Multi objective enhancement method for embedded software quality of e-commerce platform based on firefly algorithm optimization

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ABSTRACT Embedded software is the basic guarantee for the safe and stable operation of e-commerce platform. In order to improve the embedded software quality of e-commerce platform, a multi-objective enhancement method based on firefly algorithm optimization is proposed. Based on the two-dimensional strengthening model of embedded software duration cost of e-commerce platform, the application effect of embedded software is quantified by setting multi-level index system, so that the application effect of embedded software is included in the strengthening target. On this basis, the multi-objective strengthening model of embedded software duration, cost and application effect is constructed. The firefly algorithm is used to solve the multi-objective enhancement model, and the firefly algorithm is optimized by constraint priority non inferior ranking. The optimal compromise solution is selected according to the fuzzy membership degree in fuzzy mathematics. Experimental results show that the proposed method can significantly improve the quality of embedded software of e-commerce platform.

INDEX TERMS Firefly algorithm, E-commerce platform, Embedded, Software quality, Multi-objective, Enhancement.

I. INTRODUCTION

E-commerce is a modern business operation mode with network as the platform, information technology as the means and economic benefits as the center [1]. E-commerce has changed the business philosophy, management methods and means of payment of enterprises. Network marketing, online procurement and e-payment have become the necessary links of enterprise operation. Architecture technology is a development model based on a certain kind of application in the field, which provides a lot of software reuse, and provides a unified software development package and pattern architecture for developers, frees software developers from the tedious code writing, focuses on the business logic of the application, and shields the underlying code implementation details, so as to improve the development efficiency. Software is the foundation of e-commerce application [2]. At present, there are many problems in e-commerce software: inaccurate estimation of software cost and schedule, dissatisfaction of users with completed software, unreliable quality of software products, difficult maintenance of software, low productivity of software development, increasing scale of software, and increasing complexity of software development. Software functions mainly include: transaction management, online ordering, electronic account, opinion collection, advertising, service delivery, consultation and negotiation, online payment, etc. [3]. Through the realization of these functions, the transaction process of e-commerce can be completed smoothly and safely, and e-commerce can be completed smoothly and safely, and e-commerce can be more widely used.

In the modern society with the rapid development of computer technology, single computer equipment has been difficult to meet the needs of people's life and production, and people began to put forward new requirements for various types of embedded software. In daily life, embedded software can be seen everywhere. IPTV, smart home appliances, automotive electronic control, global positioning and navigation system, smart phones, smart game machines and so on are all products using embedded software. People's daily life has been inseparable from embedded software technology, and the development direction of embedded software will become the key to future production and life [4]. Therefore, it is of great practical significance to study the current situation and
development trend of embedded software for the development and progress of embedded software technology. Embedded software plays an important role in the development of computer technology. In the application process of computer technology, users can embed the software they want to install into the computer through embedded software technology. The application of this technology has been approved by people. There are three steps in this technology, namely, the design and development of chips and the professional design of system software, and finally the manufacturing of embedded professional electronic devices. The system is required memory, processor and controller, which can process some data independently. The biggest advantage of embedded software is practicability and flexibility. In the system functions, the embedded software can meet the specific needs of many customers, and the embedded software can have strong practicability. It can directly install the software on the hard disk for the workers. And the specific function setting of embedded software is also changed according to the needs of users, and in recent years, it is constantly enriching its specific functions to meet the advanced market demand and the development of the whole industry. On the other hand, embedded software also has the characteristics of flexibility [5]. In the specific development process of software, embedded software will not be limited by many factors, and its equipment is small, which is suitable for most computer systems, so it will not affect other operating systems. With the continuous upgrading of science and technology, embedded software is also undergoing innovation, and the research and development of embedded software is also constantly improving. In the future, embedded software can be flexibly applied to more fields and meet the specific needs of more people.

