the fitness value after the return. The transverse axis is the 8 parent product case selected in the design test of this parameter.



A comprehensive comparison of three images, figures 3 and 4 of low similarity individuals also has the possibility of being replicated (the fitness is about 10%). And there is a certain difference between the differences of the adaptability of different individuals. For example, the 1 fitness of the

individual is 9.4% and the fitness of the individual is 13.1%, which can reflect the impact of individual distance on the fitness. The difference in the fitness of the parameter setting scheme three is more obvious. Therefore, the choice of $g=0.5$, the distance value of 0, 0.1, 1 are used as the parameter setting scheme for the

compound fitness allocation strategy. The above is the research and analysis of fitness allocation strategy in practical application of interactive genetic algorithm. In this paper, two kinds of fitness assignment strategies, the grading interactive genetic algorithm assignment strategy and the compound fitness allocation strategy, are proposed in this paper. And emphasis is put on the analysis and description of the compound appropriate allocation strategy, and the application method is studied in detail. This paper also establishes an evaluation scheme for two fitness assignment strategies, which will be used in the design evaluation of the design examples.

Evaluation of Design Results

Design evaluation refers to the comparison and judgement of the solutions to design problems in the design process, so as to determine the value of each plan, determine its advantages and disadvantages and screen out the best design plan. Generally speaking, the design evaluation should be meaningful under the conditions of multiple schemes. In many scenarios, when the advantages and disadvantages are more interlaced, the scheme 22 is compared. One hit 1 points, liezhe hit 0 points. After the total score is calculated, the highest total score is the best scheme. The first is the evaluation of the evolutionary results of the graded interactive genetic algorithm, the score: the parent P=21; the progeny C=43.

**Table1
Progeny Compared With the Parent**

	P1	P2	P3	P4	P5	P6	P7	P8
C101	C	C	C	P	C	P	P	P
C102	C	C	C	P	C	P	C	P
C103	C	C	C	P	C	P	P	P
C104	C	C	C	C	C	C	C	C
C105	C	C	C	P	C	P	P	P
C16	C	C	C	C	C	C	P	C
C107	C	C	C	C	C	C	C	C
C108	P	C	C	P	C	P	P	P

Then it is the evaluation of the evolutionary results of the complex fitness allocation

interactive genetic algorithm. The score: P=17; C=47, optimization rate $a=176.47\%$

**Table2
Progeny Compared With the Parent**

C101	C	C	C	C	C	C	C	C
C102	P	C	C	P	P	P	P	P
C103	C	C	C	C	C	C	C	C
C104	C	C	C	C	C	P	C	C
C105	C	C	C	P	C	P	C	P
C106	C	C	C	P	C	C	P	C
C107	C	C	C	C	C	C	C	C
C108	C	C	C	P	P	P	P	P
C101	C	C	C	C	C	C	C	C

Then we set up a fuzzy evaluation matrix to

evaluate the scheme. Finally, the evaluation results

show that the algorithm designed in this paper can be more suitable for packaging products, which has good applicability and has potential for further promotion in actual production.

DISCUSSION

In this paper, the front section of the assembly line of the explosive packing machine was selected as the design object. The application of interactive genetic algorithm in packaging machinery was studied. By studying the product characteristics and development trend of packaging machinery, the design points of packaging machinery products were summarized, and the characteristics of its design process were analyzed. And the modular division method of packaging machinery for interactive genetic algorithm was proposed. The interactive genetic algorithm (GA) has been studied in all aspects of the application process of conceptual design of packaging machinery products. An application model of interactive genetic algorithm (GA) was established to assist the conceptual design of packaging mechanical products. Two interactive genetic algorithm fitness assignment strategies were proposed and analyzed in specific design cases. Two design evaluation systems of qualitative and quantitative are set up. The conceptual design examples of interactive genetic algorithm are designed and evaluated from different angles. The interactive genetic algorithm was applied to the conceptual design example of the front section of the explosive packaging line. With the application of Mat Lab and CATIA software, the application of interactive genetic algorithm on the 3D design platform was realized. It also proved that it can assist the concept design of the product to generate the optimized design scheme. Comparing with previous genetic algorithm in the two-dimensional design of mobile phone modeling and garment design, this research has innovative value in the research of three-dimensional model aided design.

Human Subjects Approval Statement

This paper did not include human subjects.

Conflict of Interest Disclosure Statement

None declared.

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