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Multi-Objective Optimization for Traffic Route Selection

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Abstract: As the traffic is increasing at a very high rate therefore; there is emerging requirement to recommend multiple route choices with optimal system. In this paper optimal path search problem is defined as a multi-objective optimization problem and evolutionary approach is used to decide the optimal path. The major area of concern is to distribute vehicles on alternative routes within an **OD** pair to meet both the objectives. The computational experiments are performed to calculate the parameters associated with the problem.

Keywords: Traffic Route Optimization, Evolutionary Algorithms, Single-Objective, Multi-objective, Pareto-Optimality.

I. Introduction

Now a days, vehicles can be often seen crawling on the road due to slow traffic move or road congestion. As we know that road network is a group of multiple roads which can be considered as a graph. Optimal path selection is always a heuristic question in everyone's mind. The major parameter of the optimal path selection is to find the shortest path between the origin-destination pair with least congestion. Algorithms like Dijikstra's, Bellman Ford, etc. were generally used for finding shortest route in a road network. Although, the shortest route should consists of multiple criteria like travelling time as well as distance. Hence there can be more than one objective for the shortest path problem. Thus the problem can be defined as multi-obj ective shortest path problem [4].

Multi-Objective problem give rise to Pareto-Optimal solution. The traditional optimization problems always prefer to convert multi-objective optimization to single objective to emphasize Pareto-Optimal solution at a time [1]. Evolutionary algorithms have proven track record to solve multi-objective optimization problems. It is well known fact that evolutionary algorithms work with the population of solution. Therefore, simple evolutionary algorithms are to be used to achieve Pareto-Optimal solution. The NSGA was proposed by N.Srinivas and K.Deb. Over the years, criticism for the NSGA approach, have been observed by the researchers. Further the improved version NSGA-II was proposed by K.Deb [2]. Thus, In this paper we have implemented a Pareto Optimal solution with reference to NSGA-II with objectives ***To minimize average travel time for all the vehicles*** and ***Minimize the travel time of the vehicle contributing in the worst travel timing*** as objective functions.

II. Related Work:

Numerical and combinatorial problems can be solved using several Heuristic algorithms. Depending on various parameters such as population based, Iterative based, stochastic, deterministic, etc., different computational group are defined, for the ease of their understanding.

It is well known fact that an algorithm working on set of solutions and trying to improve them is considered as population based and these population based algorithm are subset of evolutionary algorithms. The most trending Evolutionary algorithms is Genetic Algorithm and Particle Swarm Optimization. It is a simple computer program, actually a type of formula, based on the principles of evolution by natural selection. Lin chu-Hising, Yu Jui-Ling, et.al. [6]. applied Genetic algorithm for finding the shortest path in real time environment for very complex network. The approximately optimal path in complicated situation can be effectively computed with the help of genetic algorithm. Thus the presence of different objectives in a problem gives a set of optimal solutions (known as Pareto-Optimal solution). Classical optimization techniques tend to convert the multi-objective problem into a single

objective, emphasizing a single Pareto-optimal solution at a time. The criteria is represented as objective function, thus evaluation is done to reduce it up-to optimum level. In single criteria, the one seek for the best value of the objective function in assumedly defined function. Due to flexible nature of evolutionary algorithm, their simple implementation techniques and not requiring any derived information, they become very popular. However concerning with the real life problems, several disjoint criteria act simultaneously with the set of certain constraints. When traditional optimization techniques are used for finding multiple solutions they are to be applied many times for finding different solution each time. Thus for multi-objectives Evolutionary algorithms is again preferred as the best choice.(Deb. K., et.al.)[1]

In Multi-objective optimization we have to either maximize or minimize different constraints involved in the objective function. This evaluation leads to the problem of the Pareto- Optimality, where further processing leads to a single optimal solution. The very first motive while evaluating Multi-objective scenarios in evolutionary algorithms should be to accomplish the fitness function and selection respectively, so as to process the search in Pareto-optimal set, followed by maintaining a diverse population in order to prevent the premature convergence. The

first factor decides the Pareto and Non-Pareto optimality approach. Srinivas and Deb (1994) proposed a Non-Dominating sorting genetic algorithm (NSGA). It uses several layers of classification of an individual. The population (various paths) is to be ranked accordingly on the basis of domination of (using Pareto dominance). All Non-Dominating paths are to be kept into one category (With Dummy fitness value) to maintain the diversity of individual paths & their dummy fitness value are being shared. The non-dominating group of paths is to be removed and categorization is done again, repeating the same steps above until finding the Pareto Optimal Route. A fast and elitist multi-objective algorithm Genetic algorithm was proposed by Kalyanmoy Deb [2] named as NSGA-II which is also being able to perform epistatic problems (based on complex designs). Chira C., Bazzan Ana L. C., et.al [6] used NSGA-II in finding the optimal alternative path distribution, for vehicles while maintaining the system optimum along with the user equilibrium.

