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A Heuristic with Multiple Search Strategies to Solve Profit Maximization Solid Transportation Problem

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Abstract: *Solid Transportation Problem is formulated as a profit maximization problem under a budget constraint and fixed charge at each destination. The items are transported to different destinations from different origins using different vehicles. It is assumed that transported units are integer multiple of packets. Selling prices and purchase costs are different at different destinations and origins respectively. So the problem is formulated as constraint optimization integer programming problem. To solve the problem a sequence of different cell of transportation problem is taken as a coded solution of the problem and from this coded solution actual allocation is made by a proposed rule. At first a set of coded solutions are randomly generated. Then to improve the coded solutions different update rules are used. A counter variable for each rule is used to count the number of use of these rules which improves any solution. The initial values of the counters are set to one. Another counter variable for each solution is used to count the number of consecutive failure of the improvement using any rule. When this counter value exceeds one predefined fixed value then the solution is replaced by a randomly generated new solution in the search space. Here update rule is selected based on the roulette-wheel selection mechanism. And all update rules are based on swap operations and swap sequence. The ratio of selection of update rules which update the solution are also find in this study to analysis update rules.*

Keywords: *Solid Transportation Problem, Variable Search Strategy, Swap Operator, Swap Sequence.*

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I. Introduction

In transportation problem (TP) a commodity is transported from origin to destination with minimum cost. So, here two constraints origins and destinations are considered. But in solid transportation problem (STP) another constraint, modes of transportation (vehicles) are also considered. So in STP there are three constraints (origins, destinations and vehicles). When fixed charge is considered against units of transportation from source to destination then the problem is called fixed charge transportation problem (FCTP). There are different heuristic for solving optimization problem such as genetic algorithm (GA) [1], artificial bee colony (ABC) [2], Particle swarm optimization (PSO) [3]. Transportation problems (TP) and solid transportation problem (STP) are formulated generally as cost minimization problems. But here the problem is formulated as profit maximization fixed charge solid transportation problem (FCSTP) under destination budget constraints [4].

In the proposed method it is assumed that transported units are integer multiple of packets. Selling prices and purchase costs are different at different destinations and origins respectively. So it is formulated as constraint optimization integer programming problem [4]. This problem is solved by using multiple search strategy based on swap sequence [2,4]. A swap sequence is made with one or more swap operators where swap operator is the exchange of cells in a sequence. Different swap sequences acting on the same solution may produce the same new solution. These all swap sequences that produce same solutions are called the equivalent set of swap sequences. The sequence which has the least swap operator in the equivalent set is called basic swap sequence (BSS).

II. Assumptions And Notations

For this unbalanced fixed charge solid transportation problem under destination budget constraints, the following notations are used.

M: number of origins of the FCSTP.
N: number of destinations of the FCSTP.
K: number of vehicles transporting units from sources to destinations.

A_i: numbers of packets of item available at i-th origin.
B_j: demand at the j-th destination.
E_k: number of packets which can be carried by k-th vehicle.
C_{ij} : per packet transportation cost from i-th origin to j-th destination by k-th vehicle.
f_{ijk}: fixed transportation charge for transporting per packet from i-th origin to j-th destination by k-th vehicle.
S_j: selling price per packet at j-th destination point.
P_i: purchasing cost per packet at i-th origin.
x_{ijk}: numbers of packets of item transported from i-th origin to j-th destination by k-th vehicle.
B_{udj}: total budget at the j-th destination point.

As fixed charge is considered in this model so we introduce the following notation

$$y_{ijk} = \begin{cases} 1 & \text{for } x_{ijk} > 0 \\ 0 & \text{otherwise} \end{cases}$$

III. Mathematical Model Formulation

The mathematical model takes the following form as in [4]:

$$\text{Max } z = \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\{S_j - P_i - C_{ijk}\}x_{ijk} - \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K} f_{ijk}\, y_{ijk}$$

$$\text{Subject to} \quad \sum_{j=1}^{N}\sum_{k=1}^{K} x_{ijk} \le A_i \qquad i = 1,2,\ldots\ldots\ldots\ldots\ldots M$$

$$\sum_{i=1}^{M}\sum_{k=1}^{K} x_{ijk} \ge B_j \qquad j = 1,2,\ldots\ldots\ldots\ldots\ldots N$$

$$\sum_{i=1}^{M}\sum_{j=1}^{N} x_{ijk} \le E_k \qquad k = 1,2,\ldots\ldots\ldots\ldots K$$

$$\sum_{i=1}^{M}\sum_{k=1}^{K}\left(x_{ijk} P_i + C_{ijk}x_{ijk} + f_{ijk}y_{ijk}\right) \le Bud_j \qquad j = 1,2,\ldots\ldots\ldots N$$

$$x_{ijk} = 0 \text{ or } + \text{ve intege} \qquad ((i,j,k) = 1,2,\ldots\ldots\ldots(M,N,K))$$

