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Regional Collaborative Logistics of Agricultural Products Based on Ant Colony Optimization

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ABSTRACT

This study investigates the performance of agricultural products with collaborative logistics. Based on the analysis of the characteristics of regional agricultural products logistics, a model with multi-objective is proposed to describe the problem. In order to find the optimal results of the model, the ant colony optimization algorithm is used in the study to calculate the model. A numerical experiment is presented to show the validity of the model and the algorithm. The results indicate that the performance of the agricultural products' supply chain can be improved by the model. It is suggested that the improved model is an efficient mechanism to manage the logistics of regional agricultural products.

Key words: Agricultural products supply chain, collaborative logistics, multi-objective optimization, ant colony optimization

INTRODUCTION

Logistics cost is one of the biggest cost for China agricultural products. Since, most of agricultural logistics companies have no big scale, the collaborative logistics (collaborative task allocation) shows significance on the performance of all small logistics companies in the region. This research studies the application of collaborative logistics for agricultural products. Similar problems have been studied by former researchers. A mathematic model based on scheduling strategy of mass customization logistics was designed to improve the performance of the collaborative logistics. Zhang *et al*. (2012) and Miranda *et al*. (2009) propose a collaborative e-Work based optimization approach for assisting the strategic logistic network design problem. Wang *et al*. (2011) considered that collaborative electronic logistics market places have potential for not only vertical collaboration between shippers and carriers but also horizontal collaboration between shippers and/or between carriers. Zhang and Kong (2012) studied the mixed collaborative distribution of perishable new and old electronic products under different production modes.

In this study, financial and time costs are set as the optimization objective of regional collaborative logistics. Former researchers have done significant studies on the multi-objective optimization. Tolmidis and Petrou (2013) proposed a solution to the multi-objective optimization for dynamic task allocation. Attiya and Hamam (2006) studied the problem of task allocation in heterogeneous distributed systems with the goal of maximizing the system reliability. Using activity-travel diary data collected in the South Rotterdam Region, the Netherlands, Zhang *et al*. (2005) studied the task allocation and time use model based on a multi-linear group utility function. Shuai *et al*. (2007) proposed a novel generalized particle model for the parallel optimization of the resource allocation and task assignment in a company. Hu *et al*. (2013) studied the optimization of distribution path.

In order to find the optimal task combination, ant colony optimal algorithm is used to resolve this problem. Ant colony optimization is a technique for optimization that was introduced in the early 1990's (Blum, 2005; Li *et al*., 2013) applied ant colony optimization algorithm to schedule the imaging satellite. Garcia-Martinez *et al*. (2007) used ant colony optimization algorithm to study the bi-criteria traveling sales man problem. Yu and Yang (2011) proposed an improved ant colony optimization to solve period vehicle routing problem with time windows. Yang and Zhuang (2010) presented an improved ant colony optimization algorithm for solving mobile agent routing problem. A hybrid ant colony optimization was used by Ding *et al*. (2012) to solve the vehicle routing problem with time windows. Barcos *et al*. (2010) provided a meta-heuristic algorithm (based on Ant Colony Optimization techniques) to design for less-than-truckload problems in a reasonable computational time.

Inspired by the collaborative task allocation, this study uses the collaborative logistics to improve the performance of regional agricultural products. Financial and time costs are considered as the objective function of the model. Considered the characteristics of the ant colony optimal algorithm, the algorithm is used to resolve the model of this study.

MODEL OF COLLABORATIVE LOGISTICS FOR REGIONAL LOGISTICS

Collaborative logistics for regional agricultural logistics is used to coordinate different logistics companies. The operation costs of these companies will be decreased by the complementation of their resources. The scenario of this problem can be described as following.

