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Research Article

The Remuneration Optimization Scheme for Photo Tasks Based on Simulated Annealing Algorithm

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Abstract: According to the analysis of indetermination between completion rate and remuneration of photo tasks in crowd sourcing mode, this study proposes relation curves that completion rate varies with remuneration and ranking of remuneration in the unit area inferred by cubic-Hermite interpolation method based on task data in Guangzhou and Foshan. Then this study uses Simulated Annealing Algorithm to find the optimal remuneration scheme which means that the task completion rate significantly increases with the small increase in the remuneration. This study also compares the scheme obtained by Simulated Annealing Algorithm with the initial scheme and finds that the task completion rate increased by 13.65%, while the total task remuneration increased by 1.17%. The results show that this optimization scheme is beneficial and reasonable.

Keywords: Crowdsourcing, cubic-hermite interpolation method, optimization, photo tasks, simulated annealing algorithm

INTRODUCTION

In recent years, with the globalization of the economy and the development of network technology, the crowdsourcing characterized by the freedom, openness, equality and harmony is becoming more and more popular with companies. The crowdsourcing is a mass contract mode that the company assigns specific tasks to people outside through the designated website and pays the agreed remuneration to the people who complete the tasks (Zhang *et al*., 2012). Crowdsourcing has been proven to have many benefits for the company while also providing opportunities for amateurs to participate in business building (Xiao, 2010). The emergence of photo tasks is also affected by the crowdsourcing model and its essence is the self-service mode of the mobile Internet. Users download APP and register as a member. Then, they could take the photo tasks from APP to earn the remuneration (for instance, checking the situation of commodities in a supermarket).

Since the complicated relationship between remuneration and task completion rate, the relation function may be non-differentiable or even discontinuous. The traditional optimization method is complicated to solve such problems. Simulated Annealing Algorithm provides an efficient way and a general framework for resolving the above issues (Xiang *et al*., 2005) and gradually develops into a kind of iterative, adaptive, heuristic and probabilistic searching algorithm. People have obtained a series of application results on all kinds of optimization problems by the Simulated Annealing Algorithm.

For example, it was used to develop optimized boreholes plans, solve the Traveling Salesman Problem (TSP) and obtain the minimum of the completion time in the job shop scheduling problem (Pinheiro*et al*., 2017; Wang, 2010; Van Laarhoven*et al*., 1992).

Due to the task completion rate is not only related to the task remuneration but also has a close relationship among the task distance, task intensity and the remuneration difference of its surrounding tasks, it is tough to optimize the scheme with the traditional method. This study uses the Simulated Annealing Algorithm to optimize remuneration scheme based on relation curves that the completion rate varies with remuneration and ranking of remuneration in the unit area inferred by the cubic-Hermite interpolation method. Then we calculate a new remuneration scheme which is best for the company interests.

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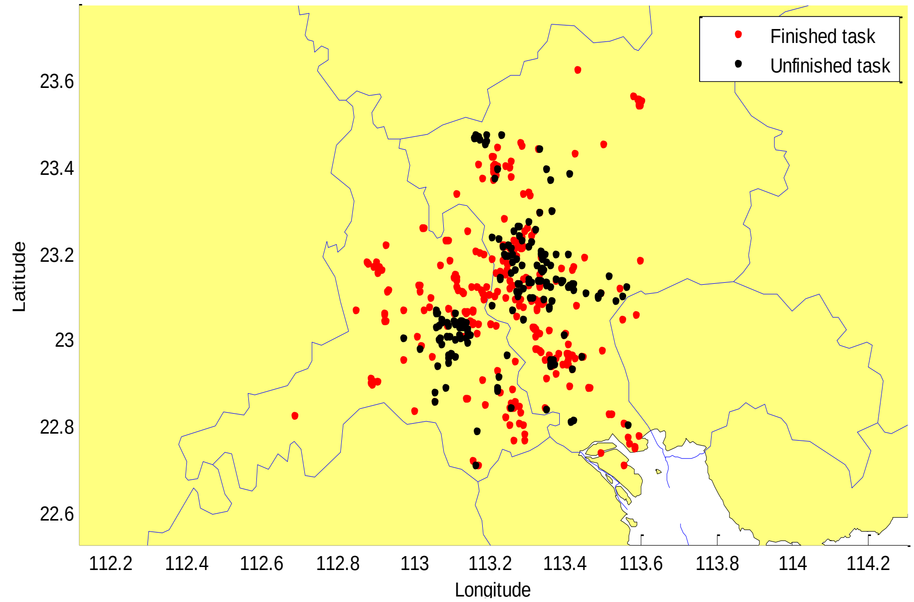

