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The Further Research on the Application of ABC to the Optimization and Control of Project

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Abstract

A new way of optimization has caught many researchers'attention, namely the heuristic algorithms, including Genetic Algorithm (GA), Simulating Algorithm (SA), Particle swarm optimization (PSO), ant colony optimization (ACO), Artificial Bee Colony Algorithm (ABC) and so on. Some ways of the heuristic algorithms belong to swarm intelligent optimizating algoritms such as PSO, ACO and ABC. ABC is the newest of the swarm intelligent optimizating algorithms, which is not developed perfectly and not be fully employed to a variety of fields. The paper introduces ABC to the optimization of the muli-objective optimization on construction project time-cost-quality and compare the results of ABC with the results of GA or PSO, which not only optimizes the project, but also proves the effectiveness of ABC, extends the applied fields of ABC and puts forword a new effective method of optimizing the construction project time-cost-quality.

Keywords: Articial Bee Colony Algorithm (ABC), Time-Cost-Quality (TCQ), Multi Attributive Utility function (MAU)

1. Introducation

1.1 Introduce the Problem

Swarm intelligence has become a research interest to many research scientists of related fields in recent years. Dorigo, inspired by the mechanism of organic evolution, proposed ant colony optimization (ACO) by simulating the foraging behavior of ant colonies. Particle Swarm Optimization (PSO) is a swarm intelligence technique developed by Eberhart and Kennedy who were inspired by the social behavior of bird flocking and fish schooling in 1995. Both ACO and PSO are swarm intelligence. In general, an individual is not intelligent. However, the whole biotic population display the ability to solve the complicated problems. Swarm intelligence is the application of the group behaviors in the field of artificial intelligence.

A numerical function optimization algorithm based on foraging behavior of honey bees, called Artificial Bee Colony (ABC) was proposed by Karaboga (2005). Karaboga and Basturk (2008) draw a conclution that ABC had the same good performance as PSO, Differential Evolution (DE) and Evolutionary Algorithm (EA） by comparing ABC to PSO, EA and DE in solving the five standard functions. Fan and Ma (2010) employ ABC to solve 0-1 knapsack problem. A. M. Bernarino and E. M. Bernarino (2010) applied ABC to the problem of weighted loading ring net. Hu, Zhao and Sa (2009) employs ABC to solve JSP and Hu and Zhao (2009) employ ABC to solve TSP, Sundar and Singh (2010) apply ABC to solve quadratic Minimum Degree Spanning Tree Problem, Hsieh, Hsiao & Yeh (2011) use ABC to predict the stock price, Karaboga (2009) employs ABC to design digital IIR filters, Kang, Li and Xu (2009) do structural inverse analysis by hybridsimplex ABC, Ho and Shi-you (2009) solve inverse problems by ABC, Hetmaniok, Slota and Zielonk (2010) get solution of the inverseheat conduction problem by using the ABC algorithm.

1.2 Explore Importance of the Problem and Describe Relevant Scholarship

Time, cost, and quality of the project are the three main aims of project management. The optimization of the three objectives can come down to the problem of muli-objective optimization. There are few literature balancing time and cost and quality in recent years. McKim, Hegazy and Attalla (2000) put forward that cost, time and quality are the three main guidelines in evaluating the construction project. These indicators are highly relevant and need being balanced. Rwelamila et al. (1995) proposed that project managers usually try to seek the most effective methods of balancing schedule and cost but rarely analyze the significance of quality. Tang and Qin (1998) introduce the model of simulating the control of construction project TCQ and the ways of analyzing risk based on the technique of PERT. Babua and Suresh (1996) and BaKhang and Mon (1999) make linear model of time,quality and cost in the construction of a specific cement plant and evaluate the effectiveness of this model. Wang, Liu and Luo (2004), Yang, Y. L. Wang and N. M.Wang (2006). and Gao, Hu and Zhong (2007) have made mathematical model on time, cost and quality repectively. Kaheled and Amr (2005) put forward the multi-objective model of balancing time, cost and quality.