IV. Procedure For Proposed Model

A MNK dimensional integer vector T= (t_1, t_2, ..., t_{MNK}) is used to represent a coded solution X, where t_j ε {1, 2, ..., MNK} and $t_j \neq t_k$ for any $j \neq k$, j, k = 1, 2, ... , MNK. So, the sequence (t_1, t_2, ..., t_{MNK}) is a rearrangement of {1, 2, ..., MNK}. From coded solution the actual solution is generated using the following formula [4].

$$j = \begin{cases} N & \text{if} \quad N|t_n \\ (t_n) \bmod N & \text{otherwise} \end{cases}$$

$$i = \begin{cases} M & \text{if } MN|t_n \\ \left(\dfrac{(t_n) \bmod MN - j}{N}\right) + 1 & \text{otherwise} \end{cases}$$

$$k = \frac{t_n - (i-1)N - j}{MN} + 1$$

i.e. i ,j, k suffixes of x_{ijk} corresponding to t_n are calculated by this formula.
To solve efficiently with minimum iteration and to improve the solution following different update rules are used.

$$V_i = V_i \oplus r_1 \odot \left(T_{pbest} - T_i\right) \oplus r_2 \odot \left(T_{best} - T_i\right)$$

$$T_i = T_i + V_i \qquad \text{--------------} \qquad (1)$$

$$V_i = r_1 \odot (T_i - T_k)$$
$$T_i = T_i + V_i \qquad \text{-----------} \qquad (2)$$

$$V_i = r_1 \odot (T_r - T_k)$$
$$T_i = T_r + V_i \qquad \text{------------} \qquad (3)$$

$$V_i = r_1 \odot (T_i - T_k)$$
$$T_i = T_r + V_i \qquad \text{------------} \qquad (4)$$

$$V_i = r_1 \odot (T_k - T_r)$$
$$T_i = T_{best} + V_i \qquad \text{-------------} \qquad (5)$$

(1) is same as update rule of swarm sequence based particle swarm optimization (SSPSO) for STP [4] others are based on [2]. Here r_1, r_2 are random numbers between 0 and 1. V_i represent a swap sequence. T_i is sequence of cells of i-th solution X_i. k ,i and r are not equal to each other. The position at which the best fitness by a solution is pbest and the best position of all solutions in current generation is gbest. $r_1 \odot (T_{pbest} - T_i)$ means all swap operators in basic swap sequence $(T_{pbest} - T_i)$ should be maintained with the probability of r_1. $r_2 \odot (T_{gbest} - T_i)$ is same as $r_1 \odot (T_{gbest} - T_i)$. The operator $\oplus$ is defined as merging of two swap sequences into one a new swap sequence.

V. Algorithm

1. Initialize parameters counter1, counter2, maxgen, t=0.
2. Randomly generate initial coded solutions.
3. Generate coded solution to actual solution using given formula.
4. Select update rule using roulette-wheel selection mechanism.
5. Update solution using update rule

a If solution is better counter1 will be increased.

b. Otherwise counter2 will be increased. If counter2 exceed a predefined number then a new solution will be randomly generated.

6. Determine best solution and its profit.
7. If t < maxgen goto step-5.
8. Output best solution.
9. End algorithm

VI. Numerical Experiment

The model is applied on problem [4]. No. of origins (M) = 2, No. of destination (N) = 2 and No. of vehicles (K) = 2.

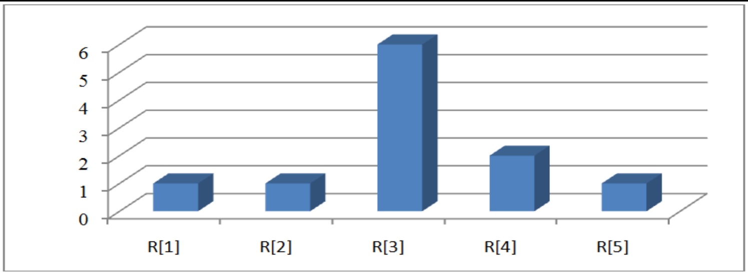
	k	1		2	
	i/j	1	2	1	2
c_{ijk}	1	3	6	2	5
	2	5	10	4	9
f_{ijk}	1	10	9	8	7
	2	11	12	9	10

Unit Transportation Cost and Fixed Charge

Parametric Values for Model

Optimum Result: Maximum Profit Z = 528

Source (A_1,A_2)	Demand (B_1,B_2)	Capacities of conv. (E_1,E_2)	Unit Selling Price (S_1,S_2)	Unit Purchasing Cost (P_1,P_2)	Budget Bud_1,Bud_2
(25,24)	(14,21)	(25,22)	(25,22)	(7,5)	(230,288)



Ratio of using update rule

From this ratio of selection of update rules one can understand the importance of every update rules for that particular problem. Here R[i] (i=1,2, - -, 5) represents i-th update rule.

VII. Conclusion

This solution technique can be applied in other areas such as inventory control, management, etc. under destination budget constraints. The technique of formulating STP problem as a maximization problem can be extended to other types of transportation models.

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