Fig. 1: Task location and completion situation

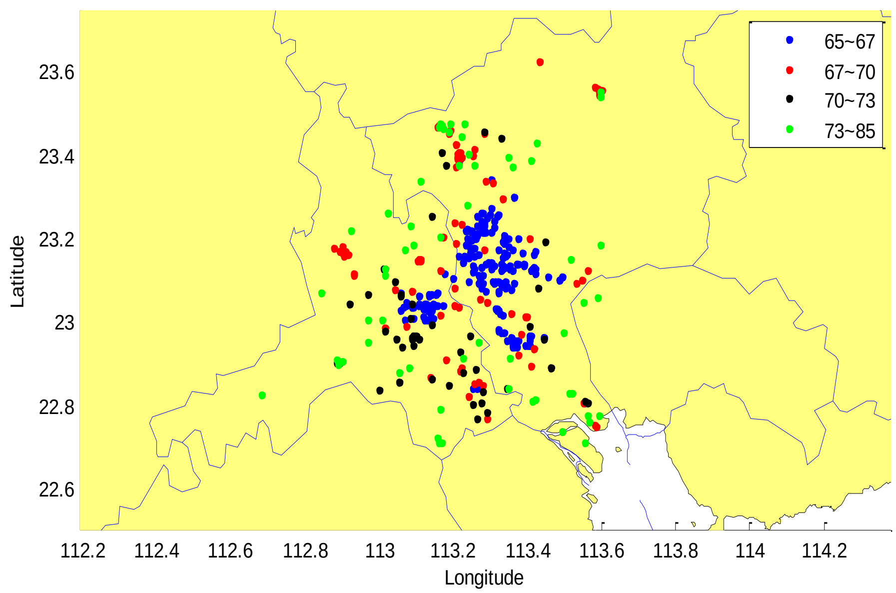

Fig. 2: Distribution of various types of task

MATERIALS AND METHODS

Data processing: The data in this study includes completion situation, task locationand remuneration in Guangzhou and Foshan, which is provided by China Undergraduate Mathematical Contest in Modeling in 2017. Task location and completion situation are shown in Fig. 1. According to the amount of remuneration, this study divides tasks into four types and calculates the total completion rate of each type. Classification results with their completion rates are shown in Table 1 and the distribution of various types of tasks is shown in Fig. 2.

Table 1: Remuneration classification and the corresponding completion rate

Type	Remuneration range	Completion rate
1	65~67	53.25%
2	67~70	77.55%
3	70~73	64.15%
4	73~85	70.79%

As the random disturbance of the remuneration has an inevitable impact on the completion of the surrounding tasks, this study sets a ranking index to measure the effect of task remuneration within the unit area. To calculate the ranking index of each task, this study at first chooses every task as the center and then

Table 2: Ranking index classification and the corresponding completion rate

Type	Ranking index range	Completion rate
1	0.0~0.3	60.73%
2	0.3~0.5	65.12%
3	0.5~0.7	39.44%
4	0.7~0.9	73.58%
5	0.9~1.0	84.09%

draws a circle with a radius of five kilometers and obtains the ranking of tasks in the circle. After that, the ranking index is calculated as the task ranking divided by a total number of tasks in the circle and all the ranking indexes are divided into five types which are shown in Table 2.

The ranking index is distributed between 0 and 1 and its size can measure the 'competitiveness' of tasks. If the value tends to 0, it means the task has the price advantage compared with other tasks around it, which is similar to the buyer market and members will give priority to complete the task with the highest remuneration ranking in the unit area. For the value of the ranking index approaching 1, most of these tasks have fewer tasks around them, which is similar to the seller market and the task completion rate is high because the members have little choice.

Because the function relationship is not straightforward among the remuneration, the ranking index and the completion rate, this study uses the cubic Hermite polynomial interpolation to make every small disturbance of remuneration have its corresponding completion rate. This method expands remuneration range from 65~85 to 65.00~85.00 totals of 2000 points and the ranking index expands to 0.001~1.000 totals of 1000 points, the formula is as follows:

$$a_1 = \left(1+\frac{2\times xx_i}{x_1-x_2}\right)\times = \left(1+\frac{xx_i\times xx_i}{x_1-x_2}\right)^2$$
$$a_1 = \left(1+\frac{2\times xx_i}{x_1-x_2}\right)\times = \left(1+\frac{xx_i\times xx_i}{x_1-x_2}\right)^2$$
$$S_i = a_1\times y_1 + a_2\times y_2$$

where,

x_1 = Coordinate of the first point
x_2 = Coordinate of the second point
xx_i = Coordinate of interpolation betweenx_1
x_2 y_1 = Function values ofx_1
y_2 = Function values of x_2
S_i = Interpolation calculated by the cubic-Hermite interpolation method.