1.3 State Hypotheses and Their Correspondence to Research Design

This paper presents the time-cost-quality tradeoff optimization model using multi-attribute utility (MAU) function theory and applies ABC to two specific cases based on network planning techniques. Then it compares the results of ABC with the result of GA in Ho and Shi-you (2009) or the result of PSO in (Zhang & Xing, 2010), which show the results of ABC is better than the results of GA and PSO. Therefore, it turns out to be that ABC can obtain the most satisfied decision result and provided a novel and effective way to project managers. In addition, if do many times of experiments, ABC can often obtain not only one best solution vector, which is beneficial for project managers to make reasonable decision flexiblely according to the specific conditions of project implementation.

2. Method

2.1 ABC

2.1.1 Bee Clony in Nature

Bee clony in nature: self-organization and division of labour are necessary and sufficient properties to obtain swarm intelligent behaviour such as distributed problemsolving systems that self-organize and adapt to the given environment:

a) Self-organization can be defined as a set of dynamical mechanisms, which result in structures at the global level of a system by means of interactions among its low-level components. These mechanisms establish basic rules for the interactions between the components of the system. The rules ensure that the interactions are executed on the basis of purely local information without any relation to the global pattern. Bonabeau et al. have characterized four basic properties on which self organization relies: Positive feedback, negative feedback, fluctuations and multiple interactions. Positive feedback is a simple behavioural "rules of thumb" that promotes the creation of convenient structures. Recruitment and reinforcement such as trail laying and following in some ant species or dances in bees can be shown as the examples of positive feedback. Negative feedback counterbalances positive feedback and helps to stabilize the collective pattern. In order to avoid the saturation which might occur in terms of available foragers, food source exhaustion, crowding or competition at the food sources, a negative feedback mechanism is needed. Fluctuations such as random walks, errors, random task switching among swarm individuals are vital for creativity and innovation. Randomness is often crucial for emergent structures since it enables the discovery of new solutions. In general, self organization requires a minimal density of mutually tolerant individuals, enabling them to make use of the results from their own activities as well as others.

b) Division of labour namely simultaneous task performance by cooperating specialized individuals is believed to be more efficient than the sequential task performance by unspecialized individuals and enables the swarm to respond to changed conditions in the search space. The foraging bees are classified into three categories employed, onlookers and scouts. All bees that are currently exploiting a food source are classified as the employed bees. The employed bees bring loads of nectar from the food source to the hive and may share the information about food source with onlooker bees. 'Onlookers' are those bees that are waiting in the hive for the information to be shared by the employed bees about their food sources and 'scouts' are those bees which are currently searching for new food sources in the vicinity of the hive.

2.1.2 Basic Thought of ABC

In the beginning of foraging behavior,all the bees have know nothing about the food sources,namely all the bees are scouts who seek randomly food sources near beehives, this stage is like the population initialization in optimizing phase; After a while, half of the bees find food source and become employed bees, the employed bees begin to spread the food information or give up the found food source and become scouts at some rate, the stage is like the stage of seeking feasible solutions in optimizating process, in which stage some solutions don't meet the constraint condition will be replaced randomly; Another half bees who haven't found food source become onlookers, the onlookers wait for the food information from employed bees and receive the food information at some probability. The probability is positively correlated to the specific information on food resource(such as sugar content and so on), this stage is like natural selection,the bigger value of fitness is more likely to be received, the received feasible solution can mutate to get the better solution. Later,the onlooker will check if the number of failure time is beyond the limited number, if the number is bigger than the limited ,then gives up the current food source for it is probable to be far away from beehive, this stage is like the verification stage in the optimizing process, in which if the current solution is not easy to be found and then it will be replaced with a new generated solution. Bee colony will not stop repeating the steps above (except the initial stage)until maximum iteration or minimum criteria is attained, it's the same story in the optimizing phase.

The specifications are shown as Figure 1 and Figure 2.