In the region A, there are m logistics companies working for agricultural products, the set of companies are $E = \{E_1, E_2, \ldots, E_q\}$. The action of E_i is defined as $A_{E_i} = \{A_i^1, A_i^2, \ldots, A_i^{mi}\}$. The company in E can do some actions in A according to its characteristics. The market demand is considered as several missions ($M = \{M_1, M_2, \ldots, M_k\}$). For a random mission M_i ($i \leq k$), it is consisting of many actions of N. The actions of M_i is defined as $A_{Mi} = \{A_i^1, A_i^2, \ldots, A_i^{pi}\}$, where, p_i is the count of actions of M_i. The objective of this study is to optimize the time and cost for all missions. Since, the complexity of real world, this study sets the following assumptions to define the collaborative logistics problem.

- There is no priority at the time of t = 0. This means every mission can be done by the corresponding company at the beginning
- One action only can be done by one company. The company can not interrupt the running action
- One company can not implement more than one action simultaneously. Based on the analysis, the financing cost of the problem is proposed in the Eq. 1:

$$f_1(x_{ijm}) = \sum_{i=1}^{k} \sum_{j=1}^{pi} \sum_{m=1}^{q} x_{ijm} C_{ijm} \quad (1)$$

where, $f_1(x_{ijm})$ is the financing cost of all missions. If the mission M_i's action A_i^j is done by E_i, then $x_{ijm} = 1$, $x_{ijm} = 0$ on the otherwise and C_{ijm} is the cost of E_i doing A_i^j.

In order to analyze the working time of actions, the study supposed that TT_{ij} is the time of E_i doing A_i^j, ST_{ij} and Et_{ij} is the beginning and end time of action A_i^j. The PT_{ij} is the free time of E_i doing A_i^j in A_{E_i} and w is the cost of unit time (ten thousand/hour).

Considering the sequence of all actions in mission M_i, A_i^j can be done after the finish of A_i^{j-1}. The constraint of this problem is shown in the following pseudo-code.

```
for i = 1 to k
  for j = 1 to pi
    if Ai^j is finished then
        Ai^j+1 can be implemented.
        else
        for r = j+1 to pi
        Ai^r can not be implemented.
      next
    end if
  next
next
```

Since, same actions can not be done by one company simultaneously, all actions of E_i should obey the following rules.

```
Stij = Eti, j-1
for m = 1 to q
  for s = 1 to mi
if PTms≤STij then
  Etij = STij+TTij
PTms = PTms+TTij
  else
  STij = PTms
  ETij = STij+TTij
    PTms = PTms+TTij
end if
next
  next
```

According the time rules, the time cost of the distribution is suggested in Eq. 2:

$$f_2(x_{ijm}) = w\sum_{i=1}^{k}\sum_{j=1}^{p}\sum_{m=1}^{q} x_{ijm}TT_{ijm} \tag{2}$$

Considering the time and financial costs are conflicting in the problem, the study supposes that w_1 is the weight of financial cost and w_2 is the weight of the time cost. The objective function of the collaborative distribution problem is proposed in Eq. 3:

$$\min f(x_{ijm}) = w_1\sum_{i=1}^{k}\sum_{j=1}^{p}\sum_{m=1}^{q} x_{ijm}C_{ijm} + w_2 w\sum_{i=1}^{k}\sum_{j=1}^{p}\sum_{m=1}^{q} x_{ijm}TT_{ijm} \tag{3}$$

The target of Eq. 3 is to find the optimal actions combination with minimal $f(x_{ijm})$.

Since, the model of Eq. 3 is a kind of multi-objective optimization problem, this problem is difficult to resolve with deterministic algorithms. Ant Colony Optimal (ACO) algorithm is an effective heuristic algorithm for the NP problem. The ants find food and return to their colony while laying down pheromone trials in the real world. Other ants prefer to follow the trail if they find such a path. The pheromone trail will be reinforced if they eventually find food. Since, the pheromone trail will evaporate with time, the short path retains higher pheromone than the other paths. If the pheromone doesn't evaporate at all, the first path will tend to be excessively attractive to the following ants. In that case, it is possible to converge to a locally optimal solution. The ant colony optimization algorithm is based on the simulations of these behaviors. This study uses ACO to find the optimal actions combination of Eq. 3. The algorithm process can be explained by the following.