III. Multi-Objective Approach of Traffic Route Optimization

Evolutionary ideas of natural selection and genetics are main working base for adaptive heuristic search performed by evolutionary algorithms. In order to solve optimization problems they use intelligent exploitation mechanism for random search of OD pairs. Although, EAs have nothing to do with the term random, as these exploit historic information to direct its search process within the search space for better performance. At each generation, according to the level of fitness in the problem, the process of selecting individuals creates a new set of approximation and breed them together using operators borrowed from natural genetics. Thus, this process is signified as evolution of population of individuals which is better from its previous generation, similar as natural adaptation process. Various articles can be found discussing over multi-objective evolutionary algorithms in Intelligent Transportation System. A. Meskat and J. L. M. Varncken [4], summarize about the current approaches of

Multi-objective evolutionary algorithms in road network. Thus, this emphasizes us to adopt new approach for optimal path problems by using improved Non-Sorting Dominating Genetic Algorithm (NSGA-II). The generic algorithm is summarized below as:

Input: **N: Population size**

: archive size

T: Maximum Number of Generations

Output: **A: Non-Dominated set of Solutions**

Step 1: **The initial population is generated as and time is T=0.**
Step 2: **Empty Archive = ® is created, two objective functions are defined**
To minimize average travel time for all the vehicles

• *Minimize the travel time of the vehicle contributing in the worst travel timing.*

All the Non-Dominated chromosomes are copied in current Population and archive. If size of our current archive is not equal to population size P, then reduce with truncation operator or fill with dominated individuals as per the case may be.

Step 4: **Crossover and Mutation are applied with pre-defined probability. The algorithm is terminated either manually or after specified number of generation.**

a) *Genetic Parameter Selection:* **A chromosome is defined as an individual consists of the nodes covering the path from Origin-Destination pair (O-D pair). The length of the chromosomes is < M where M is the total number of nodes in OD pairs.**

b) *Initial Population*: **A path is generated randomly in an ordered sequence from origin to destination node. It is a well-known fact than a number of solution increases exponentially with the number of objectives. It is handled by integrating a dynamic sizing of population in Genetic Algorithm or by estimating the size of initial population. In this paper the latter approach has been implemented. The initial population is created randomly with the uniform distribution. Population is loaded from the existing file by using the last population. If the population size is less than the current population then the random numbers are used to fill the populations.**

c) *Objective Function:* **two variables are defined asX,_ and X_2, such that X_1 e [O.1, 1.0] and X_2 e [0,6]. Two objective functions are defined the first one is known as** *Traffic Density* $F_1(x) = X_1$ **and the second objective function is defined as** $F_2(x) = \frac{}{x_i}$**.The objective functions are subject to the constraints** $G_1(x) = 9X, + X_2 < 6$ **and** $G_2(x) = 9X_1 - X_2 > 1$

d) *Selection:* **In this paper we have used preference based selection to make the decision with a set of alternative solutions with in a limited area of the objective space. It is very helpful and allows better result set in the preferred area without violating the optimization time. Alternatively the density of the solution surrounding a particular solution is estimated through the average distance of two solutions neighboring to the current solution. This particular distance is called crowding distance. For each objective function the boundary populations are assigned. Populations are assigned extreme values and intermediate populations are assigned on the basic of crowded distance. Since the selection is one of the most important factor in improving the quality of population. The individuals with the highest crowding distance are selected if both are from the same front otherwise the lower on are selected.**

e) *Crossover:* **Parents are selected randomly with uniform distribution. The one child is generated with the addition operator and second with the subtraction operator.**

f) *Mutation:* **A single point mutation method is used for the purpose. A Uniform mutation has been implemented. The mutation point is selected randomly and a random number is replaced at a random point.**

g) *Stopping-Criteria:* **The algorithm can either be stopped manually or by pre-setting the limits for the number of iterations**

IV. *Experiments and Results:*

The algorithm was applied to minimize two objective function distance and delay simultaneously.

