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Investigation of Ant Colony Optimization with Intelligent and Dull Ants

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Abstract

In the previous study, we have proposed Ant Colony Optimization with Intelligent and Dull Ants (IDACO), which two kinds of ants coexist. We have applied IDACO to various TSP problems and confirmed the effectiveness. However, the association between the rate of dull ants and its behaviors was not completely clear. In this study, we investigate the effect of the rate of dull ants in IDACO and of the parameter which is related to the distance between the cities.

1. Introduction

The Ant Colony Optimization (ACO) [1] is an evaluational optimization algorithm inspired by the pheromone effect of ants and is effective to solve difficult combinatorial optimization problems, such as Traveling Salesman Problems (TSP) [2], graph coloring problems, Quadratic Assignment Problems (QAP) and so on. TSP is a problem in combinatorial optimization studied in operations research and theoretical computer science. In TSP, given a list of cities and their pairwise distances, the task is to find the shortest possible tour that each city exactly once. In ACO algorithm, the ants drop the pheromones on the path connecting cities. The pheromones are updated depending on the behavior of the ants to find a food source through paths having strong pheromone deposits. By communicating with other ants according to the pheromone strength, the algorithm tries to find the optimal solution. However, ACO has a problem which is to fall into local solutions. Therefore, it is important to enhance the algorithm performances by improving its flexibility.

An interesting report about the real ant world [3] was proposed. This report has confirmed that about 20 percent of the ants are unnecessary ants called “dull ant”. The dull ant keeps still or stay around their colony whereas the other ants in a colony perform feeding behavior. In a computational experiment, the researchers performed the feeding behavior by using intelligent ants, which can trail the pheromone exactly, and the dull ant which can not trail the pheromone exactly. From the results, the ants group including the dull ant can obtain more foods than the group containing only the intelligent ant. It means that the coexistence of the intelligent and the dull ant improves the effectiveness of the feeding behavior.

In our previous study, we have proposed a new ACO algorithm; Ant Colony Optimization with Intelligent and Dull ants (IDACO) [4]. The important feature of IDACO is that two kinds of ants coexist. The one is the intelligent ant and the other one is the dull ant. The intelligent ant can trail the pheromone exactly and the dull ant can not trail the pheromone. These features are essentially similar to the real ant world. Therefore, IDACO algorithm is closer to the real ant colony than the standard ACO algorithm. We have applied IDACO to various TSP problems and confirmed the effectiveness. However, the association between the rate of dull ants and its behavior was not completely clear. In this study, we investigate effect of the rate of dull ants on IDACO.

2. Ant Colony Optimization with Intelligent and Dull Ants

We explain IDACO algorithm in detail. The important feature of IDACO is that two kinds of ants coexist; *the intelligent ant* and *the dull ant*. The intelligent ant is the same as the ant of the standard ACO, and it can exactly trail the pheromone. In constant, the dull ant can not trail the pheromone. The input space of N-city positions is denoted as

$$S \equiv \{P_1, P_2, \cdots, P_N\}, P_i \equiv (x_i, y_i), \quad (1)$$

where the input area is normalized from 0 to 1, and P_i is the i-th city position. M ants are deposited on each city at random. $d \times M$ ants are classified into a set of the dull ants S_{dull}. d is the rate of dull ants on all the ants.

[Step1](Initialization): Let the iteration number $t = 0$. $\tau_{ij}(t)$ is the amount of pheromone deposited on the path (i, j) between the city i and the city j at time t, and $\tau_{ij}(t)$ is initially set to τ_0.

[Step2](Find tour): For the intelligent ants and the Dull ants, the visiting city is chosen by the probability $p_{ij,I}(t)$ and $p_{ij,D}(t)$, respectively, as shown in Fig. 1. The probability of k-th ant moving from the city i to the city j is decided as;

$$p_{k_{ij},D}(t) = \frac{\eta_{ij}}{\Sigma_{l\in N_k}\eta_{il}}, \quad \text{if } k \in S_{\text{dull}} \tag{2}$$

$$p_{k_{ij},I}(t) = \frac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}]^{\beta}}{\Sigma_{l\in N_k}[\tau_{il}(t)]^{\alpha}[\eta_{il}]^{\beta}}, \quad \text{otherwise,} \tag{3}$$

where $k = 1, 2, \cdots, M$, and $1/\eta_{ij}$ is the distance of the path (i, j). The adjustable parameters α and β control the weight of the pheromone intensity and of the city information, respectively. Therefore, the searching ability goes up and down by changing α and β. As Eq. (2) does not include the amount of deposited pheromone $\tau_{ij}(t)$, the dull ants can not trail the pheromone. Therefore, while the intelligent ants judge next city by both the pheromone and the distance from the present location, the dull ants judge next city depending on only the distance from the present location. N_k is a set of cities that k-th ant has never visited. The ants repeat choosing next city until all the cities are visited.

