Proceedings of the 2021 IEEE 24th International Conference on Computer Supported Cooperative Work in Design

A Bacterial Foraging Optimization Algorithm for User Interface Layout Design in Complex Human-computer Interaction System

Xinyan Li
China North Vehicle Research Institute
Beijing, P. R. China,100072
lixinyan@noveri.com.cn

Yan Cui*
China North Vehicle Research Institute
Beijing, P. R. China,100072
cuiyan0127@qq.com

Nianfu Jin
School of Mechanical Engineering
Dalian University of Technology
Dalian, P. R. China, 116024
jnf@mail.dlut.edu.cn

Jin Su
China North Vehicle Research Institute
Beijing, P. R. China,100072
380854928@qq.com

Fengying Pang
China North Vehicle Research Institute
Beijing, P. R. China,100072
pangfengying1983@163.com

Ming Gao
China North Vehicle Research Institute
Beijing, P. R. China,100072
787107288@qq.com

2021 IEEE 24th International Conference on Computer Supported Cooperative Work in Design (CSCWD) | 978-1-7281-6597-4/21/$31.00 ©2021 IEEE | DOI: 10.1109/CSCWD49262.2021.9437686

Abstract—The layout design of user interface (UI) is a key issue in making a better human-computer interaction system for complex system such as spacecraft or vehicles, which directly affects the information level, tactical performance and operational efficiency. Firstly, this study builds a model for the layout design of UI which concerns the importance and use frequency of the layout components. Then, an improved bacterial foraging optimization algorithm is proposed to solve the layout optimization problems, which include the process of chemotaxis, replicates and migration. The preliminary results showed the feasibility of the proposed method.

Keywords—User Interface; Bacterial Foraging Optimization Algorithm; Layout Optimization Problems

I. INTRODUCTION

The human-computer interaction system of special vehicles often has high complexity because of the nature of task execution [1]. Generally, the design of man-machine interaction system is from bottom to top, which means that the design starts with acquiring the information of each subsystem/equipment in the vehicle, and then organize and classify them to form the interface organization framework and layout scheme.

However, in the actual use of passengers, the relationship between task requirements and system presentation information is often not close enough. Even the same task command needs to call out multilevel menus to enter multiple pages to complete. This display and control mode greatly reduces the operational efficiency and human-machine friendliness. Thus, a model-driven design method of complex human-computer interaction system is urgently needed. In this study, we tried to present a bacterial foraging optimization algorithm as a model-driven design method.

II. RELATED WORK

Luo [2] proposed an automatic user interface layout approach for the ontology-based reconfigurable system according to the structural principle of the usable user interface design guidelines. Oliver et al. [3] used evolutionary algorithms to design web site interfaces. The implementation of the algorithm allowed for the simultaneous optimization of both the style and the layout of the web site. These studies have made great contributions to the layout optimization problem. Constantine [4] concluded a series of usable user interface design guidelines, and the structural principle is considered as one of the most basic principles used to guide the user interface layout. Cheng et al. [5] proposed a particle api algorithm based on hybrid AI for layout optimization in facility. Chung et al. [6] propose a method for automatically optimizing the layout placement of user interfaces in commercial applications. However, they mainly focused on the layout of web site instead of a complex human-computer interaction system.

The algorithms used to address the layout optimization problems are mainly traditional heuristics including genetic algorithm, particle swarm optimization (PSO), and simulated annealing algorithm. New algorithm such as bacterial foraging optimization algorithm (BFOA) has not been proposed to solve the problem. BFOA was proposed by Passino [7] in 2002 to simulate the foraging behavior of human. Recently, researches have focused on the improvement of the original algorithm and its application. Dasgupta and Das et al. [8-11] theoretically analyzed the influence of the step size of the adaptive mechanism on the convergence and stability of the algorithm. BFOA can achieve parallel search and easily jump out of the local minimum, which makes it become another hotspot in the field of biological heuristic computing. This paper proposes BFOA to solve the layout optimization problems in a complex human-computer interaction system to achieve human-machine friendliness and improve the operational efficiency of the operators.

III. PROBLEM DESCRIPTION

III. The abstraction of the human-computer interaction system

Fig.1 shows the human-computer interaction interface diagram of a special vehicle. Since each line control terminal needs to provide more information and operation content for the occupant, it is necessary to design different interface categories to display different types of information and control interfaces. According to the function and use frequency of each component, the interface is divided into five areas: interface menu area, main information area, auxiliary information area, prompt information area, and operation menu area. We need to determine the partitions of the components to be arranged according to their functions. When we carry out the layout optimization problems, the components to be laid out can only appear in the preset area.