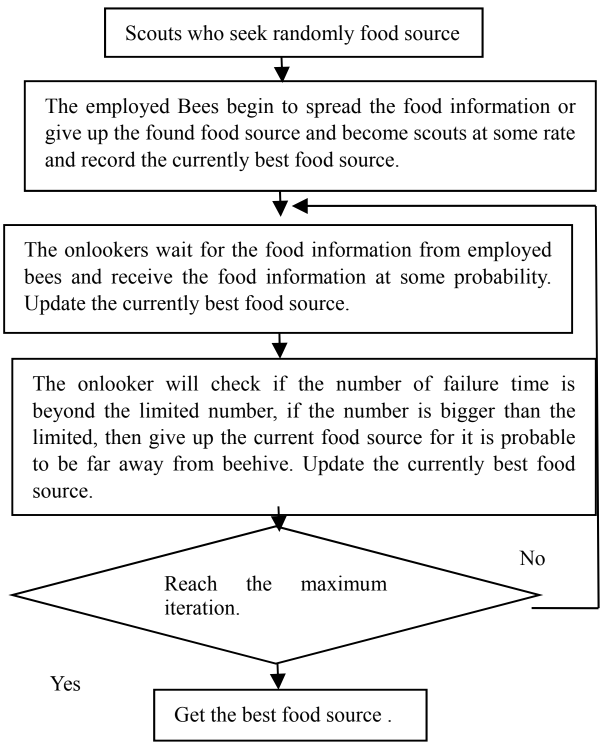

Figure 1. Behaviour characteristics of forager

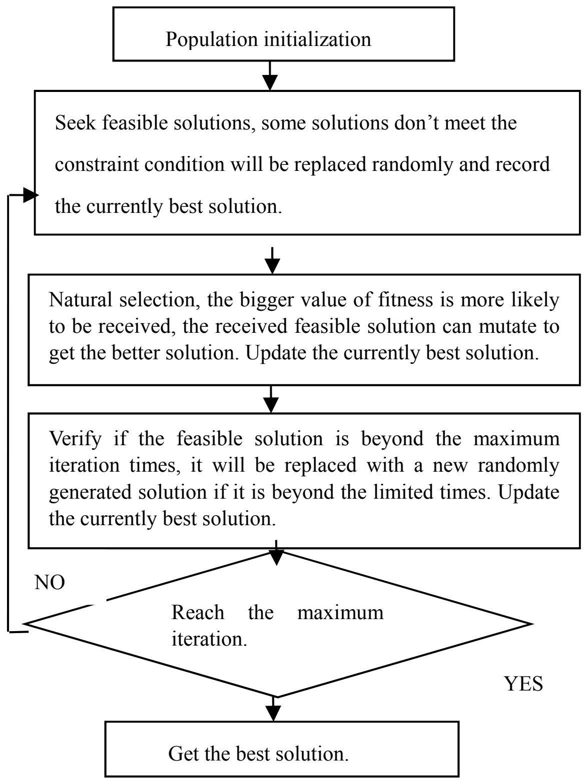

Figure 2. Corresponding optimizating stages

2.1.3 Detailed Pseudocode of the ABC Algorithm

1: Initialize the population of solutions $x_{i,j}$;

2: Evaluate the population;

3: cycle=1;

4: repeat;

5: Produce new solutions (food source positions) $v_{i,j}$ in the neighbourhood of $x_{i,j}$ for the employed bees using the formula $v_{i,j} = x_{i,j} + \Phi_{ij}(x_{i,j} - x_{k,j})$ (k is a solution in the neighbourhood of I, Φ is a random number in the range [-1,1])and evaluate them;

6: Apply the greedy selection process between x_i and v_i;

7: Calculate the probability values P_i for the solutions x_i by means of their fitness values using equation (1)

$$P_i = x_{i,j} \Big/ \sum_{i=1}^{SN} fit_i \tag{1}$$

In order to calculate the fitness values of solutions we employed the following equation (2)

$$fit_i = \begin{cases} 1/(1+f_i) \ldots f_i \geq 0 \\ 1 + abs(f_i) \ldots f_i < 0 \end{cases} \tag{2}$$

Normalize p_i values into [0,1];

8: Produce the new solutions (new positions) v_i for the onlookers from the solutions x_i, selected depending on p_i, and evaluate them;

9: Apply the greedy selection process for the onlookers between x_i and v_i;

10: Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution x_i for the scout using the equation (3)

$$x_{ij} = \min_j + rand(0,1) * (\max_j - \min_j) \tag{3}$$

11: Memorize the best food source position (solution) achieved so far;

12: cycle=cycle+1;

13: until cycle= Maximum Cycle Number (MCN).

