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A Genetic Algorithm Based Approach to Solve Transport Problems for School Buses

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Abstract: Transport service problem consist of multiple paths to some destination among which only one path works best on basis of certain constraints such as time, distance, etc. These constraints give different measures for optimal path to be selected. A Genetic Algorithm (GA) performs natural selection. GA belongs to the class of evolutionary algorithms known to give better results. In urban areas most of the schools with more than 50 school buses running around the large cities to pick-up students from different destinations driving towards school. Any student after being picked in a school bus must travel for least time towards school. Along with that each school bus must be occupied such that only optimal number of school buses is required. Here, the genetic algorithm generates chromosomes which evolve in each iteration that minimizes the time requirement for each bus along the best path. At the end an optimal solution is obtained which shows path for each bus.

Key words: Genetic algorithm, transport service problem, cross-over, mutation, selection, chromosomes

INTRODUCTION

In urban areas there are many schools with more than 1000 students and more than 50 buses to pick and drop these students. Due to the large area of cities the buses has to be optimally distributed all over the city to pick students from each and every corner within a limited time. For example: a student picked from 20 km distance to school cannot travel for another 30 km more as that would be in appropriate. For this reason each student picked from his/her stop (fixed in advance) in a way that the bus capacity is utilized to the maximum and all the students are picked within a given time. Also, buses consume fuel and other resources which are maintained by the school management, hence, minimization of these resources is needed. Genetic algorithm here evolves over a number of iterations to form best chromosome with the basic principle of survival of the fittest where each chromosome gives information about allotment of all the buses on routes that cover all pick-up destinations. The fittest chromosomes in each iteration go through certain processes as:

- Selection
- Cross-over
- Mutation
- Stopping criteria

Genetic algorithm is said to obtain the best chromosome as a result which gives an optimized solution for allotment of buses to the routes.

Literature review: Many prior works have been done on the applications of recommender systems. Huang *et al*. (2015) use Genetic algorithms to solve carpool service problems in cloud computing. They used the concept of Genetic-based Carpool Route and Matching Algorithm (GCRMA).

Mesbah *et al*. (2011) uses a Genetic algorithm to optimize transit priority in transportation problem. They used a parallel Genetic algorithm which has considerably shorter execution time.

Hu and Paolo (2008) has proposed a binary-representation-based Genetic algorithm for aircraft arrival sequencing and scheduling. They used efficient Genetic algorithm based on a binary representation of arriving queues.

Lau *et al*. (2010) used Genetic algorithms to solve the multidepot vehicle routing problem. They proposed to use a stochastic search technique called Fuzzy Logic Guided Genetic Algorithms (FLGA).

Saenz *et al*. (2012) used Vehicular Ad hoc Network (VANET) for sharing messages among vehicles to detect traffic jams. Complex Event Processing (CEP) useful for beacon messages from the VANET to identify traffic congestion.

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Jellouli solved the travelling salesman problem generalized travelling salesman by using intelligent dynamic programming. Genetic algorithm and simulated annealing are used together to obtain the best optimized results.

Moohong Kang used Genetic algorithm to allocate students to their nearest bus stops termed as bus stop selection such that each student has to walk least distance from the residence. Students from different schools can travel in same bus. Also, students are classified according to the bus stops allotted and schools for chromosome representation. After generation of initial population the chromosomes that are smaller than cross-over rate are selected for crossover and rest for mutation. The results obtained by Genetic algorithm uses heuristic approach hence optimal solutions may not be obtained thus results should be compared to some optimized result from a problem of such size that can be evaluated with different methods.

Xuesong Yan *et al*. used improved particle swarm optimization algorithm where the convergence speed of particle is fast. Here, the best item in the swarm is selected and the information sharing mechanism make other particles to approach local optimum gradually and become 0 in the end. Hence, a genetic selection strategy is used to avoid local optimum.

Jianguo Wang and Xueqiao Huang developed system implementing the algorithm to allow the real world application on a web based software system. Here, along with vehicle routing problem, student safety and time students spend on the bus is also considered.

Emrana Kabir Hashi used a GIS (Geographical Information System) which gives a better understanding of distribution of students across the city as well as it helps in mapping the actual points on the map to show the routes.

Genetic algorithm: In order to minimize these expenses available buses are required to be properly optimized such that unnecessary buses can be removed easily. Apart from this some paths could be more congested than others hence a new bus could be suggested on some route or a bus with higher capacity on other route can pick these students. In case of bus break-down some other bus has to be diverted towards the stops of this bus. All these things are currently being managed manually. According to the requirement gathering analysis the management person himself tracks all the stops along the city, makes different routes and sets buses over these routes. This process takes a week of time during which trial and error basis comes in scenario. Addition of new students in the school adds up to the work of management where reassigning of buses is done. Using genetic algorithm for this optimization problem uses chromosomes which are possible assignments of each bus on a given route. Each chromosome contains.