Fig.1 The human-computer interaction interface diagram of a special vehicle.

III. The mathematics model of the layout design

We solve the layout problem of the interactive interface as an optimization design problem. Assume the total number of components and the function interfaces are *N*, *M* respectively. The layout problem of the project refers to the reasonable allocation of *N* components into *M* functional interfaces, so that the collection of each design target is optimized as possible.

According to the analysis and control layout requirements, the position of the component to be distributed can be represented by its centroid position. If the center position of the component *i* ($i \in N$) is X_i , then $X_i = (x_i, y_i, \beta_i)$, where x_i, y_i are the centroid of the component *i* projected in the o-xy coordinate system and β_i is the function interface symbol ($\beta_i \in [1, M]$) of the component *i*. The mathematical expression is as follows: assign the set *u* composed of *N* components to different function interfaces and assure the balance of the components' positions in one interface at the same time. Due to the assignment of the N components can depend on their functions, this paper only address the layout optimization problem in one function interface.

Two kinds of constraints are mainly considered including boundary constraints and overlapping constraints in the establishment of the model for the layout optimization problem. The boundary constraints mean that the layout cannot exceed the boundary of the interface while the overlapping constraints mean that the positions of the components cannot intersect, which can be seen in equation (1).

$$\begin{cases} \frac{s_i}{2} \le X_i \le L - \frac{s_i}{2} \\ \frac{q_i}{2} \le Y_i \le W - \frac{q_i}{2} \\ \left| X_i - X_j \right| \ge \frac{s_i + s_j}{2} \\ \left| Y_i - Y_j \right| \ge \frac{q_i + q_j}{2} \end{cases} \tag{1}$$

Where *L* is the length of the interface, *W* is the width of the interface, s_i, q_i are the dimension of the component *i* in the *X* and *Y* directions respectively.

The objective of the layout optimization problem is to maximize the weights of the solutions, which can be quantified by the evaluation indicators. After consulting the experts in the relevant fields, we select two more important evaluation indicators, the use frequency and the importance degree of the components. We use the fuzzy analytic hierarchy process to quantify the weights of the importance and the use frequency of the components.

Firstly, we establish a relative fuzzy complementary judgment matrix between the various manipulation components. Then, employ the fuzzy analytic hierarchy process to sort the importance and the use frequency of the components, and Imi, Fri are the weights of importance and use frequency of each component respectively.

The importance and use frequency are directly related to the optimal viewpoint position coordinates in the layout space. The greater the weights of the importance and use frequency of the component, the closer the component should be placed in the middle of the view. Thus the sub-objective functions concerning the importance degree and the use frequency are:

$$F_1(\boldsymbol{X}, \boldsymbol{Y}) = \sum_{i=1}^{n} I_{mi} \bullet (C - d_{ip}) \tag{2}$$

$$F_2(\boldsymbol{X}, \boldsymbol{Y}) = \sum_{i=1}^{n} Fr_i \bullet (C - d_{ip}) \tag{3}$$

Where *C* is a fixed constant and d_{ip} is the distance from component *i* to the best viewpoint *p*. The larger the value, the more the layout conforms to the principle of importance and operating frequency.

Then the total function is shown in equation (4):

$$F(\boldsymbol{X}, \boldsymbol{Y}) = \omega_1 F_1 + \omega_2 F_2 \tag{4}$$

Where ω_1 , ω_2 denote the weights of the sub-objective function F_1, F_2 respectively and the sum of these two weights is equal to 1.

IV. THE PROPOSED BACTERIAL FORAGING OPTIMIZATION ALGORITHM FOR LAYOUT DESIGN

Internal flow conditions of different time steps under two conditions were separately simulated. The velocity vectors of several different time steps in two cycles (with an interval of 40 ° rotation of the impeller) at 50% of the impeller blade height under winter condition were taken as an example to illustrate the flow characteristics under impeller-diffuser interaction, as shown in Fig.4.