2.2 Multiple Attribute Utility of the Project

2.2.1 The Basic Principles of Multiple Attribute Utility

Multiple attribute utility (MAU) which originated in the eighteenth century was developed by Zeng, Jie and Cun (2004). MAU theory is an analytical method for decision-making based on multiple criteria. Applications of MAU in the construction field include the studies on procurement route selection (Chang & Ive, 2002) and performance assessing of construction engineering.

Attribute utility means a measure of the desirability of outcomes associated with an alternative action. An alternative may be chosen according to the preference of decision-makers or the importance of each single criterion or performance. Each alternative to be evaluated is measured through multiple attribute functions that respectively represent each single criterion and are composed using a series of weights. Such a weight may reflect the preference of decision-makers or the importance of each performance.

If there are J≥1 criteria for each alternative, then let $(u_1, u_2, \ldots, u_J)$ denote a vector of performances for an alternative, then the composite attribute utility for measuring this alternative can be obtained as (4)

$$U = \sum_{j=1}^{J} w_j u_j \{U \in [0,1]; uj \in [0,1]\} (j = 1,2,\ldots J) \tag{4}$$

Where u_j is the single attribute utility function for the performance j and is scaled from 0 to 1. w_j is the weight for the performance j and the sum of all the weights is equal to 1, i.e $\sum_{J=1}^{J} w_j = 1$. The risk neutral utility function is commonly used and is defined as (5)

(5)

Where a_j and b_j are the constants and can be determined based on the best and the worst performances where their measure levels respectively reach the lowest value 0 and the highest value 1.

2.2.2 The Method of Creating the Multiple Attribute Utility Function of TCQ

With regards to the project performances such as time, cost and quality associated with a combination of construction methods, the equations for computing the single utility values for time, cost and quality of a project can be expressed as (6), (7), (8):

$$u_T = \begin{cases} a + b(T - T^-)^2 \ldots T \in [T^-, T^+] \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots T \notin [T^-, T^+] \end{cases} \tag{6}$$

$$u_C = \begin{cases} c + d(C - C^-)^2 \ldots C \in \left[C^-, C^+\right] \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots C \notin \left[C^-, C^+\right] \end{cases} \tag{7}$$

$$u_Q = \begin{cases} e + f(Q - Q^-)^2 \ldots Q \in \left[Q^-, Q^+\right] \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots Q \notin \left[Q^-, Q^+\right] \end{cases} \tag{8}$$

Where T, C and Q respectively represent the time, cost and quality of a project. T^+ and T^- respectively represent the longest and shortest project durations; C^+ and C^- respectively represent the maximum and minimum total cost; Q^+ and Q^- respectively represent the maximum and minimum overall quality of a project. If the weights for the three performances are w_T, w_C and w_Q respectively, then the composite attribute utility can be obtained through (9)

$$U = w_T u_T + w_C u_C + w_Q u_Q \tag{9}$$

The optimal alternative should be the one that has the largest composite attribute utility.

