A realizable Architecture for Genetic Algorithm in Solving Multi-Depot Vehicle Routing Problem

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Abstract
Multi-Depot Vehicle Routing Problem (MDVRPs) is an expansion of classical Vehicle Routing Problem (VRPs) with more than one depot; appropriate to organizations which have several branches and each branch aimed at delivering goods or services to their customers simultaneously. Since MDVRP is hard to solve with exact methods such as branch and bound, branch and cut algorithms, Genetic Algorithm (GA) was prove to be effective in solving MDVRP. This research is aimed to propose architecture for solving MDVRP with GA, to achieve the aim of this research; this paper proposes architecture for solving MDVRP with GA. The proposed architecture will provide an efficient strategy and highlight of components required while using Genetic Algorithm to solve MDVRP. The proposed Architecture shows that Genetic Algorithm is the effective method for solving MDVRP.

Keywords: Chromosome; fitness Evaluation; Evolutionary Algorithm; Genetic Algorithm.

INTRODUCTION

Genetic Algorithm (GA) was viewed by Hashim et.al. (2016) as a meta-heuristic stimulated by the process of natural selection that belongs to the larger class of Evolutionary Algorithms (EA). EA's are a meta-heuristic enthused by natural selection and proficient strategies for solving optimization problems (Oliveira, Enayatifar Sadaei,Guimaraes, Potvin, 2015). Furthermore, Mauro, Franco & Roberto (2008) acknowledged that EA involve mechanisms motivated by biological evolution such as reproduction, mutation, recombination, natural selection and survival of the fittest. In this improvement, there are two main forces that structure the basis of evolutionary systems: Recombination and mutation build the necessary diversity and thereby facilitate novelty, while selection acts as a force increasing quality. Evolutionary Programming, Evolution Strategies, Genetic Algorithms, and Genetic Programming are sub-areas of EAs (Abraham, 2006). EAs usually undergoes through evolutionary process. The figure 1 depicts the universal scheme of evolutionary process:

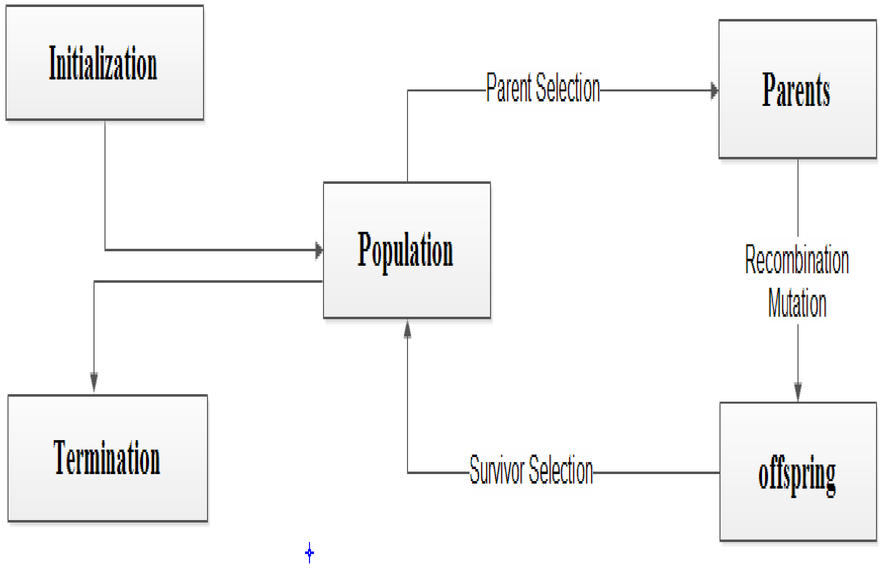

Figure 1: Universal Scheme of Evolutionary Process (Eiben & Smith, 2015)

GA is described as an algorithm based on the Darwin's theory of "survival of the fittest". This algorithm tries to replicate this theory in various problems and has been found to be quite successful. The algorithm is based on the various steps such as initialization, selection, crossover, mutation and replacement (Skok, Skrlec & Krajcar, 2001). GA is applied to solve numerous problems and can be used in number of applications such as optimization, business, robotics, machine learning, networking, image processing, etc.

The biggest problem in implementing a GA is identifying the fitness function. However, if the fitness function is accurately identified, the GA can converge in a speedy manner. Another important aspect in using a GA is the use of operators which are selection, crossover and mutation. The selection mechanism depends on the problem, though it should be selected so that neither the convergence is premature nor it is very slow (Mauro, Franco & Roberto, 2008). Crossover and mutation are very important aspects for maintaining the diversity in the population. The probability of crossover and mutation should be selected such that neither more fit solutions are lost nor diversity is lost (Hashim, Muhammad, Fazl, Ahmadullah, Salman,Yasir, 2016). The algorithm should terminate in a finite number of steps depending on various criterions. The major advantage of the GA is in its parallelism i.e. it work on multiple solution in the search space simultaneously as compared with some other methods like Hill Climbing which works only from a single point. The advantage of starting with multiple points is that the solution will not be trapped in local maxima and the chances of finding the global maximum are very high (Skok, Skrlec & Krajcar, 2001).