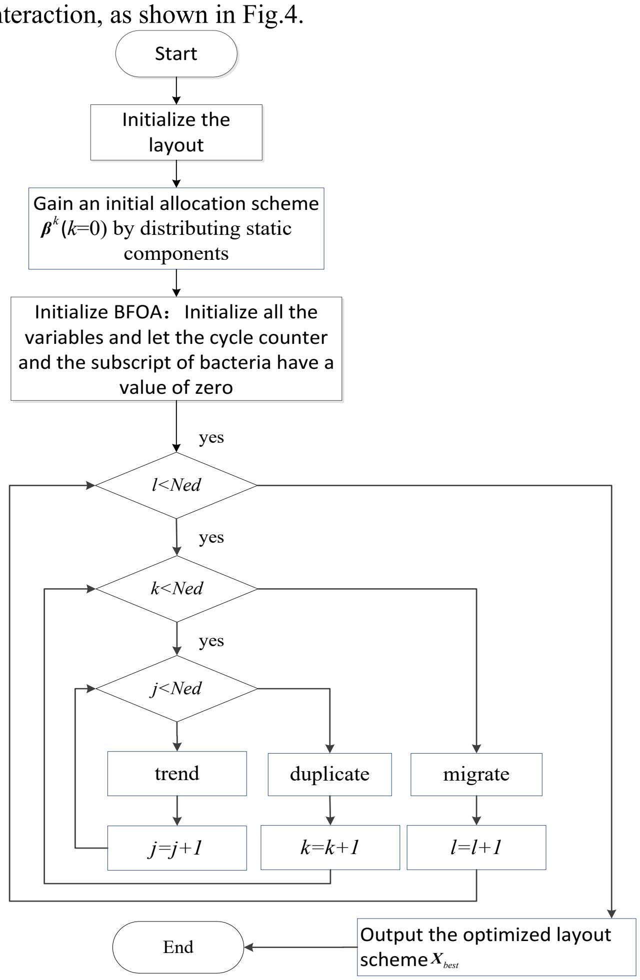

Fig.3 The flow chart of bacterial foraging algorithm for layout optimization problem.

In the previous section we obtained design variables and target evaluations for the layout optimization problems. This section will focus on the study of layout integration optimization methods to solve the problem of display control layout design in a complex human-computer interaction system. A method based on BFOA is proposed to optimize the layout of the components in one functional interface. In the iteration process of the layout optimization, the merits of the component allocation scheme should be evaluated according to the objective functions introduced in section III.

Fig.3 showed the flow chart of BFOA in solving layout optimization problem. Let the bacterial population size be S, and the location of a bacterium represent a candidate solution $\boldsymbol{X}=(X_1,X_2,...,X_N,)$ of the layout optimization problem defined above. Let the information of bacterium i be $\theta^i=(\theta_1^i,\theta_2^i,...,\ \theta_N^i)$. As a result, $\theta_i(j,k,l)$ can be used to represent that the ith bacterium chemotaxis in step j, replicates in step k, and migrates in step l. Suppose N_c, N_{re} and N_{ed} are the execution times of the chemotaxis, replication and migration respectively. The optimization of the layout scheme mainly includes three stages:

IV. Chemotaxis

This stage simulates the movement of an escherichia coli cell by using flagella to swim and flip. An escherichia coli can move in two different ways. They can swim in the same direction for a certain amount of time or flip, or alternate between the two modes of operation for the entire life cycle. Suppose $D(i)$ is the size of the step (running length unit) that takes the specified random direction during the flip process. Then, during the calculation of the trend, the movement direction of bacteria can be expressed as follows:

$$\theta^i(j+1,k,l)=\theta^i(j,k,l)+C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}} \quad (5)$$

Where Δ is specified as a random direction vector with the element range of [-1,1].

IV. Replicates

The healthy bacterium eventually dies at least when each healthy bacterium divides asexually into two and is then placed in its place which can keep the population size not be changed.

IV. Migration

Gradual or abrupt changes in the environment in which bacteria live can occur for a variety of reasons. For example, a significant rise in local temperatures could kill a group of bacteria that currently live in an area with a high nutrient gradient. This can happen in such a way that all the bacteria in an area are killed or a group of bacteria spread to a new area. The simulation of this phenomenon in BFOA is that some bacteria are randomly cleared with a small probability, as new replacement cells are randomly initialized in the search space.

For the initial control and control scheme, the layout design variable $\boldsymbol{X}=(X_1,X_2,...,X_N,)$ will be initialized through the chemotaxis, replication and migration process of the above bacterial foraging based on the layout objective function $F(X,Y)$ in section III. Then the optimal layout design result $\boldsymbol{X}_{best}$ of the display control interface can be obtained.

V. PRELIMINARY RESULTS

In order to verify the performance of the algorithm, we made a small case, where twenty different shapes and sizes of components will be arranged on a two-dimensional interface of 800mm×1000mm. The specific data of the components are shown in Table 1, which are from a military special vehicle.