3. The Introduction of Two Specific Cases and the Creation of Their MAU Functions

3.1 The Creation of the Multiple Attribute Utility Function of Specific Case I

3.1.1 The Introduction of the Specific Case I

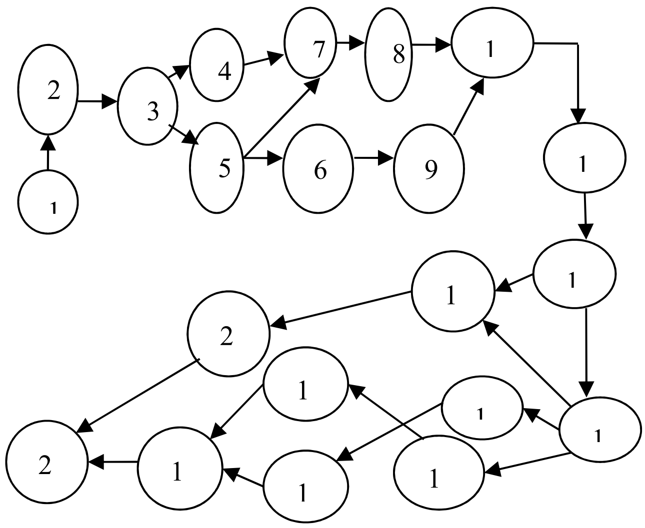

Figure 3. The Network-planning diagram

Table 1. Specific parameters

Jname	Activity number	Activity name	back closely activity	T+d	T- d	C+ yuan	C- yuan	Q+ %	Q- %	w_Q
A	1	preliminary work	2	0	0	0	0	0	0	0
B	2	foundation	3	24	20	110527	154608	1	0.9233	0.0875
C	3	Wall in the first floor	4、5	18	15	85563	119788	1	0.9133	0.0772
D	4	beam and slab in the first floor	7	30	25	135581	189816	1	0.9156	0.0637
E	5	Stairs betwee the first and second floor	6、7	13	12	9867	13813	1	0.8889	0.0557

F	6	cast-in-situ in the first floor	9	7	5	9762	13667	1	0.8700	0.0356
G	7	Wall in the second floor	8、9	18	15	85563	119788	1	0.9033	0.0678
H	8	Beam and slab in the second floor	10	30	25	135581	189816	1	0.8989	0.0609
I	9	Stairs between the second and third floor	10	13	12	9867	13813	1	0.8789	0.0533
J	10	Wall in the third floor	11	20	16	100003	140007	1	0.8956	0.0661
K	11	Beam and slab in the third floor	12	30	25	135581	189816	1	0.8744	0.0594
L	12	roof	13、19	11	8	63315	88641	1	0.8822	0.0476
M	13	Doors windows and decorations in the first floor	14、15	13	9	67997	95195	1	0.8600	0.0316
N	14	facilities installation in the first floor	16、17	4	2	15062	21086	1	0.8922	0.0508
O	15	Doors windows and installation in the second floor	16、17	13	9	65332	91464	1	0.8689	0.0331
P	16	Facilities installation in the second floor	18	4	2	15062	21086	1	0.8878	0.0523
Q	17	Doors windows and installations in the third floor	18	13	9	65332	91464	1	0.8700	0.0338
R	18	Facilities installation in the third floor.	21	4	2	15062	21086	1	0.8856	0.0509
S	19	External wall decoration	20	16	12	56246	79342	1	0.8644	0.0367
T	20	Steps water apron and so on	21	5	3	5505	7708	1	0.8700	0.0360
U	21	Final end	-	0	0	0	0	0	0	0

The network-planning diagram is shown as Figure 3, specific parameters are shown as Table1.

3.1.2 The Creation of MAU Function of Case I

$T^{+}=224$, $C^{+}=1662004$, $Q^{+}=1$, $T^{-}=178$, $C^{-}=1186808$, $Q^{-}=0.8931$, take them into (10), (11), (12), get a=1b=$(1/46)^2$, c=1, d=$(1/475196)^2$,e=0,f=$(1/0.1087)^2$

$$u_T=\begin{cases} a+b(T-T^{-})^2 \ldots T\in\left[T^{-},T^{+}\right] \\ 0\ldots\ldots\ldots\ldots\ldots\ldots T\notin\left[T^{-},T^{+}\right]\end{cases} \tag{10}$$

$$u_C=\begin{cases} c+d(C-C^{-})^2 \ldots C\in\left[C^{-},C^{+}\right] \\ 0\ldots\ldots\ldots\ldots\ldots\ldots C\notin\left[C^{-},C^{+}\right]\end{cases} \tag{11}$$

$$u_Q = \begin{cases} e + f(Q - Q^-)^2 \ldots Q \in \left[Q^-, Q^+\right] \\ 0 \cdots\cdots\cdots\cdots\cdots\cdots Q \notin \left[Q^-, Q^+\right] \end{cases} \tag{12}$$

$$U = w_T * \left[1 - \left(\left(T - 178\right)/46\right)^2\right] + w_C * \left[1 - \left(\left(C - 1186808\right)/475196\right)^2\right] + \left[1 - w_Q * \left(\left(Q - 1\right)/0.1087\right)^2\right] \tag{13}$$