Under certain specific conditions, when the embedded software of e-commerce platform exposes its own “congenital” defects, it will bring inestimable serious consequences to e-commerce platform, social economy and even the whole mankind [6]. Therefore, the research on embedded software enhancement of e-commerce platform is of great significance. In order to solve the multi-objective enhancement problem, the traditional methods mainly use linear weighting method, gradual tolerance method, trade-off ratio substitution method, maximum minimum method to solve the multi-objective solution set [7], and most of these methods are solved by mathematical programming, but the error of numerical calculation itself often leads to the result error, resulting in pseudo effective solution. Then Schaffe proposed using intelligent optimization algorithm to solve multi-objective optimization problem [8]. The first intelligent optimization algorithms were including genetic algorithm, particle swarm optimization algorithm, bacterial foraging algorithm and so on. As an effective method to solve multi-objective optimization problems, genetic algorithm has attracted great attention, but it is required a large evolutionary population to maintain its diversity, which leads to low computational efficiency. Particle swarm optimization (PSO) has been rapidly applied to some original fields of genetic algorithm since it was proposed. However, due to the characteristic of PSO itself, it is easy to fall into local optimum, which leads to the algorithm can not find the optimal solution.

The three objectives of project quality management are duration, cost and application effect. Software projects are the same. Because of the conflict and unity among these three objectives, strengthening the quality of embedded software with these three objectives as the quality enhancement index of embedded software has become one of the hot issues in the field of embedded software project quality management at home and abroad. Firefly algorithm (FA) is a group intelligence algorithm based on single objective optimization [9]. The idea of this algorithm is that fireflies attract their partners or prey by light-emitting mechanism in nature, which leads to the aggregation of most fireflies. In Firefly algorithm, the attraction and displacement of firefly are two core concepts in the algorithm. In the artificial firefly swarm optimization algorithm, each firefly is regarded as a solution of the solution space. The firefly population is randomly distributed in the search space as the initial solution, and then moves each firefly in the solution space according to the natural way of fireflies’ movement. Through the movement of each generation, the fireflies will eventually gather around the better fireflies, that is, to find multiple extreme points, so as to achieve the goal of population optimization. The firefly algorithm is applied to the multi-objective enhancement of embedded software quality on e-commerce platform. A multi-objective enhancement method of embedded software quality based on the optimization of firefly algorithm is proposed.

II. MATERIALS AND METHODS

A. DETERMINATION OF THE ENHANCEMENT TARGET OF EMBEDDED SOFTWARE QUALITY ON E-COMMERCE PLATFORM

The project quality enhancement includes three goals: duration, cost and application effect. The same is true for embedded software project on e-commerce platform. Therefore, the three objectives are the targets of embedded software quality enhancement on e-commerce platform.

1) DURATION OF EMBEDDED SOFTWARE PROJECT ON E-COMMERCE PLATFORM

The duration of embedded software project on e-commerce platform refers to the whole time span of embedded software project on e-commerce platform from signing the contract to delivery of the buyer for testing and final acceptance [10-11]. The total duration of embedded software project on e-commerce platform is obtained by summing up the activity time on the key line of PERT diagram of embedded software project on e-commerce platform, namely

$$T = \sum_{i=1}^{L} T_i , i = 1, 2, L , l$$  \hspace{1cm} (1)$$

In equation (1), $T$ refers to the total duration of embedded software project on e-commerce platform; $T_i$ refers to the implementation time of the $i$-th activity; $l$ refers to the activity code on the key line.