Table1: The components in the layout optimization problem

Number	1~4	5~8	9~12	13~16	17~18	19~20
Shape	squ	cub	cub	cub	cyl	cyl
The number of interface β	1	1	1	1	1	1
length *l/mm*	100	150	150	100	50	100
width *w/mm*	100	50	100	50	50	100

The number of components N is 20, so we set the number of bacteria S=20. The other parameters are as follows, the number of trending times N_c=50, the maximum step size of the one-way motion in the chemotaxis operation is N_s=4, and the step size of the individual bacteria advances after the bacteria reverses the selected direction C = 0.001*ones (s,1), number of copy operation steps N_{re} = 4, dispersal (migration) operand N_{ed} = 2; the initial solution was randomly generated by the system. Fig.4 showed a layout diagram of the restored components. We can see that a feasible solution can be obtained.

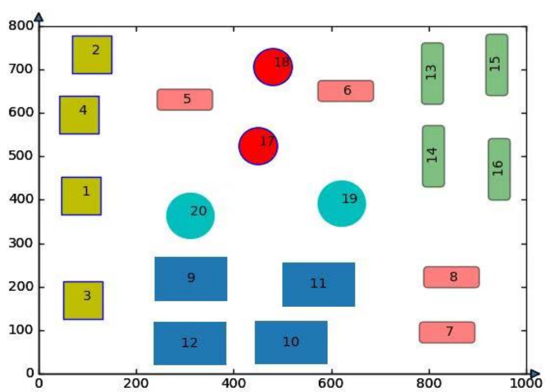

Fig.5 A layout diagram of the restored components.

VI. CONCLUSIONS

This paper addresses the layout optimization problems in complex human-computer interaction system. Firstly, we abstract the components into regular figures and establish a model considering the importance and use frequency of the components. Then we focus on the layout optimization problems in a function interface and propose a novel algorithm called bacterial foraging optimization algorithm to optimize the layout scheme. The preliminary results showed that the method is feasible. This study tries to contribute to make human-machine friendliness and improve the operational efficiency of the operators in complex human-computer interaction system. In the further study, we will make more experimental and compared with the other model-design methods.

REFERENCES

[1] M. Mao, Y. Liu, J.J. Hu. “Research on the Overall Design of Integrated Electronic Information System for Tank and Armored Vehicles” ,2009,06(6):155-165.

[2] S.Y. Luo, Y.L. Wang, J.M. Guo. “Research on ontology-based usable user interface layout approach.” International Conference on Intelligent Computing and Intelligent Systems, 2009.

[3] A. Oliver, N. Monmarché, G. Venturini. “Interactive design of web sites with a genetic algorithm.” In Proceedings of the IADIS International Conference Internet, Lisbon, Portugal, November 13 -15 2002,355-362.

[4] L. L. Constantine. “Canonical abstract prototypes for abstract visual and interaction design”. Lecture Notes in Computer Science, 2003，2844 : 1-15.

[5] M. Y. Chen, L. C. Lien. "A hybrid ai-based particle bee algorithm for facility layout optimization." Engineering with Computers, 2012, 28(1):57-69.

[6] Chung et al. “Layout placement optimization methods using repeated user interface sequence patterns for client applications”, Information Visualization, 2019,3(2):14-27.

[7] K.M. Passino "Biomimicry of bacterial foraging for distributed optimization and control." [J]. IEEE Control Systems Magazine, 2002, 22: 52-67

[8] S. Das, A. Biswas, S. Dasgupta, et al. “Bacterial foraging optimization algorithm: Theoretical foundations, analysis, and applications”. Foundations of Computer Intel, 2009, 3: 23-55.

[9] S. Dasgupta, A. Biswas, A. Abraham et al. “Adaptive computational chemotaxis in bacterial foraging optimization: An analysis.” [C]CISIS-2008, Barcelona, Spain. [S. l.]: IEEE Computer Society Press,2008: 64-71.

[10] S. Dasgupta, S. Das, A. Abraham et al. “Adaptive computational chemotaxis in bacterial foraging optimization: An analysis”. IEEE Transactions on Evolutionary Computation, 2009, 13(4): 919-941.

[11] S. Das, S. Dasgupta, A. Biswas, et al. On stability of the chemotactic dynamics in bacterial foraging optimization algorithm. IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, 2009, 39 (3): 670-679.