While w_T, w_C and w_Q is calculated by experts grading method,they respectively are $w_T = 0.3$, $w_C = 0.4$ and $w_Q = 0.3$, take them into (13) and get (14)

$$U = 1 - \left[0.3 * \left(\left(T - 178\right)/46\right)^2 + 0.4 * \left(\left(C - 1186808\right)/475196\right)^2 + 0.3 * \left(\left(Q - 1\right)/0.1087\right)^2\right] \tag{14}$$

3.2 The Creation of the Multiple Attribute Utility Function of Specific Case II

3.2.1 The Introduction of the Specific Case II

The network-planning diagram is shown as Figure 4, specific parameters are shown as Table 2.

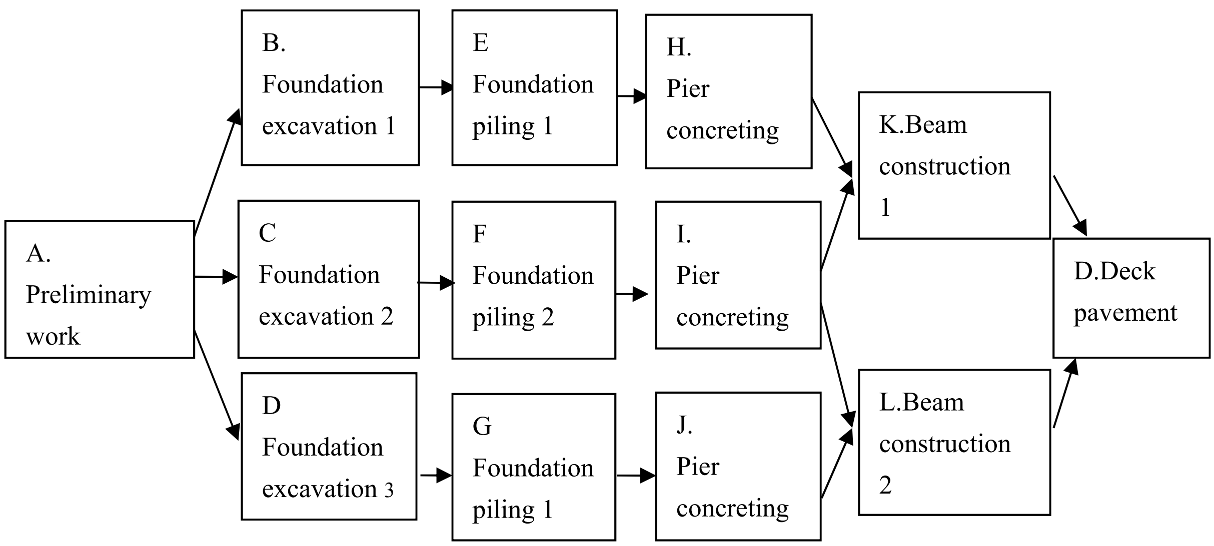

Figure 4. The Network-planning diagram

Table 2. Specific parameters

Activity number	Jname	Activity name	T+ d	T- d	C- yuan	C+ yuan	Q+ %	Q- %	w_Q
1	A	Preliminary work	26	30	416	600	1	0.9	0.01
2	B	Foundation excavation 1	40	46	6400	8280	1	0.9	0.08
3	C	Foundation excavation 2	40	50	6600	9250	1	0.9	0.09
4	D	Foundation excavation 3	39	49	6240	8820	1	0.9	0.08
5	E	Foundation piling 1	36	40	4464	5760	1	0.9	0.11
6	F	Foundation piling 2	46	54	8280	10800	1	0.9	0.11
7	G	Foundation piling 3	38	42	4940	6300	1	0.9	0.11
8	H	Pier concreting 1	83	87	17430	20010	1	0.7	0.08
9	I	Pier concreting 2	87	93	20010	23250	1	0.7	0.08
10	J	Pier concreting 3	83	87	18260	20880	1	0.7	0.08
11	K	Beam construction 1	18	22	1980	2860	1	0.9	0.06
12	L	Beam construction 2	20	24	2400	3360	1	0.9	0.06
13	M	Deck pavement	22	28	1298	1988	1	0.9	0.05

3.2.2 The Creation of MAU Function of Case II

$T^+ = 279$, $C^+ = 122158$, $Q^+ = 1$, $T^- = 215$, $C^- = 98718$, $Q^- = 0.852$.