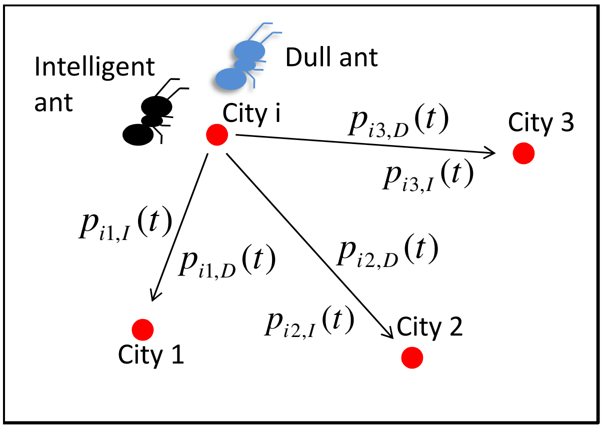


Figure 1: Probability $p_{ij}(t)$ of intelligent and dull ants

[Step3](Pheromone update): After all ants have completed their tour, the amount of deposited pheromone on each path is updated. We should note that the dull ants can not trail the pheromone, however, they can deposit the pheromone on the path. Then, compute the tour length $L_k(t)$, and the amount of pheromone deposited by k-th ant on the path (i, j) is decided as;

$$\Delta\tau_{k_{ij}}(t) = \begin{cases} 1/L_k, & \text{if } (i, j) \in T_k(t) \\ 0, & \text{otherwise,} \end{cases} \tag{4}$$

where $T_k(t)$ is the tour obtained by k-th ant, and $L_k(t)$ is its length. Updated $\tau_{ij}(t)$ of each path (i, j) depending on its $\Delta\tau_{k_{ij}}(t)$;

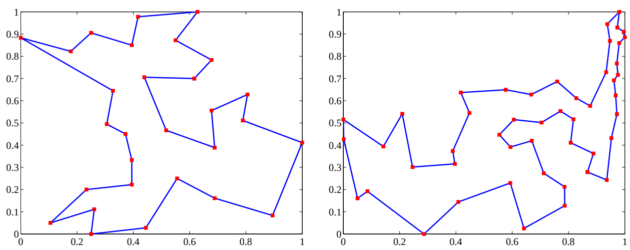
$$\tau_{ij}(t + 1) = (1 - \rho)\tau_{ij}(t) + \sum_{k=1}^{M} \Delta\tau_{k_{ij}}(t), \tag{5}$$

where $\rho \in [0, 1]$ is the rate of pheromone evaporation.

[Step4] Let $t = t + 1$. Go back to [Step2] and repeat until $t = t_{\text{max}}$.

3. Numerical Experiments

In order to investigate the association between the rate of dull ants and its behavior, we apply IDACO to two TSP problems and compare IDACO with the different rate of dull ants with the standard ACO. The TSP problems is conducted on *bayg*29 (composed of 29 cities) shown in Fig. 2(a) and *att*48 (composed of 48 cities) shown in Fig. 2(b).



(a) (b)

Figure 2: Two benchmark problems and their optimal tours. (a) *bayg29*. (b) *att48*.

In the experiments, the number of ants M in the standard ACO and IDACO are set to the same as the number of cities. The standard ACO contains only the intelligent ants. IDACO includes the dull ants, which are $d \times 100$ percent of all the ants, and the intelligent ants which are the others. We repeat the simulation 10 times for all the problems. The parameters of the standard ACO and IDACO were set to the follows;

$$\rho = 0.3, \ \alpha = 1, \ t_{max} = 2000, \tag{6}$$

where the evaporation rate ρ, the weight of pheromone α, the weight of distance β and the search limit t_{max} are fixed values. In order to compare the obtained solution with the optimal solution, we use the error rate as follow;

$$\text{Error rate[\%]} = \frac{(\text{obtained solution}) - (\text{optimal solution})}{(\text{optimal solution})} \times 100. \tag{7}$$

This equation shows how close to the optimal solution the standard ACO obtains the tour length. Thus, the error rate nearer 0 is more desirable.

Table 1: Results of ACO and IDACO with varying parameter β for *bayg*29.