The interpolation results of the remuneration are shown in Fig. 3. The interpolation results of the ranking indexes are shown in Fig. 4.

Through the interpolation, the function of the relationship between remuneration or its ranking index and task completion rate can be obtained. So each small disturbance has its corresponding completion rate.

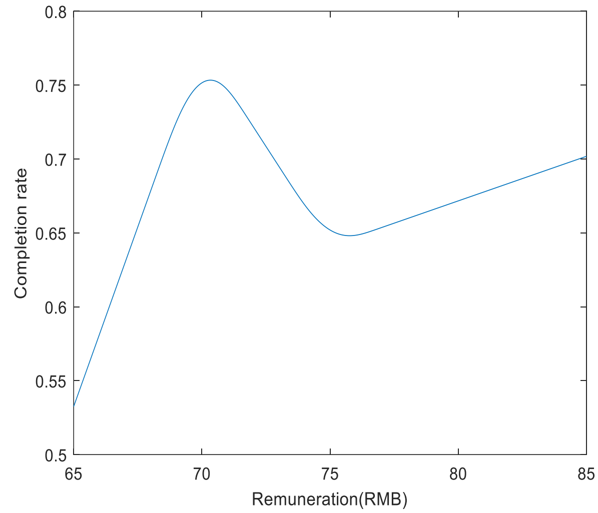

Fig. 3: Relationship between task remuneration and completion rate

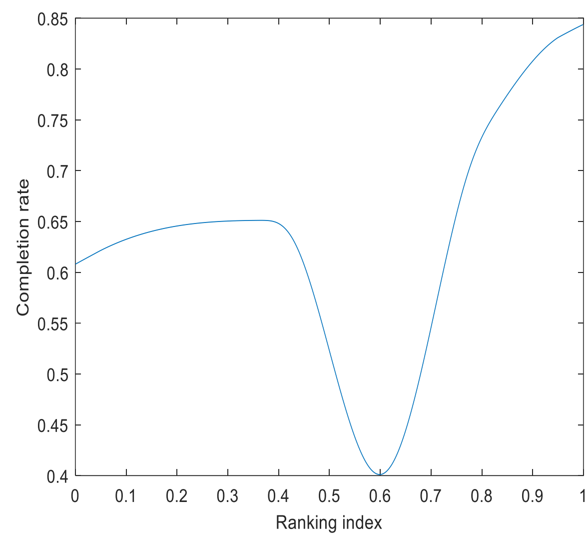

Fig. 4: Relationship between ranking index and completion rate

Establishment of model: From the view of company's point, the purpose of the new scheme is to improve the completion rate with low cost. Therefore, the primary factor in determining the amount of remuneration is to get a higher completion rate. The curves of Fig. 3 and 4 show a complicated relationship of task completion rate with remuneration and its ranking index. This study gives the two factors same weight to calculate the proportion of the task completion rate, together with the percentage of increase of the remuneration as the standards to measure the rise of remuneration and the advantage and disadvantage with the different amount whose mathematical representation is given as:

$$L = P_{competition} - P_{price}$$

where,

$P_{competition}$ = Increase proportion of the task completion rate
P_{price} = Increase proportion of task remuneration
L = The criterion for judging whether the scheme is the optimal scheme

When L is the largest, the total completion rate of the corresponding scheme will be far higher than the increase in remuneration. Due to the randomness of the disturbance and changing remuneration of each task will have an impact on the completion rate of other tasks around, there are massive optimization schemes which brings inconvenience to the calculation. This study uses Simulated Annealing Algorithm to simplify the calculation of this optimal solution.

Simulated annealing algorithm: Kirkpatrick *et al.* (1983)proposed a simulated annealing algorithm to simulate the annealing process of solid matter in physics. The physical annealing process consists of three parts: heating process, isothermal process and cooling process.