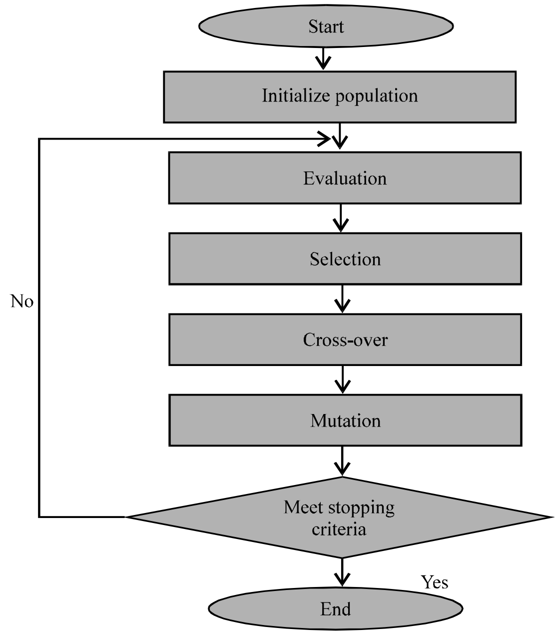

Fig. 1: The flowchart of the process

Unique chromosome identification. Information for all buses such as unique bus identification, bus capacity, utilized capacity (in terms of seats), number of stops covered and total time taken to cover these stops. Information about each stop/pick-up destination such as destination identity, total items (in reference to number of students) and number of items picked.

These chromosomes then are selected on basis of a fitness function which is formulated such that certain chromosomes will be selected and rest will be rejected. These selected chromosomes then go through the processes such as cross-over and mutation until the stopping criteria is met (Fig. 1).

MATERIALS AND METHODS

The main purpose of study is to use genetic algorithm to optimize the solution. The capacity of buses will be fixed in the beginning which will be same of all buses throughout the chromosomes. Similarly, the capacity of items at each destination is fixed at the beginning. Buses will be allotted according to their capacity at the time when initial population is created. Hence, the capacity dimension of buses is already considered. As the buses are allotted to each destination

Table 1: Descriptions of notations

Notation	Description
X_i	ith chromosome
FF_i	Fitness function of ith chromosome
P_i	Set of all pick-points, i = 1, 2, ..., n
B_j	Set of all buses, j = 1, 2, ..., m
C_j	Set of capacities of all buses, j = 1, 2, ..., m
BR_j	P_i-a, Pi-b, P_i-c, Pi-d, i = 1, 2, ..., n and j = 1, 2, ..., m (a+b+c+d)< C_j
$T_{P[n], P[d]}$	Time taken by bus to cover all pick-points allotted to that bus say n and reach final destination $P_{[d]}$
$TF_{P[i], P[d]}$	Time taken by bus to reach final destination $P_{[d]}$ from farthest pick-point $P_{[i]}$ out of all pick-points allotted to the bus
DL_n	Introducing delay of 5 min each according to the number of pick-points n covered by the bus

with some capacity of items forming the chromosome. Many such chromosomes are created initially called as 'Initial population'. Out of this initial population some chromosomes are selected on the basis of fitness criteria. This fitness criterion is adaptive as the iterations take place creating new chromosomes each time. 'Only the fittest survive'.

Here, x_i is the ith chromosome whose fitness function X^{ff}_i is smaller than threshold $_f$then chromosome X_i is selected. All such chromosomes constitute a population that is fit according to the fitness criteria. All the fittest chromosomes are selected and go through two important processes namely cross-over and mutation and a stopping criterion which will decide if next iteration occurs or not (Table 1).

RESULTS AND DISCUSSION

Chromosome structure: The chromosome structure consist of buses which have a fixed capacity, the students that these buses pick from each pick-points, route of each bus is given according to the pick-points it covers and the distance between these pick-points along with the delay for each pick-point (Fig. 2).