2) EMBEDDED SOFTWARE PROJECT COST OF E-COMMERCE PLATFORM

The traditional embedded software project cost of e-commerce platform is estimated by constructive cost model
(COCOMO) [12]. It estimates the total cost of embedded software project on e-commerce platform by using the number of original lines of code and some cost impact factors as independent variables. The econometric model is as follows:

$$C = aS^b \times EAF \times W$$  \hspace{1cm} (2)

In equation (2), $C$ is the total cost of embedded software project on e-commerce platform; $S$ is the program scale in thousands lines of original code (KLOC); $a$ and $b$ are two factors that change with the development mode; $EAF$ is a workload adjustment factor; $W$ is the wage rate in yuan / (person \cdot month). The accuracy of the budget results of the proposed model largely depends on the determination of the above independent variables, and it only reflects the cost caused by workload, but can not reflect the cost caused by insufficient quality before and after the completion of the embedded software project on e-commerce platform. Therefore, life cycle cost (LCC) is introduced into the cost model of embedded software project on e-commerce platform. LCC refers to the sum of the present value of the cost of owning, operating, maintaining and disposing a project or the cost of project system over a period of time [13]. In the software project, it includes the total cost of embedded software of e-commerce platform in the whole life cycle from preliminary research, market demand analysis, R & D, debugging to final maintenance and upgrade, and the rework and maintenance cost of embedded software of e-commerce platform because insufficient quality. According to LCC theory, the project cost of embedded software on e-commerce platform can be divided into duration cost and quality cost [14]. The duration cost consists of direct cost and indirect cost. Direct cost refers to the cost of manpower, software equipment, hardware equipment, materials, etc. in order to complete the project within the specified time; indirect cost refers to the management cost, financial cost and other related expenses in the process of project implementation. Quality cost includes quality assurance cost and quality loss cost. Quality assurance cost refers to the expenses incurred to ensure that the quality level of the project is within or above a certain range; quality loss cost refers to the rework, maintenance and other related expenses incurred before and after the completion of the project due to insufficient quality level.

In the process of calculating the life cycle cost of embedded software on e-commerce platform, the embedded software project on e-commerce platform is subdivided into $n$ activities with logical relationship, such as requirement analysis, system architecture, code writing, unit debugging and so on, which constitute the embedded software project on e-commerce platform. Each activity has several resource utilization modes $M_i$ ($i = 1,2, L, m$) to choose from. Each resource utilization mode specifies the type $k (k = 1,2, L , r)$ and quantity $r_{ik}$ of resources required to complete the activity. Based on this, the activity time $T_i$, activity duration cost $C_{ij}$, activity quality cost $C_{qij}$ and activity quality $Q_{ij}$ are calculated. The summary of duration cost and quality cost of each activity is the whole life cycle cost (LCC) of the whole embedded software project on e-commerce platform.

3) APPLICATION EFFECT OF EMBEDDED SOFTWARE PROJECT ON E-COMMERCE PLATFORM

The overall application effect of embedded software project on e-commerce platform is quantified by setting multi-level quality indexes and weights [15]. The overall application effect $Q$ of embedded software on e-commerce platform is defined as Level 1 quality index, and the application effect $Q_i (i = 1,2, L, n)$ of each activity is defined as Level 2 quality index. The application effect of each activity is comprehensively measured by $x(1 = 1,2, L , h)$ sub application effect indexes, so sub application effect indexes are called Level 3 application effect index. Thus, the application effect calculation model of embedded software project on e-commerce platform can be established.

$$Q = \sum_{i=1}^{n} w_{i} \sum_{j=1}^{k} w_{ij} \times Q_{ij}$$  \hspace{1cm} (3)

In equation (3), $Q_{ij}$ represents the value of the $x$-th Level 3 application effect index of the $i$-th activity under the $j$-th resource utilization mode; $w_{ij}$ represents the weight of the $x$-th Level 3 application effect index in the level 2 application effect index of the $i$-th activity, defined as the Level 3 weight; $w_{i}$ represents the weight of the level 2 application effect index of the $i$-th activity in the Level 1 application effect index, defined as the Level 2 weight. Analytic hierarchy process (AHP) or data envelopment analysis (DEA) are used to measure these two kinds of weights, so as to obtain the overall application effect of embedded software project on e-commerce platform.