The initial temperature is determined in the process of optimization firstly and then this algorithm randomly selects an initial state, examines the objective function value of the state, adds a small disturbance to the current state and calculates the objective function value

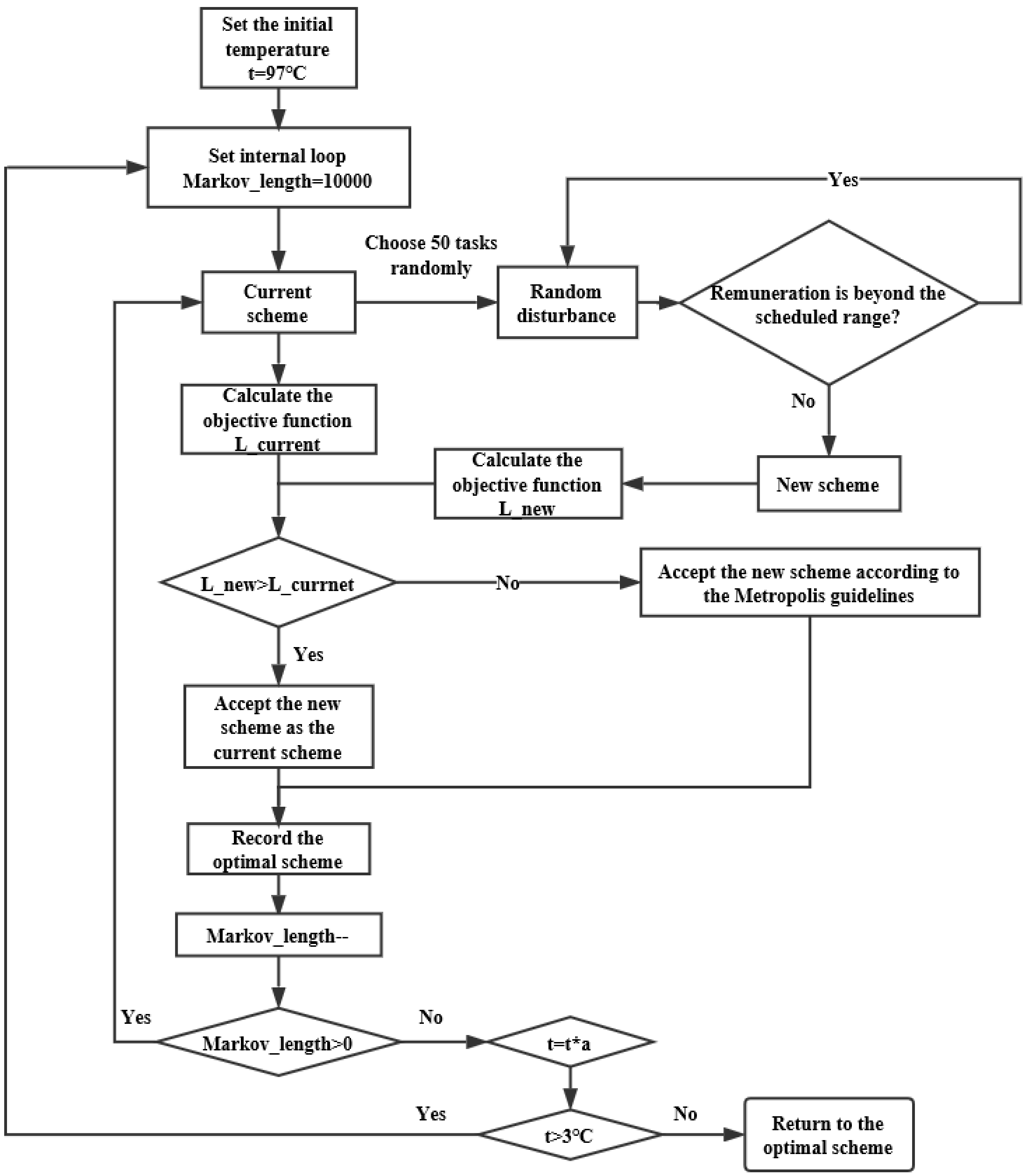

Fig. 5: Simulated annealing optimization process

of the new state. This algorithm accepts a better point with probability 1 and a worse point with probability which is defined as:

$$M = e^{(\frac{L_j \times L_i}{T})}$$

where,

M = Probability calculated by Metropolis guidelines
L_j = The objective function of the new scheme
L_i = The objective function of the current scheme.

The specific implementation of the algorithm is shown in Fig. 5.

The annealing temperature controls the optimization to the optimal solution and it receives the inferior solution at a certain probability so that the algorithm can jump out of the local optimum. After a slow enough annealing process, the algorithm can find the best remuneration optimization scheme for Photo Tasks.