Each bus will cover certain pick-points with the restriction of number of seats in that bus. BR_j gives route for bus i covering P_i pick-points and number of students a, b, ... from each pick-point in the sequence given. Ex- $BR_1 = \{P_1\text{-}8, P_4\text{-}3, P_7\text{-}6\}$, capacity of bus $B_1 = 17$. No more students can be added here. Bus 1 will start from Pick-point P_1 where it will pick 8 students then it will go to Pick-point P_4 and pick 3 more students and at the end Pick-point P_7 where it will pick 6 students. A distance matrix D contains all the pick-points and time needed to travel between them. T gives total when the bus covers all pick points relative to the distance covered by the bus will be given as follows:

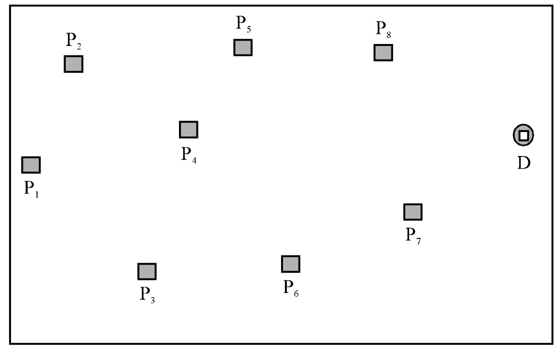

Fig. 2: Pick-points across the city (P_i), D as destination (school location)

$$T1 = \left[T_{p[1],\, p[4]} + T_{p[4],\, p[7]} + T_{p[7],\, p[d]} + DL_3\right] - \left[TF_{p[1],\, p[d]}\right]$$

Chromosome X_i:

BR_1	**BR_2**	**BR_3**	**...**	**BR_m**

Each chromosome consists of all the buses and their routes along with which pick-point each covers and students picked from each pick-point. Initially random population is generated considering all the possible paths. After the initial random population is generated the maximum T is considered for relative fitness function for each chromosome similarly number of students missed by the buses of each chromosome given as LS_i. The fitness function will range from [0, 1]. The fitness function is given as follows:

$$FF_i = \frac{Max\left[X_i\left[T_i\right]\right]\times 0.25}{Max\left[T_i\right]} + \frac{X_i\left[LS_i\right]\times 0.75}{Max\left[LS_i\right]}$$

The above function will give fitness function for each individual chromosome such that chromosomes with buses that picks up all the students with least travel time. Threshold will be set relative to the maximum and minimum FF values. Mean of these values is taken as a threshold. Chromosomes having FF value greater are rejected while the rest are selected for cross-over.

Cross-over: In cross-over two fit chromosomes are cross combined to form two new chromosomes. Suppose chromosomes X_1 and X_2 cross combine to form new chromosomes say X_3 and X_4. Cut-points are indicated by dashed lines.

Chromosome X_1:

$X_1[BR_1]$	$X_2[BR_2]$	$X_1[BR_3]$	$X_1[BR_4]$	$X_1[BR_5]$

$X_2[BR_1]$	$X_2[BR_2]$	$X_2[BR_3]$	$X_2[BR_4]$	$X_2[BR_5]$

Chromosome X_2.

After cross-over: Chromosome X_3:

$X_1[BR_1]$	$X_2[BR_2]$	$X_1[BR_3]$	$X_2[BR_4]$	$X_1[BR_5]$

Chromosome X_4:

$X_2[BR_1]$	$X_1[BR_2]$	$X_2[BR_3]$	$X_1[BR_4]$	$X_2[BR_5]$

By combining the two fittest chromosomes new chromosome thus formed will be added to the next Generation of chromosomes.

Mutation: In the process of mutation the over-lapping that occurs as a result of cross-over among new chromosomes is solved. For example: 2 buses may be allotted the same destination after cross-over which is resolved by keeping any one of the allotment and reallocating some leftover destination to this bus.

Stopping criterion: The iteration process will continue until the number of chromosomes is 1 or in case where more than 1 chromosome are fittest and has similar time variant then only one of them is kept as a result only 1 chromosome is obtained which has least time variant as compared to others. Here, the number of iterations can be controlled with the help of fitness threshold or by limiting the number of chromosomes that undergo cross-over. When the stopping criterion is met no more iterations occur. The result will be displayed that will contain allotments of bus to the destinations.

CONCLUSION

The scheduling problem for school buses undertaken is successfully optimized by use of Genetic algorithm. The final result mostly the cross-over of some fittest chromosomes is witnessed. Number of iterations and changes in chromosome structure happening after each iteration are tracked.

This scheduling problem can be further optimized by adopting multi-objective fitness function as used in study (Huang *et al*., 2015). In this study, the objective revolves around minimization of time for each bus and each student. Buses can also be optimized for capacity of seats.

SUGGESTIONS

Further new buses can be suggested on routes that are very busy. In this study least number of buses are use in order to optimize use of resources by school and reduce other maintenance cost required behind each bus. Adaptive Genetic algorithm can be used in which the number of iterations can be easily reduced by using a adaptive fitness function similarly applied for cross-over and mutation.

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