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Particle Swarm Optimization: Optimizing Transportation Cost Problem

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Abstract
Transportation is literally defined as an act, process or instance of transporting or being transported. Many business organizations are relying on transportation in running their business. In these years, the transportation cost has increase from time to time and become a problem to the organization to maintain the cost and profit. To overcome this problem, the optimization of cost is applied in order to make sure the business is in the right financial condition by finding the minimum cost of transporting a single commodity from a given number of sources to a given number of destinations. In this study the modified Particle Swarm Optimization is used to solve the Transportation Cost Problem (TCP) in finding the optimal solution of the amount of product transported with the minimum cost. The model of nonlinear cost function had been used throughout this study. As a result, the minimum cost of transportation is 340.69 with the amount of product transported 17, 15, 32, 16, and 20 following the arc A(x)={(1,5), (2,4), (2,6), (3,4), (3,5)} respectively.

Keywords: *Transportation Cost Problem, Particle Swarm Optimization, Optimization.*

Introduction
In this era of ever-increasing competitive market, the companies of businesses become highly competitive to produce high level of service at the lowest possible cost. A stable operational cost need to be maintained by the organization to survive in the market for a long term. Operational cost is aimed on monitoring some important parts in the organization. It is importance in minimizing the cost, stabilize the company performance, achieve company's objectives and maintain company's revenue. The cost minimization is often applied by an organization as a cost stabilization approach. Cost optimization is about to find the most effective cost or high achievable performance under the given constraints, by increasing desired factors and decreasing undesired ones (Free Dictionary).

The optimization of cost should be applied in any business in order to make sure the business is in a right financial condition. Recently, the transportation cost is a crucial problem. Transportation cost includes the expenses involved in moving product or assets to different places which are often passed on consumer (Business Dictionary). Based on the article in SinarHarian online which was published on 4 September 2013 by WartawanSinarHarian, it stated that, the charge of transportation will increase by 4 to 5 percent due to the increasing in petrol charge.

Nowadays, the global market competition among business is unpredictable and to achieve the business goals, it requires high involvement in transportation. The transportation cost must be at the lowest state so that the business can get more benefit. The objective of this study is to obtain the optimal solution of the amount of product transported of the nonlinear cost function by using Particle Swarm Optimization (PSO).

The research is a continuance from the previous study on a genetic ant colony approach for concave cost transportation problem carried out by Altiparmak and Karaoglan in 2007. This study will use the model proposed by them and will be implemented using PSO method. The model introduced transportation model which consist of three constraints which are the nonlinear cost function, the capacity constraint and the guarantees of all demands are met. The model is based on the transportation cost problem with three demand nodes, three supply nodes and five routes, A(x) which are A(x)={(1,5), (2,4), (2,6), (3,4), (3,5)}.

Related Work in Minimizing Transportation Cost

The problem of transportation cost problem is crucial over century. Previous study showed that the cost problem is a large scale problems and time consuming (Altiparmak and Karaoglan, 2007).The study implemented the Ant Colony (AC) and Genetic Algorithm (GA) method to solve the Concave Cost Transportation Problem (CCTP). They introduced a new algorithm with the combination of hybrid GA and AC which is h_GACO. The effectiveness of the h_GACO is then compared using five different approaches. The result showed that h_GACO performs a good approach with respect to the solution quality and suggested the ACO can be used in other optimization that deals with problems of scheduling, vehicle routing and others. The combination of PSO and GA is implemented in the next study on minimizing an adapted vendor managed inventory and transport problem with fuzzy demand (Sadeghi et al., 2014).

This study is carried out to find the optimal retailer's order quantities so that the inventory and transportation cost can be decreased while satisfying several constraints. Because of the NP-hardness of the problem, an algorithm based on Particle Swarm Optimization (PSO) is proposed to find a near optimum solution, where the centroid defuzzification method is employed for defuzzification. Since there is no benchmark available in the literature, another meta-heuristic, namely genetic algorithm (GA), is presented in order to verify the solution obtained by PSO. Besides, to make PSO faster in finding a solution, it is improved by a local search. The parameters of both algorithms are standardized using the Taguchi method to have better quality solutions.

Particle Swarm Optimization (PSO)

Previous studies have used and implemented PSO extensively especially in solving optimization problem and is also proven to be very effective in solving Vehicle Routing Problem (VRP) in terms of finding the most suitable optimum cost ((Xuedan& Wang, 2009 and Chun, 2007).They also said that PSO is a well-known method due to its simplicity and effectiveness in wide range of application with low in computational cost. In general, PSO is defined as an optimization method imitating from social behavior of bird flocking and fish schooling (Hu &Eberhart, 2002).This method was adopted to a group of birds aimlessly looking for food in an area but they do not know how far the food is in each iteration (Kulkarni et al., 2015). Therefore, the effective way is to follow the bird which is nearest to the food. PSO was rooted from that scenario and used it to describe the optimization problems.