The artificial ants are distributed to 'n' actions randomly. The costs of action ijm is $\{d_{ijm}|d_{ijm} = f(x_{ijm})\geq 0, \forall_{ijm}$. The path cost of choosing action ijm+1 after doing ijm is d_{ijm+1}. At the beginning, each ant will choose a path to the next action according to the pheromone trail. The probability of ant moving from action i to action j is:

$$p_{i,j} = (\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta}) / \sum(\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta}) \qquad (4)$$

where, $\tau_{i,j}^{\alpha}$ is the pheromone on the path between action i and action j, α is the parameter to control the influence of $\tau_{i,j}^{\alpha}$, $\eta_{i,j}^{\beta}$ is the visibility of action j from action i (typically is $1/d_j$), β is the parameter to control the influence of $\eta_{i,j}^{\beta}$.

After all ants finished their tours, the shorter trail should be leaved more pheromone than the longer trail. The update rule for the pheromone leaved in every path can be written as Eq. 5:

$$\tau_{i,j}(t+1) = \rho\tau_{i,j}(t)+\Delta\tau_{i,j} \qquad (5)$$

where, t is the simulation period, $\tau_{i,j}(t+1)$ is the amount of pheromone on the path between i and j in period of t+1, $\tau_{i,j}(t)$ is the amount of pheromone on the path between i and j in period of t, ρ is the rate of pheromone evaporation and $\Delta\tau_{i,j}$ is the amount of pheromone deposited, typically given by:

$$\Delta\tau_{i,j} = \sum_{k=1}^{l} \Delta\tau_{i,j}^{k}$$

$\Delta\tau_{i,j}^{k}$ is the amount of pheromone deposited caused by ant k. If the ant k travels on path of action i and j, $\Delta\tau_{i,j}^{k} = 1/L_k$ where L_k is the cost of the kth ant's tour between action i and j (typically is the cost between the two actions). Otherwise, $\Delta\tau_{i,j}^{k}$ is zero. After a number of iterations, the optimal combination of actions can be suggested by the artificial ants.

EXPERIMENTAL ANALYSES

The study supposed that there are eight agricultural logistics companies in a region. The working abilities of these companies are proposed in Table 1. For example, company 1 (third line of Table 1) has the abilities of doing Action 1, 2 and 3.

Table 1: Working abilities of the eight companies

	$A_{E_i} = \{A_i^1, A_i^2, \ldots, A_i^{mi}\}$						
Companies	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6	Action 7
1	√	√	√				
2	√	√	√				
3		√	√	√			√
4				√		√	
5				√	√		
6	√			√			√
7		√	√		√	√	√
8	√						

Table 2: Financial cost of the six missions (Ten thousand Yuan)

	M1				M2				M3			M4			M5			M6		
Companies	2	1	3	4	2	1	3	7	2	3	4	6	5	4	2	3	7	6	5	1
1	2	12	1	-	1	10	2	-	3	2	-	-	-	-	2	4	-	-	-	11
2	2	10	3	-	2	11	2	-	1	2	-	-	-	-	1	5	-	-	-	13
3	3	-	2	4	2	-	4	4	4	1	5	-	-	3	3	2	5	-	-	-
4	-	-	-	7	-	-	-	-	-	-	4	15	-	2	-	-	-	11	-	-
5	-	-	-	9	-	-	-	-	-	-	7	-	10	4	-	-	-	-	9	-
6	-	8	-	6	-	9	-	8	-	-	6	-	-	3	-	-	7	-	-	10
7	1	-	4	-	2	-	3	6	5	4	-	20	12	-	3	3	9	18	12	-
8	-	14	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	12

Table 3: Time cost of the six missions (Ten thousand Yuan)