Take the data in to(10)～(12), get a=1, b=1/64, c=1, d=1/23340, e=0, f=1/0.148

$$U = w_T * \left[1 - \left((T-215)/64\right)^2\right] + w_C * \left[1 - \left((C-98718)/23340\right)^2\right] + \left[1 - w_Q * \left((Q-1)/0.148\right)^2\right] \tag{15}$$

While w_T, w_C and w_Q is calculated by experts grading method,they respectively are $w_T = 0.3$, $w_C = 0.4$ and $w_Q = 0.3$, take them into (15), get (16)

$$U = 1 - \left[0.3 * \left((T-215)/64\right)^2 + 0.4 * \left((C-98718)/23340\right)^2 + 0.3 * \left((Q-1)/0.148\right)^2\right] \tag{16}$$

4. The Application of ABC to the Two Cases

4.1 The Application of ABC to Optimize the Specific Case 1

4.1.1 The Choice of Parameter

The number of population namely NP=20;

The number of food source namely Foodnumber=10;

The maximum times of failure namely Limit=100;

The maximum cycling times nameyMax=500;

The number of parameters: D=60;

The lower bound namely Lb:[0,20,15,25,12,5,15,25,12,16,25,8,9,2,9,2,12,3,0,110527,85563,135581,9867,9762,85563,135581,9867,100003,135581,63315,67997,15062,65332,15062,56246,5505,0,0.9233,0.9133,0.9156,0.8889,0.8700,0.9033,0.8989,0.8789,0.8956,0.8744,0.8822,0.8600,0.8922,0.8689,0.8878,0.8700,0.8856,0.8644,0.8700]

The upper bound namely Ub=[0,24,18,30,13,7,18,30,13,20,30,11,13,4,13,4,13,4,16,5,0,154608,119788,189816,13813,13667,119788,189816,13813,140007,189816,88641,95195,21086,91464,21086,91464,21086,79342,7708,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]

4.1.2 The result of experiment and the analysis of the result

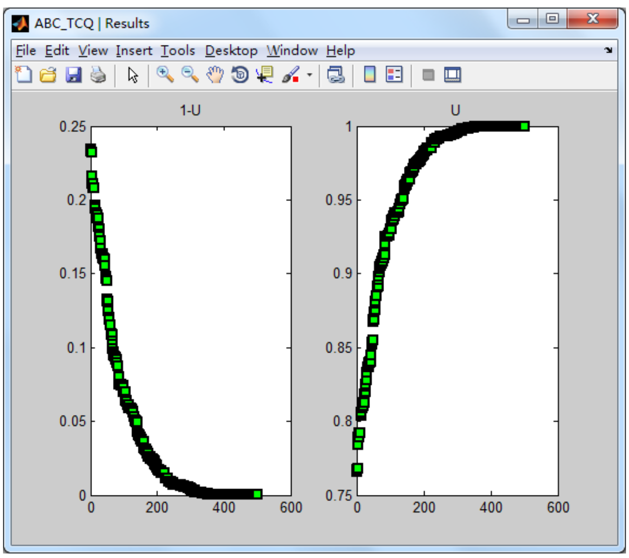

Figure 5. The result of ABC algorithms

The result of experiment is shown as Figure 5 When maximum iteration is equal to 500, the maximum utility is 1, the best solution vector is not unique, one of them is as follows:

[0,20,15,25,12.5053,6.3985,15,25,8,9,3.4113,9,3.7384,9,2,13.5524,3.3389,0,110527,85563,135581,9867,9762,85563,135581,9867,100003,135581,63315,67997,15062,65332,15062,65332,15062,56246,5505,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]

T=178; C=1186808; Q=1

4.1.3 The Analysis of the Result

Table 3. The analysis of the results

Best solutions	The maximum utility	
	ABC	*GA in(Ho& Shi-you,2009)*
values	1	0.8480

The results of various algorithms is in Table 3. Compare optimal solution of the ABC algorithm to GA in (Ho & Shi-you, 2009), we can see that the solution quality of ABC algorithm is better and robuster than the optimum solutions of GA algorithm.

