Advances in Mathematics: Scientific Journal **9** (2020), no.6, 3887–3893
ISSN: 1857-8365 (printed); 1857-8438 (electronic)
https://doi.org/10.37418/amsj.9.6.68 Spec Issiue on ICAML-2020

SOLVING BULK TRANSPORTATION PROBLEM USING A POSITION BASED GENETIC ALGORITHM

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ABSTRACT. Genetic Algorithm (GA) is a well known meta-heuristic algorithm, generally, applied to solve many combinatorial optimization problems. It is based on the evolution theory and 'evolves' through search space towards the optimal solution. In this paper, GA is modified to incorporate a position-based encoding/decoding technique to solve the bulk transportation problem. The proposed algorithm also maintains the condition of bulk purchase of the product from a single source. The obtained results have proved the efficiency of proposed GA and validated by some statistical measures.

1. INTRODUCTION

Being an important class of logistics system, transportation problem (TP) is used to determine an optimal shipping pattern satisfying certain supply and demand constraints with minimizing cost objective. Since its inception by Hitchcock, [5] and Koopmans, [6], different variants of the TP has been discussed and dealt with different solution procedures.

One of the variants of TP is the bulk transportation problem (BTP) whereby each destination is restricted to satisfy its demand from single source only with an aim to minimize the transportation cost. This problem is considered in regard of resource allocation in the areas of production planning, scheduling and facility location.

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2010 *Mathematics Subject Classification.* 68T20, 90B06.
Key words and phrases. bulk transportation, genetic algorithms, logistic system.

The mathematical formulation of the problem, C as the total cost, is as follows:

$$\begin{aligned} \text{Minimize } C &= \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \\ \text{subject to } \sum_{j=1}^{n} b_j x_{ij} &\leq a_i \qquad (i = 1, 2, \cdots, m) \\ \sum_{i=1}^{m} x_{ij} &= 1 \qquad (j = 1, 2, \cdots, n) \\ x_{ij} &= 0 \text{ or } 1 \qquad (i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, n) \end{aligned}$$

where a_i is availability at m sources and b_j is demand of n destinations. And c_{ij} be the unit cost of goods being transported from source i to destination j and x_{ij} be the decision variables indicating weather an allocation at (i, j) has been made or not by assuming the value 0 or 1.

As part of existing literature different solutions procedures, range from exact to heuristics, have been discussed in [1, 4, 8–12, 14]. Although effective but are computationally expensive. So, alternatively, various evolutionary techniques have been applied in [2, 3, 7, 13, 15].

So in this motivation, a position based representation is introduced to encode/decode a chromosome of Genetic Algorithm (GA) while solving the bulk transportation problem (BTP). This position based representation is simple and easy to implement as well as suitable to facilitate the encoding/decoding of a chromosome in GA. The primary objective of this paper is to introduce an alternate efficient method to solve the bulk transportation problem as well as conform the logistic decisions of industry.

2. Proposed GA for Bulk Transportation Problem

Genetic algorithm (GA) is a well-known meta heuristic inspired by evolutionary biology and has an adaptive capability to deal with complex optimization problems. In GA, the evolution usually starts by a population of randomly generated individuals and iterated sequentially through steps like the fitness evaluation (of objective function), the modification (crossover, mutation) and selection for new generation leading towards the optimal solution.

The proposed algorithm has five modules which are implemented within the procedure of basic GA. In the first module (Algorithm 1), the population is initialized randomly as per conditions of the BTP. In the second module a position based encoding technique is implemented to covert the matrix into chromosome, as given in Algorithm 2. The crossover operator is used to exchange the genes of chromosomes among generations of GA and to explore new solution space. The proposed method use the position based crossover operator as given in [16], and mutation is done as given in [7]. Then the Algorithm 3 is used to decode the chromosomes back into a matrix form. And an additional module to deal with the infeasible solutions is given in Algorithm 4.

Algorithm 1: Initial Basic Feasible Solution Procedure

Input: TMTP TP, Supply S_i and Demand matrix D_j

Output: IBFS X

Initialize a solution matrix X as $X = zeros(m, n)$ where $[m, n] = size(TP)$

Set RX as a random elements matrix of size $m \times n$

for $itr = 1$ **to** mn **do**

    Do allocation in X as follows

    Choose position (i, j) of maximum element in RX

    if $d(j) <= s(i)$ **then**

        $X(i, j) = d(j)$

        $s(i) = s(i) - d(j)$

        $d(j) = 0$, $RX(i, j) = 0$

return X

Algorithm 2: Encoding Procedure

Input: Initial solution X

Output: Chromosome Ch

Set $[m, n] = size(X)$ and $a = Supply$ and $b = Demand$

Set RX as a random elements matrix of size $m \times n$

Initialize the chromosome vector Ch as $Ch = zeros(1, m * n)$

Scan X from position $(1, 1)$ to (m, n) and identify the location of non-zero elements of X

Set these locations to chromosome Ch from first to onward positions

Similarly, again scan X from position $(1, 1)$ to (m, n) and identify the location of zero elements of X

Set these locations to chromosome Ch at the vacant to onward positions

return Ch

Algorithm 3: Decoding Procedure

Input: Cost Matrix $tp_{i,j}$, Supply s_i, Demand d_j, Chromosome vector Ch and $crosscount$
Output: Decoded matrix mat