	M1				M2				M3			M4			M5			M6		
Companies	2	1	3	4	2	1	3	7	2	3	4	6	5	4	2	3	7	6	5	1
1	3	4	2	-	2	4	2	-	2	1	-	-	-	-	1	2	-	-	-	4
2	3	5	2	-	1	5	1	-	2	1	-	-	-	-	2	3	-	-	-	4
3	2	-	4	3	2	-	3	2	1	3	2	-	-	2	3	4	4	-	-	-
4	-	-	-	2	-	-	-	-	-	-	2	5	-	1	-	-	-	5	-	-
5	-	-	-	2	-	-	-	-	-	-	2	-	4	2	-	-	-	-	5	-
6	-	5	-	3	-	6	-	1	-	-	3	-	-	3	-	-	3	-	-	5
7	2	-	3	-	3	-	2	3	4	2	-	4	4	-	4	3	2	4	4	-
8	-	3	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	6

The study suggests that six missions (M1, M2, M3, M4, M5, M6) need to be finished by these companies. The requirements of these missions are defined as A_{M1} = {Action 2, Action 1, Action 3, Action 4}, A_{M2} = {Action 2, Action 1, Action 3, Action 7}, A_{M3} = {Action 2, Action 3, Action 4}, A_{M4} = {Action 6, Action 5, Action 4}, A_{M5} = {Action 2, Action 3, Action 7}, A_{M6} = {Action 6, Action 5, Action 1}. The time and financial cost of doing these actions for the eight companies are proposed in Table 2 and 3. The second line in Table 2 and 3 is the actions of the mission in the first line.

The study uses VB6.0 to code the ACO algorithm and runs the program on the platform of WinXP. The optimal result of the problem is in Fig. 1 with Gantt chat.

Figure 1 shows that the four actions of M1 are implemented by companies coded with 7, 6, 1 and 3. The M2 is implemented by companies coded with 2, 1, 2 and 3. The implement of M3, M4,

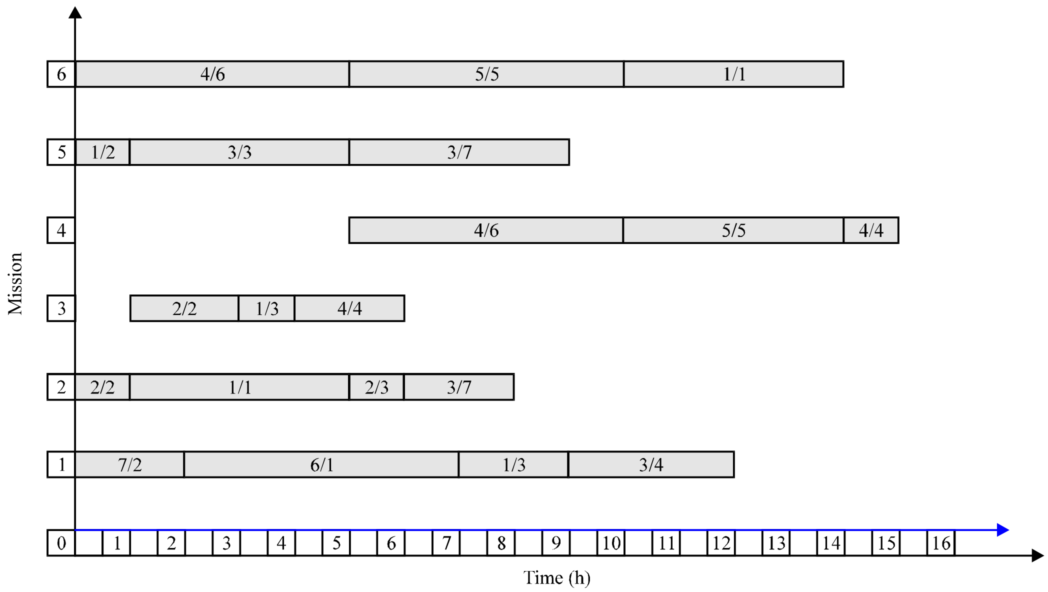

Fig. 1: Optimal combination of actions

M5 and M6 is illustrated in Fig. 1. The time of doing these actions is 15 h. The cost of doing these actions is 1060 hundred. This is the optimal resolution for this collaborative logistics problem proposed by ACO.