B. MULTI OBJECTIVE ENHANCEMENT OF EMBEDDED SOFTWARE QUALITY OF E-COMMERCE PLATFORM

According to the above analysis, the following multi-objective enhancement model of embedded software quality on e-commerce platform can be established:

$$\begin{align*}
\min T &= \sum_{i=1}^{n} T_i \\
\min C &= LCC = \sum_{i=1}^{n} C_i = \frac{(C_d + C_{ind}) + C_s}{(1 + r)^r} \\
\max Q &= \sum_{i=1}^{n} w_{i} \sum_{j=1}^{k} w_{ij} \times Q_{ij}
\end{align*}$$  \hspace{1cm} (4)

Set the following constraints:

$$t_{(i+1)}, -t_{i, j} \geq 0, i = 1,2, L, n$$  \hspace{1cm} (5)

$$\sum_{i=1}^{n} r_{ik} \leq R_{i,k} = 1,2, L, r$$  \hspace{1cm} (6)

$$\sum_{i=1}^{k} w_{r_{i,k}} = 1, x = 1,2, L , h, \quad 0 \leq w_{r_{i,k}} \leq 1$$  \hspace{1cm} (7)

$$\sum_{i=1}^{n} w_{t_{ij}} = 1,0 \leq w_{t_{ij}} \leq 1$$  \hspace{1cm} (8)

$$0 \leq Q_{ij} \leq 1$$  \hspace{1cm} (9)

In the above equation, $T_i$ represents the duration of activity $i$; $C_d$ represents the direct cost of the project; $C_{ind}$ represents the indirect cost of the project; $C_s$ represents the project quality cost; $r$ represents the discount rate; $Q_{ij}$ represents the $x$-th Level 3 application effect index value of activity $i$ in the $j$-th mode; $w_{t_{ij}}$ represents the earliest start time of activity $i$; $w_{r_{i,k}}$ is the weight of the $x$-th Level 3 application effect index of activity $i$ in the activity application effect (Level 3 weight); $w_{i}$ represents the weight (Level 2
weight) of application effect of activity $i$ in the application effect of embedded software project on e-commerce platform.

C. MODEL SOLVING

1) STANDARD FIREFLY ALGORITHM

The central idea of firefly algorithm is that fireflies with higher absolute brightness attract fireflies with lower absolute brightness to approach it, and update their position according to the position update equation. The mathematical expression of the motion of firefly $i$ attracted by another more attractive firefly $j$ (with smaller objective function value) is as follows:

$$x_{new} = x_{old} + \beta_i \left( r_j \right) \left( x_{old} - x_{old} \right) + \alpha \cdot \xi_i$$

(10)

In equation (10), the second term is the gravitational action term, and the third term is the random moving step term; $\alpha$ is a constant, $\alpha$ can generally take the random value of $[0,1]$, which belongs to the random step; $\xi_i$ is the random number vector obtained from Gaussian distribution, uniform distribution or other distribution.

The expression of attraction function $\beta_i$ is as follows:

$$\beta_i \left( r_j \right) = \beta_i e^{-r_j^2}$$

(11)

In equation (11), $\beta_i$ is the attraction at $r_j = 0$; parameter $\gamma$ determines the characteristics of attraction change, which is very important in determining the convergence speed and the performance of firefly algorithm [16]; $r_j$ represents the distance between any two fireflies $i$ and $j$ at $x_i$ and $x_j$.

$$r_j = \left\| x_i - x_j \right\| = \sqrt{\sum_{k=1}^{n} \left( x_{i,k} - x_{j,k} \right)^2}$$

(12)

In equation (12), $d$ is the dimension; $x_{i,k}$ is the space coordinate of the $i$-th firefly $x_i$ in the $k$-th dimension; $x_{j,k}$ is the space coordinate of the $j$-th firefly $x_j$ in the $k$-th dimension.