β	ACO (d=0)	IDACO			
		d=0.1	d=0.2	d=0.3	d=0.4
2	3.74%	2.62%	1.72%	1.72%	1.54%
3	2.87%	2.08%	1.73%	1.7%	1.38%
4	2.49%	2.47%	2.18%	1.74%	1.7%
5	2.66%	2.6%	2.27%	2.02%	1.83%

Table 2: Results of ACO and IDACO with varying parameter β for *att*48.

β	ACO (d=0)	IDACO			
		d=0.1	d=0.2	d=0.3	d=0.4
2	4.06%	3.04%	2.55%	2.93%	3.19%
3	3.61%	3.43%	2.21%	2.59%	3.92%
4	2.78%	2.65%	2.72%	3.1%	3.07%
5	2.85%	2.46%	2.36%	2.81%	3.06%

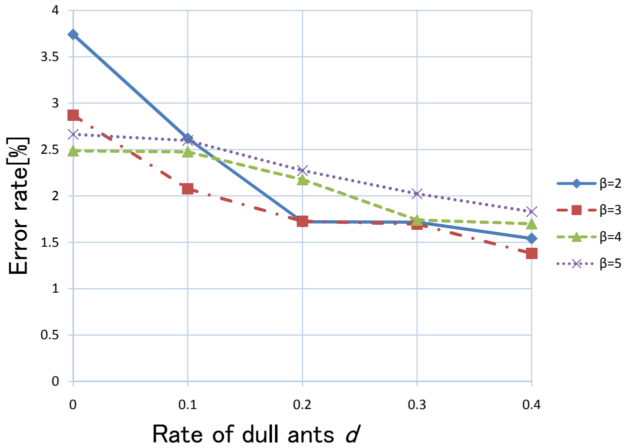


Figure 3: Results of ACO as d=0 and IDACO with varying parameter β for *bayg*29.

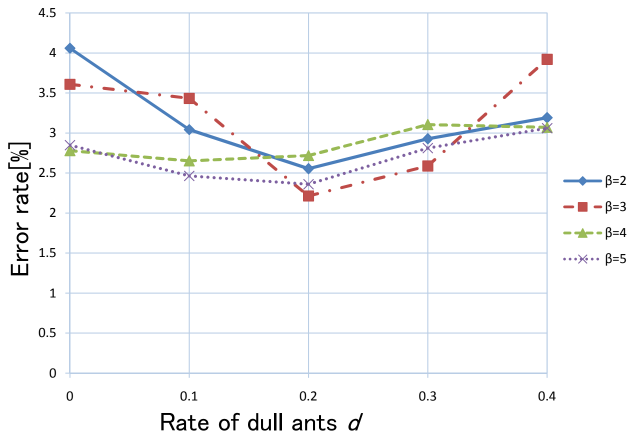


Figure 4: Results of ACO as d=0 and IDACO with varying parameter β for *att*48.

Tables 1 and 2 show the average values of the shortest tour for *bayg*29 and *att*48 in the standard ACO and IDACO with the difference rate of dull ants, respectively. The parameter β, which is related to the distance between the cities, is changed from 2 to 5. Figures 3 and 4 show the results obtained from Tables 1 and 2, respectively. The vertical axis shows the error rate and the horizontal axis shows the rate of dull ants d. IDACO with $d = 0$ is exactly the same as the standard ACO.

In Fig. 3, we can confirm that all IDACO obtain better values than the standard ACO, and IDACO including more dull ants obtains the better results. Furthermore, even if the parameter β is changed, IDACO consistently obtains better values than the standard ACO. As the results, we can say that IDACO including more dull ants obtains the effective result when the number of cities is small.

In Fig. 4, we can say that IDACO including about 20 percent of dull ants obtains the best value. Furthermore, even if the parameter β is changed, IDACO including about 20 percent of dull ants almost obtains better value than the standard ACO. As the results, when the rate of dull ants is the same as the rate of dull ants in the real ant world, IDACO obtains the effective results.

4. Conclusions

In this study, we have investigated the effect of the rate of dull ants on Ant Colony Optimization with Intelligent and Dull Ants (IDACO) and of the parameter β for various problems. We have confirmed that the obtained results depend on the rate of dull ants and the number of cities. Furthermore, even if the parameter β is changed, IDACO including about 20 percent of dull ants obtain better values than the standard ACO. In consequence, we can say that IDACO obtains the effective results, when the rate of dull ants is the same as the rate of dull ants in the real ant world.

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