RESULTS AND DISCUSSION

The formula for annealing temperature is given as:

$$T_{k+1} = T_k \times a$$

where,

T_{k+1} = Current temperature
T_k = Previous annealing temperature
a = Constant which is set to 0.95 for finding the optimal scheme

According to the formula of annealing temperature, the annealing temperature is used to control the cycle. In the internal cycle, each time chooses 50 tasks to propose random disturbance which uniformly distributes from the interval [-2, +2]. The scheme recovers the original task remuneration and makes the new disturbance to the task if the cumulative disturbances overrun the range of [-5, 5].This method canavoid sudden interference with the normal operation of the market.A new remuneration scheme is formed after the 50 tasks are disturbed. Then the evaluation value L of the new scheme is calculated. During the annealing process,Lcould be obtained for each cycle and L_{best} is the maximum of all the evaluation values corresponding to the optional scheme.

Optimization scheme and discussion: The objective function L is the optimization criterion and the

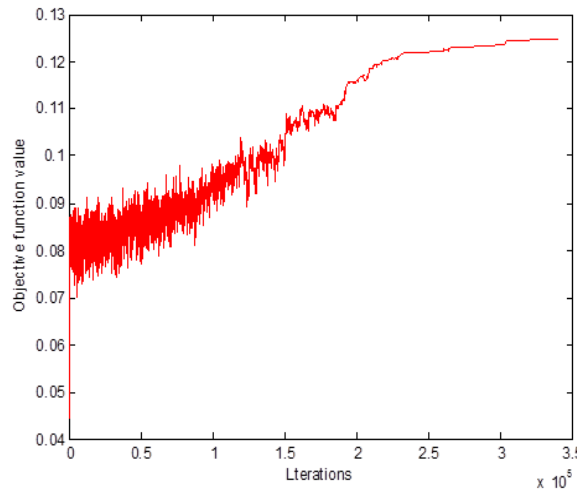

Fig. 6: The objective function value change process

evolution of the simulated annealing algorithm during its execution is shown in Fig. 6. Since a large number of iterations, this study selects a data as a sample from 100 iterations. As the iterative process progresses, L increases from 0 to 0.1248. It could be seen from the graph that L reaches a stable value in the final 10^7 iterations, the final L equals to 0.1248. The result indicates that the algorithm has finally converged to approximate global optimal. Some data of the optimization scheme are shown in Table 3, which means that the task completion rate is significantly increased with the small increase in the remuneration.

Table 3 indicates that each task has its price increase or decrease. What's more, total remuneration of the optimal scheme increase slightly within the acceptable range of the company.

After optimizing the remuneration of the task, the optimal effect of the new scheme is illustrated by calculating the growth rate of the task completion rate, the rationality is illustrated by calculating the growth rate of the remuneration. The task remuneration couldn't be too high to guarantee the company's interests. The task completion rate increased by 13.65%, while the total task remuneration increased by 1.17%, which achieves the purpose of the slight increase of the remuneration and significant improvement of the task completion rate.

A similar study used 0-1 programming model to solve remuneration optimization problem (Jiang and

Table 3: Part of the new scheme changes in task remuneration

Task number	Task1	Task 2	Task 3	Task 4	Task 5	Task 6
Task latitude	23.186	23.168	23.199	23.079	22.808	22.751
Task longitude	113.597	113.420	113.406	113.429	113.554	113.582
Original task remuneration	75.000	66.500	68.500	70.5	66.500	70.000
Remuneration disturbance	-3.7357	+0.483	+3.200	+0.628	+0.679	-2.357
Optimized remuneration	71.2643	66.983	71.700	71.128	67.179	67.643
Disturbance proportion	-4.98%	+0.73%	+4.67%	+0.89%	+1.02%	-3.37%

Cheng, 2017), but it did not have a detailed solution process and data analysis compared by this study. Roy*et al*. (2015) presented a task-assignment optimization scheme (Roy *et al*., 2015) which had similar optimization ideas to this study. It should be noted that the date in this study comes from Guangdong, China. This optimization may be not suitable for all regions. However, it can provide reference to remuneration optimization schemes of crowdsourcing in other countries.

CONCLUSION

This study uses the data of photo tasks in Guangzhou and Foshan to calculate the relationshipbetween task completion rate and remuneration or ranking index by the cubic-Hermite interpolation method. It is difficult for traditional ways to find a remuneration optimization scheme with the high taskcompletion rate under a slight pay increase.Therefore, this study adopts the simulated annealing algorithm to calculate remuneration optimization scheme, which solves the problems of high computational complexity and slow calculation speed of other traditional algorithms with large-scale samples. By comparing the percentages increase of the completion rate and remuneration of the new scheme, it can be seen that the task completion rate of the new scheme improves significantly. The new scheme has higher efficiency, reliability and practical value, meanwhile, it has a reference value for other forms of crowdsourcing to amend the task pricing scheme.

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