2) MULTI OBJECTIVE FIREFLY ALGORITHM

The standard firefly algorithm mainly depends on the value of the objective function to update the position in the optimization process of the single objective optimization problem, while the multi-objective optimization problem optimizes several constrained and conflicting objective functions at the same time [17]. Therefore, in the optimization of multi-objective problems, the way of evolutionary selection is different from that of single objective problems.

In the algorithm iteration of single objective optimization problem, the comparison of fitness value is the most direct method to distinguish the advantages and disadvantages of particles; in multi-objective optimization, Pareto optimal concept is the method to distinguish the advantages and disadvantages of particles [18]. To solve the enhancement problem of embedded software quality on e-commerce platform, a multi-objective firefly algorithm is proposed, and Pareto dominance is redefined.

In the multi-objective enhancement of embedded software quality on e-commerce platform, the total constraint violation value of quality variables (duration, cost and application effect) is calculated according to the following equation [19]:

$$S_{vio}(u_i) = \sum_{j=1}^{nc} \max \left( g_j(x,u_i), 0 \right), c \in G$$

(13)

In equation (13), $S_{vio}(u_i)$ is the total value of constraint violation of different quality variables; $c$ is the number of quality variable inequality constraints; $G$ is the total number of quality variable inequality constraints and control variable inequality constraints; $g_j(x,u_i)$ is the $i$-th quality variable inequality constraint.

Two groups of Pareto solutions $u_p$ and $u_q$ are randomly selected to compare whether the total violation values $S_{vio}(u_p)$ and $S_{vio}(u_q)$ are equal.

If they are equal, the following equation is judged:

$$\begin{cases} \forall i \in \{1, 2, L, M\} : f_i(x,u_p) \leq f_i(x,u_q) \\ \exists j \in \{1, 2, L, M\} : f_j(x,u_p) < f_j(x,u_q) \end{cases}$$

(14)

If it is satisfied, then $u_p$ dominates $u_q$;

If $S_{vio}(u_p) < S_{vio}(u_q)$, then $u_p$ dominates $u_q$;

In the optimization of multi-objective problems, the conflict among multiple objective functions can not make all the objectives reach the optimal at the same time. Therefore, according to the Pareto dominance relation of constraint priority, the solution sets are compared.

Referring to Srimivas and Deb's non inferior hierarchical ranking and crowding distance calculation, in the basic non inferior hierarchical ranking method, the Pareto dominance relation of constraint priority is used [20], and two attributes of individual $x_i$ are obtained, which are Pareto order value $rank(x_i)$ and crowding distance $distance(x_i)$. In this way, the total order relation can be determined.

$$rank(x_i) < rank(x_j)$$

(15)

or

$$rank(x_i) = rank(x_j)$$

and

$$distance(x_i) > distance(x_j)$$

(16)

The optimal compromise solution is obtained by fuzzy membership method.
FIGURE 1. Multi objective enhancement process of embedded software quality of e-commerce platform

The above total order relation is expressed as $x_i, p_n, x_j$. Then, the position movement between firefly $i$ and firefly $j$ no longer refers to the value of the objective function, and the updating rule of attraction becomes based on the total order relation, that is, if $x_i, p_n, x_j$, firefly $j$ is close to firefly $i$ according to equation (10).

The multi-objective enhancement flow chart of embedded software quality on e-commerce platform is shown in Figure 1.

III. EXPERIMENTAL TEST

In order to verify the practical application effect of the multi-objective enhancement method for embedded software quality on e-commerce platform based on firefly algorithm optimization proposed in this paper, the embedded software of a clothing e-commerce platform is selected as the experimental object, and its quality is intensively tested by the proposed method. The parameter setting of this method is shown in Table 1.

A. DETERMINATION OF FEASIBLE SOLUTION

The proposed method is used to get the target value of the experimental object directly. Through MATLAB simulation, the trade-off target values corresponding to all feasible solutions (points) are obtained in the same plane coordinate, and the results are shown in Figure 2.