Some studies also focused on Vehicle Routing Problems (VRP) where the objective is to find the most suitable path to cut cost and save time. The problem of transportation routing and time give important impact on the controlling of inventory costs, transportation costs and economic efficiency (Xuedan& Wang, 2009). The study focused on solving the problem faced by dispatching vehicle with regards that each customer is served exactly once in each delivery in a fixed route and the total demand of all customers must not exceed the capacity of the delivery vehicle.

This study used the improved discrete PSO algorithm with mutation operation (in which all the particles are reinitialized when the swarm is decayed). The result is then compares from the improved discrete algorithm and concluded that modified discrete PSO is an efficient method to solve the discrete combination optimization such as VRP. In other study, the VRP is solved using predicting PSO with Time Windows (TW) (Chun, 2007). In this paper, the predicting PSO algorithm which modified by three new solution strategies has been proposed to adjust the continuous properties of basics PSO to be more suitable to be applied in Vehicle Routing Problem with Time Windows (VRPTW) presentations. The findings illustrate that the suggested algorithm achieve other experimental algorithm and the predicting PSO algorithm not only can adjust the variance between current status and memorial best status, but also can forecast the best position at the next status based on memory.

In conclusion, there has been extensive research on the TCP which is mostly carried out to achieve the same objective which is to find optimal solution or minimize the cost or routes. Mostly, the method used to solve the TCP and VRP is Ant Colony (AC), Genetic Algorithm (GA) and several combination of PSO with other method to solve the problems and the result obtained is optimized and suitable for the problems.

Research Methodology

The model of concave cost transportation problem which originally proposed by Altiparmak and Karaogalan in 2007 is represented as follows:

Minimize $$f(x)=\sum_{i=1}^{m}\sum_{i=1}^{n}c_{ij}\sqrt{x_{ij}} \tag{3.1}$$

Subject to: $$\sum_{i=0}^{n}x_{ij}<a_i, \qquad \forall i\in N, \tag{3.2}$$

$$\sum_{i=0}^{m}x_{ij}\geq b_j, \qquad \forall j\in M, \tag{3.3}$$

$$x_{ij}\geq 0, \text{ integer}, \qquad (i,j)\in A, \tag{3.4}$$

where,

A : Set of all arcs,
M : Set of all demand nodes (customers, warehouse, etc),
N : Set of all supply nodes (facilities distribution, centers, etc),
a_{ij} : The capacity of suppliers $i, i\in N$,
b_j : The demand of the customer $j, j\in M$,
x_{ij} : The amount of product transported (i.e flow),
c_{ij} : The per unit variable cost corresponding to (i,j).

The cost function in Eq. (3.1) is considered as nonlinear cost function. The amount of the product to be transported from supply node, i to each demand node, j must be determined so that all constraints is satisfied and the transportation cost can be minimized.

PSO Algorithm

The PSO algorithm begins by generating the initial particles, and allocating each of initial velocity. Since in this study is using CNOP, there are some modifications in PSO's original algorithm which involve the process of initialization and computation of *pbest* and *gbest* (Hu &Eberhart, 2002). For the process of initialization, all particles are constantly adjusted until they fulfill all constraints while when computing the *pbest* and *gbest* values, only those conditions in feasible space are calculated.

The Modified PSO Algorithm

Six steps on performing the modified PSO algorithm are defined as follows:

Step 1 : Initialize the particle.
The particle and velocity initialization is usually performed randomly in space and the initial velocities are often distributed randomly (Ho et. al, 2008).

Step 2 : Evaluating the initial particle to get personal best and global best.
For each particle, the initialized positions are set as their personal best positions $P_i = [p_{i1}, p_{i2}, ..., p_{iN}]^T$, where $i = 1, ..., m$. Then, all particles should be evaluated according to the project duration using the proposed serial scheme to determine the global best, *gBest*.