Set length as $len = length(Ch)$ and Set $[m, n] = size(tp)$
Initialize mat as null vector: $mat = zeros(m, n)$
for $p = 1$ **to** $(m * n) - crosscount$ **do**
    $i = floor((sol(p) - 1)/n) + 1$ and $j = mod(sol(p), n)$
    $smin = min(s(i), d(j))$
    if $smin > 0$ **then**
        if $d(j) <= s(i)$ **then**
            $mat(i, j) = d(j)$ and $s(i) = s(i) - d(j)$, $d(j) = 0$
Insert the crossed cells into the matrix mat
return mat

Algorithm 4: Repair In-feasible Solution

Input: Solution Matrix $sol\_mat_{i,j}$, Supply s_i, Demand d_j
Output: Repaired matrix mat

Take matrix mat as null vector of size $m \times n$
Set a temporary matrix $temp\_mat$ as: $temp\_mat = sol\_mat$
Do allocations in mat and modify the supply s_i, Demand d_j as follows:
for $j = jj$ **to** n **do**
    for $i = 1$ **to** m **do**
        if $isnan(mat(i, j)) == 0$ **then**
            if $d(j) <= s(i)$ **then**
                $mat(i, j) = d(j)$, $s(i) = s(i) - d(j)$ and $d(j) = 0$
return mat

3. Results and Discussion

To validate the proposed GA, an experimental design containing 12 test problems of different sizes was developed. The problems, for sake of convenience, were denoted as P1, P2, P3, $\cdots$, P12. Data for these test problems were generated in Matlab using $randi()$ with range given in Table **1**.

TABLE 1. Data range for Test Problems

Variable	Range	Description
c_{ij}	$1 \le c_{ij} \le 100$	Cost
S_i	$10 \le S_i \le 40$	Supply (Availability)
D_j	$10 \le D_j \le 30$	Demand (Requirement)
where $i = 1, 2, \cdots, m$	$j = 1, 2, \cdots, n$	for m sources and n destinations.

A total of 10 runs, each containing 100 iterations and population size of 10, are conducted to get the global best value for each test problem. The obtained solutions are given in Table 2 along with the statistical measures such average (avg), standard deviation (std) and minimum iterations (min_itrs) to converge global best solution.

TABLE 2. Obtained results by using proposed GA for each test problem

Problems	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**
Dimension	3*4	4*5	5*6	6*10	10*20	20*30	30*40	40*50	50*100	100*100	100*200	200*200
initial_best	67	97	108	167	379	620	830	1043	2039	2378	4274	4644
global_best	**64**	**80**	**74**	**143**	**326**	**560**	**795**	**1000**	**1955**	**2237**	**4271**	**4611**
avg	64.05	83.79	80.89	151.66	326.86	584.12	796.40	1009.92	1960.49	2253.92	4271.66	4621.56
std	0.36	3.85	5.68	11.32	6.02	25.54	6.89	6.63	20.44	46.05	1.25	15.47
min_itrs	3	28	71	62	5	52	5	75	8	12	22	32

The solution quality of proposed method is measured by the Relative Percentage Deviation (RPD) ($RPD = \left(\frac{solution - optimal\ solution}{optimal\ solution}\right) * 100$). The plot given in Figure **1** indicates the competency of the proposed algorithm.

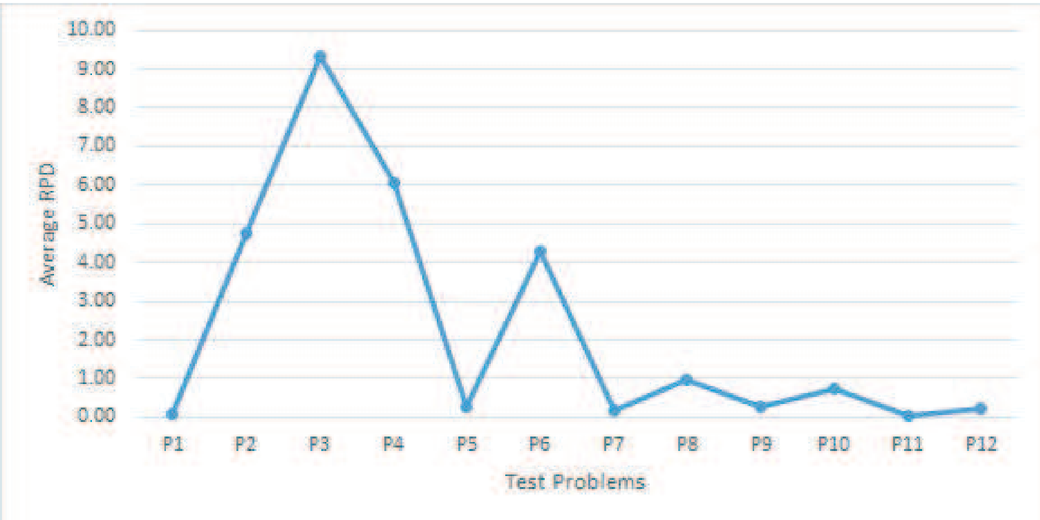

FIGURE 1. plot of average RPD for each test problem

4. CONCLUSION

Genetic Algorithm has wide range of applicability to deal with a complex optimization problem. In this paper, a position based encoding/decoding representation has been introduced and incorporated with the basic GA to solve the bulk transportation problem (BTP). These simulation results, obtained from the test problems, have revealed the efficiency as well as effectiveness of the proposed GA. Hence the procedure of this paper can be extended to other types of transportation problems with single or multi-objective goals.

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