CONCLUSION

The study analyzed characteristics of regional agricultural logistics. The collaborative logistic is used to improve the performance of all logistics companies in the region. Based on the analysis of the time constraint, the time and financial costs are considered as the objective function of the proposed model. The weight of time and financial cost can be adjusted by the user of the model. Ant colony optimal algorithm is used to find the optimal result of the model. The results show that all actions can be coordinated under the constraints with minimal time and financial costs.

The study presented here can be extended along several directions. For example, the model can be used in more complex regions. More actions can be forged in the collaborative model. Such extensions may be able to provide better conclusions to improve the agricultural products supply chains.

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REFERENCES

Attiya, G. and Y. Hamam, 2006. Task allocation for maximizing reliability of distributed systems: A simulated annealing approach. J. Parallel Distrib. Comput., 66: 1259-1266.

Barcos, L., V. Rodriguez, M.J. Alvarez and F. Robuste, 2010. Routing design for less-than-truckload motor carriers using Ant Colony Optimization. Transp. Res. Part E: Logist. Transp. Rev., 46: 367-383.

Blum, C., 2005. Ant colony optimization: Introduction and recent trends. Phys. Life Rev. J., 2: 353-373.

Ding, Q., X. Hu, L. Sun and Y. Wang, 2012. An improved ant colony optimization and its application to vehicle routing problem with time windows. Neurocomputing, 98: 101-107.

Garcia-Martinez, C., O. Cordon and F. Herrera, 2007. A taxonomy and an empirical analysis of multiple objective ant colony optimization algorithms for the bi-criteria TSP. Eur. J. Oper. Res., 180: 116-148.

Hu, K., D. Liu and X. Yu, 2013. An improved FCM algorithm with application in path optimization. J. Comput. Inform. Syst., 9: 6719-6726.

Li, Y., R. Wang and M. Xu, 2013. Scheduling and rescheduling of imaging satellite based on ant colony optimization. J. Comput. Inform. Syst., 9: 6503-6510.

Miranda, P.A., R.A. Garridob and J.A. Ceronic, 2009. e-Work based collaborative optimization approach for strategic logistic network design problem. Comput. Ind. Eng., 57: 3-131.

Shuai, D., Q. Shuai and Y. Dong, 2007. Particle model to optimize resource allocation and task assignment. Inform. Syst., 32: 987-995.

Tolmidis, A.T. and L. Petrou, 2013. Multi-objective optimization for dynamic task allocation in a multi-robot system. Eng. Appl. Artif. Intell., 26: 1458-1468.

Wang, Y., A. Potter, M. Naim and D. Beevor, 2011. A case study exploring drivers and implications of collaborative electronic logistics marketplaces. Ind. Marketing Manage., 40: 612-623.

Yang, J. and Y. Zhuang, 2010. An improved ant colony optimization algorithm for solving a complex combinatorial optimization problem. Applied Soft Comput. J., 10: 653-660.

Yu, B. and Z.Z. Yang, 2011. An ant colony optimization model: The period vehicle routing problem with time windows. Transp. Res. Part E: Logist. Transp. Rev., 47: 166-181.

Zhang, J., H.J.P. Timmermans and A. Borgers, 2005. A model of household task allocation and time use. Transp. Res. Part B: Methodol., 39: 81-95.

Zhang, L. and Y. Kong, 2012. Optimization of mixed collaborative distribution with different production modes. J. Transp. Syst. Eng. Inform. Technol., 12: 17-23.

Zhang, M.H., X.L. Gao, X.Y. Zhou and J. Yang, 2012. An intelligent scheduling strategy of collaborative logistics for mass customization. Procedia Eng., 29: 2621-2626.