It can be qualitatively concluded from Figure 2 that: (1) when the construction period compression is tight, with the increase of the strengthening plan construction period of the experimental object, that is, the direct cost of the strengthening plan of the experimental object decreases faster than the indirect cost, and the total cost shows a downward trend. When the construction period of the experimental object is delayed to a certain extent, it becomes uneconomic to reduce the cost by increasing the construction period, because increasing the construction period will increase the indirect cost more than the direct cost. (2) The results show that the application effect of the experimental object enhancement slightly decreases with the decrease of the cost and the increase of the construction period, and the application effect tends to be the maximum with the increase of the cost and the construction period.

B. MULTI OBJECTIVE ENHANCEMENT RESULTS

In order to reflect the effect of the proposed method on the multi-objective enhancement of the experimental object quality, three commonly used indexes in the multi-objective optimization problem: generation distance, diversity index and super volume index are used to analyze the multi-objective enhancement effect of the experimental object. At the same time, in order to further verify the effect of this method, the multi-objective enhancement method based on tabu search algorithm and the multi-objective enhancement method based on fuzzy evaluation are selected as comparison methods, which are named comparison method 1 and comparison method 2 respectively. The three indexes of the multi-objective enhancement effect of the two comparison methods on the experimental object quality are counted and compared with the three evaluation indexes of the results obtained by the proposed method. The results are described in the form of box line diagram, as shown in Figure 3. Table 2 shows the average value and standard deviation of the evaluation indexes of the three algorithms.

![Image](image-url)
It can be seen from the results in Table 2 that the average values of the four distance and diversity indexes in the evaluation indexes for the enhancement effect of the method in this paper are significantly less than the results of the two comparison methods, aiming at the three-objective enhancement problem of quality, duration, cost and application effect of experimental subjects. This shows that the Pareto solution set obtained by the proposed method is closer to the real Pareto front end, and the distribution uniformity of the solution set obtained by this method is better than that of the two comparison methods. It can also be seen from Figure 3 that the proposed method is superior to the two comparison methods in terms of convergence, completeness and universality of distribution shape. From the standard deviation of the three indexes, the results of the evaluation indexes for the strengthening effect of the proposed method are smaller than those of the two comparison methods, which shows that the solution process of the proposed method is stable and the deviation is small.

**TABLE II**

| Evaluating index | Generational distance | Diversity index | Over volume index |
|------------------|-----------------------|-----------------|------------------|
| Method of this paper | Average value | 0.063 | 0.742 | 862.701 |
| | Standard deviation | 0.0131 | 0.0121 | 8.3270 |
| Comparison method 1 | Average value | 0.685 | 0.801 | 729.756 |
| | Standard deviation | 0.2774 | 0.0405 | 190.0555 |
| Comparison method 2 | Average value | 0.342 | 0.779 | 792.416 |
| | Standard deviation | 0.1327 | 0.0302 | 92.2511 |

**C. Application effect ANALYSIS**

1) **OUTPUT RESULTS OF DATA SCHEDULING**

The effect of internal data processing is shown in Figure 4 before and after the multi-objective enhancement of the experimental object quality by using the proposed method.
The analysis of Figure 5 shows that after the multi-objective enhancement of the experimental object quality by using the proposed method, the quality of each enhancement target of the experimental object has been improved. The experimental results fully show that this method can significantly improve the quality of the experimental object, and has good application effect.

IV. CONCLUSION

Embedded software is the operating system and development tool software embedded in hardware, which is the basic guarantee for the safe and stable operation of e-commerce platform. Aiming at the unity of opposites of the three objectives of duration, cost and application effect in the field of software project quality management and the status quo of incomplete software cost measurement, this paper proposes a multi-objective enhancement method for embedded software quality on e-commerce platform based on firefly algorithm optimization, constructs a multi-objective enhancement model, and uses firefly algorithm to solve the model. Experimental results show that this method can improve the quality of embedded software on e-commerce platform.

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