PARAMETERS	SET VALUES
Population of Z	100
Number of Generations	500
Crossover Probability	0.7
Mutation Probability	0.005

In this paper we have focused on vehicles with the worst travel time. Two objectives under consideration are

- **To minimize average travel time for all the vehicles**
- **Minimize the travel time of the vehicle contributing in the worst travel timing**

In this case we consider the minimization of overall travel time of all O-D pairs next to the worst travel time. For the

purpose the well known Non-Domination based genetic algorithm for multi-objective optimization (NSGA-2) with variations. For each O-D Pair Number of routes are predetermined using nearest neighbor algorithm. The chromosomes contain one of the shortest-routes for each vehicle in its OD pair. For the road network under consideration, there are 1500 vehicles and one of the 6 pre-determined routes in specific OD pairs are used. The population is initialized randomly using uniform distribution. Intermediate crossover and Gaussian mutation are applied on each generation with pre-determined probability. Chromosomes are considered in Pareto-Optimal manner

that is two individuals don't dominate over each other. Any Nth individuals are dominated by N-1th individuals. To maintain the diversity of the population crowding distance is also considered

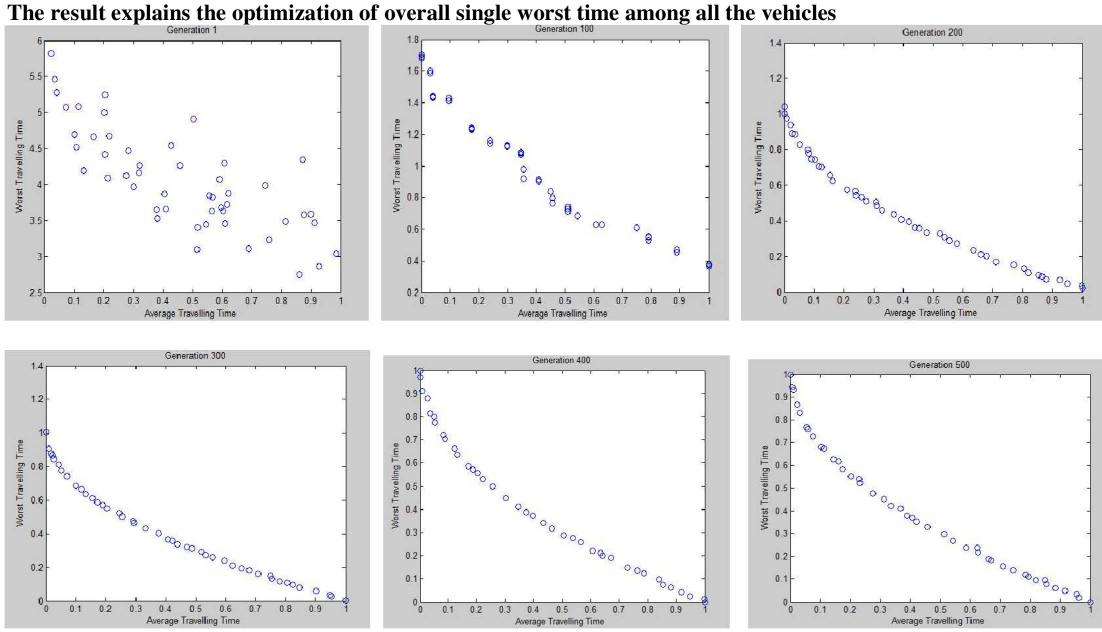
It is an established fact that higher the population size and the number of generation size is directly proportional to the better solution in evolutionary algorithms however the cost to benefit ratio between computational cost and improved solution is also a matter of concern. If the travel time improves less than 5% and computation time increases from minutes to hours then it is of no use.

In a specific OD pair to ensure a minimum travel time for vehicle to route distribution Multiple-objective are defined. However, the minimum travel time is achieved, but it may not necessarily lead to global minima.

The table present result obtained from Multi-Objective Optimal Path Search algorithm Pareto front is based on minimum average travel time for all the vehicles. The table shows the best travel time, the average travel time and the Standard Deviation used for the model in this paper.

Best Travel time	Average Travel time	Standard Deviation
69.08	69.39	0.128

The result explains the optimization of overall single worst time among all the vehicles



V. *Conclusion:*

The Result provides important information regarding each set of the shortest path in OD pairs from different perspective strictly according to the objectives. It has been found that the average travel time for all vehicles cannot be improved unless the worst travel time is very high. In future, further simulation can be done utilizing the number of vehicles per link. The analysis can be embed with traffic light signal timing can be one of the concern.

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