4.2 The Application of ABC to Optimize the Specific Case II

4.2.1 The Choice of Parameter

The number of population namely NP=20;

The number of food source namely Foodnumber=10;

The maximum times of failure namely Limit=100;

The maximum cycling times nameyMax=2500;

The number of parameters: D=39.

The lower bound namely

Lb=[26,40,40,39,36,46,38,83,87,83,18,20,22,416,6400,6600,6240,4464,8280,4940,17430,20010,18260,1980,2400,1298,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.7,0.7,0.7,0.9,0.9,0.9]

The upper bound namely

Ub=[30,46,50,49,40,54,42,87,93,87,22,24,28,600,8280,9250,8820,5760,10800,6300,20010,23250,20880,2860,3360,1988,1,1,1,1,1,1,1,1,1,1,1,1,1]

4.2.2 The result of experiment

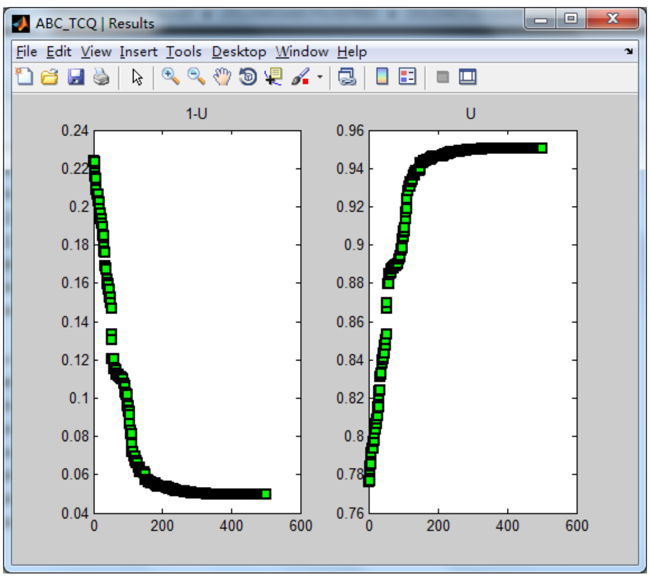

Figure 6. The result of ABC algorithms

Table 4. The analysis of the results

Best solutions	The maximum utility	
	ABC	*PSO in (Zhang&Xing,2010)*
values	0.9504883	0.906

The result of experiment is shown as Figure 6. When maximum iteration is equal to 2500, the maximum utility is 0.9504883, the best solution vector is not unique, one of them is as follows:

[26,42,40,40,39,46,40,87,87,83,19,20,22,416,6400,6600,6240,4464,8280,4940,17430,20010,18260,1980,2400,1298,1,1,1,1,1,1,1,1,1,1,1,1,1]

T=241; C=100260; Q=1

4.2.3 The Analysis of the Result

The results of various algorithms is in Table 3, Compare optimal solution of the ABC algorithm to PSO in (Zhang & Xing, 2010), we can see that the solution quality of ABC algorithm is better and robuster than the optimum solutions of GA algorithm.

5. Discussion and Conclusion

This paper presents the time-cost-quality tradeoff optimization model using multi-attribute utility (MAU) function theory and applies ABC to two specific cases based on network planning techniques. Then it compares the results of ABC with the result of GA in (Ho & Shi-you, 2009)or the result of PSO in (Zhang & Xing, 2010), which not only show the results of ABC is better than the results of GA and PSO but also display the robustness of ABC. In conclusion, the paper not only proves the effectiveness of ABC, extends the applied fields of ABC, but also puts forword a new effective method for project managers to optimize the construction project time-cost-quality.

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