Step 3 : Velocity updating.
Based on the previous velocities and the distances of the current positions from personal best and global best, all particles' new velocities are calculated using Eq. (3.5) below.

$$v_i(t+1) = wv_i(t) + c_1 r_1[\hat{x}_i(t) - x_i(t)] + c_2 r_2[g(t) - x_i(t)] \quad (3.5)$$

where,

i	:	the particle index,
$v_i(t)$	:	the particle's velocity at time *t*,
$v_i(t+1)$	:	the velocity of particle *i* at iteration *t+1* (new particle velocity),
$x_i(t)$	:	the current particles (solution),
r_1 and r_2	:	random number within the range [0,1],
w	:	the inertial coefficient,
c_1 and c_2	:	acceleration coefficient,
$\hat{x}_i(t)$	:	the particle's individual best solution at time *t*, *pBest*,
$g(t)$	:	the swarm's best solution at time *t* or *gBest.*

The value of inertial coefficient is between 0.8 and 1.2 while the value of acceleration coefficient is a random number uniformly distributed within the range [0,2].

Step 4 : Particle updating.
Based on the updated velocity, the new position is calculated according to Eq. (3.6).

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad (3.6)$$

Step 5 : *pBest* and *gBest*updating.
Each updated particle is transformed to the schedule using the revised serial scheme based on the current position. The new *pBest* and *gBest* are determined.

Step 6 : Stopping criteria.
The particle will terminate if it meet the maximum iteration. If the current iteration does not meet the termination signal, then it will repeat step 3.

Results and Discussions

Data Analysis

The data gained by generating the initial population of the model after determine the initial transportation tree by a Heuristic Approach based on the characteristics of concave cost network flow problems (Altiparmak and Karaoglan, 2007). Fig. 1 will illustrate the initial transportation tree.

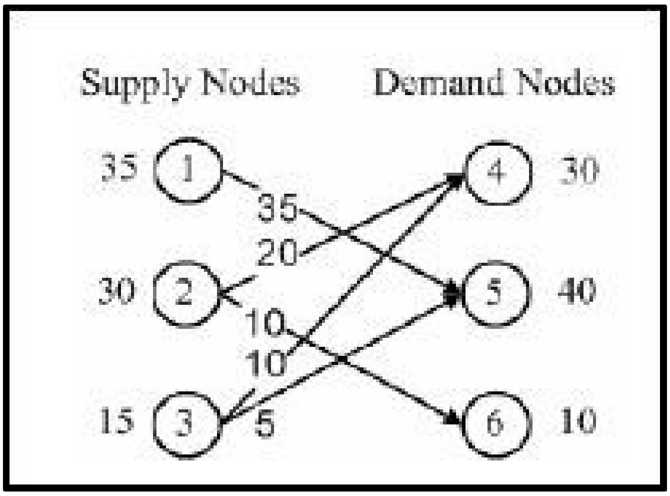

Figure 1: Transportation Tree (Basic Solution)
(Source: Altiparmak and Karaoglan, 2007)

Table 1: Data of Transportation Tree

Arc, A(x)	Source	Destination	Cost, (c_{ij})	Supply, (α_j)	Demand, (b_j)
p	1	5	35	35	40
q	2	4	20	30	30
r	2	6	10	30	10
s	3	4	10	15	30
t	3	5	5	15	40

Table 1 shows three demand nodes (1,2,3) and three supply nodes (4,5,6) involved. The total arc is five which are p, q, r, s, t and the set of arcs in the transportation tree is $A(x) = \{(1,5),(2,4),(2,6),(3,4),(3,5)\}$. Using the above data, all the values will be substituted into the model to check if the constraints are satisfied or not. The constraints is checked as stated in Eq. (3.2), (3.3) and (3.4) and assumed to be true.

The method of modified PSO is implemented in this study. In this study, the maximum iteration is set as 1000 iterations. The value of the particle will iterate 1000 times and the best value (minimum value) in all iterations will be assigned as *gBest*.

Optimizing Transportation Cost Problem using Modified PSO Algorithm

After running the algorithm, the result obtained is approximately lower than the actual cost. Table 2 shows the optimal solution of supply in order to have a minimum cost in TCP.

Table 2: The Optimal Solution of TCP

Arc,A(x)	Source	Destination	**New supply**	**New cost**
p	1	5	**17**	144.31
q	2	4	**15**	77.46
r	2	6	**32**	56.57
s	3	4	**16**	40.00
t	3	5	**20**	22.36
			Total cost	**340.69**

Based on the result in Table 2, the new supply from the arc *p, q* and *r* is 17, 15 and 32 respectively. While for the arc *s* and *t*, the new supply after optimized is 16 and 20. With these optimal values, the new TCP is 340.69 which is lower than the actual cost, 429.47.

Conclusions

This study is useful to find the optimal solution for the amount of product transported and minimum cost of the problem. The result shows that the optimal solution for the amount of product transported from source to the desired destination is optimized where the new value is 17, 15, 32, 16 and 20 following the arc, A(x)={(1,5), (2,4), (2,6), (3,4), (3,5)} respectively with the total cost of 340.69.

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