The effectiveness, wider used of GA for solving MDVRP, and the formal consultation from the literature reviewed, there is no Genetic Algorithm architecture proposed for solving MDVRP these indicate the need to have the a simplified GA architecture for Solving Multi-Depot Vehicle Routing Problem. The main objective of this research is to proposed Genetic

Algorithm for solving MDVRP. Stating all the necessary step and procedures required in using GA to solve MDVRP.

Start of the Art for solving MDVRP

The work done by Surekha & Sumathi (2011) Stated that MDVRP is hard to solve with exact methods such as branch and bound, branch and cut algorithms, heuristic techniques such as Genetic algorithms, Genetic Programming, Evolutionary Strategies, Evolutionary Programming and host of others are meta-heuristic used for optimizing this type of problem. The efficiency of MDVRP largely depends on the heuristics used in Assigning Customer to a depot.

Rani & Kumar (2014) described GA as the function optimizers, although the range of problems to which genetic algorithms have been applied is quite broad. In a broader usage of the term, a genetic Algorithm is any population based model that uses selection and recombination operators to generate new sample Points in a search space. It is helpful to view the execution of the genetic algorithm as a two stage process, it starts with the current population selection is applied to the current population to create an intermediate population. Then recombination and mutation are applied to the intermediate population to create the next population. The process of going from the current population to the next population constitutes one generation (Eiben and smith, 2015).

A Study conducted by Hashim, Muhammad, Fazl, Salman,Yasir (2016) declared that GA is used to find out solutions to utmost optimization problems like traveling salesman problem; sequential scheduling problem, vehicle Routing Problem etc. in the work new demonstration technique was proposed for finding the optimal path for traveling salesman problem, technique was the use of fittest criteria and binary matrix. The fittest criteria improve the crossover and mutation process to get optimal solution. In addition, Fozia, Nasiruddin, Syed & Shaikh (2013) solved same problem and generated high quality solutions using sequential consecutive crossover operation, the application of genetic algorithm to any problem, researcher encodes the solutions like a better chromosomes combination as the crossover operation leads solution to optimization. Further research work Liu (2014) research work presented a powerful Genetic Algorithm (GA) to solve the Traveling Salesman Problem (TSP), Edge Swapping(ES) with a local search procedure to determine good combinations of building blocks of parent solutions for generating better upspring solutions were used.

The research conducted by Karakati & Podgorelec (2015) presented different genetic approaches, methods and operators, commonly used in practical applications to solve this well-known research problem. In addition an up-to-date overview of the research area was stated, the efficiency of different existing genetic methods was evaluated in detail based on the standard benchmark problems. The strengths and weaknesses of exact methods, operators and settings were evaluated and presented, with the view to help researchers and practitioners to optimize their solutions in further studies done with the similar type of the problem in mind. Also a review was on the vehicle routing problem with multiple depots (MDVRP) between 1988 and 2014 form the state-of-the-art, (Montoya-Torres, Franco, Isaza, Jimenez, Herazo-Padila, 2015) in which several variants of the model are studied: time windows, split delivery, heterogeneous fleet, periodic deliveries, and pickup and delivery. Their review also classifies the approaches based on the optimized single or multiple objectives.

To this extent, Lalla-Ruiz, Christopher, Shervin & Stefan (2015) proposed a new mixed integer programming formulation for the MDOVRP by improving some constraints from the literature and proposing new ones. CPLEX was used for the implementation. (Mirabi, fatemi and Jolai 2014) proposed a hybrid meta-heuristic algorithm coupling simulated annealing and electromagnetism to minimize travel distance and customer waiting time for service. In addition, Rodrigues, Isabel & Barbosa-Povoa (2014) simultaneously evaluated travel distance and level of carbon emissions in a multi-depot vehicle routing problem found in waste collection supply chain.

Genetic algorithms are parallel search optimization technique which can be either being executed in a centralized mode or distributed mode. Thus, the majority of parallel searches in genetic algorithms were data based parallelism (centralized processing) (Al-Angari, 2005). Parallel computing is used by default in the Island evolution approach, in Island approach the population is partitioned in a set of subpopulations (islands) in which isolated GAs are executed on separated processor runs. Occasionally, some individuals from an island migrate to another island, thus allowing subpopulations to share genetic material (Konfrˇst, 2004).

Genetic Algorithms (GA) were viewed by Surekha & Sumathi (2011) as a parallel search mechanism, which makes it more efficient than other classical optimization techniques such as branch and bound, tabu search method and simulated annealing. The basic idea of GA is to maintain a population of candidate solutions that evolves under selective pressure. The GA can avoid getting trapped in a local optimum by tuning the genetic operators, crossover and mutation. Due to its high potential for global optimization, GA has received great attention in solving multi-depot vehicle routing problems. The work of Moonsri, Sethanan, Worasan, in 2022 a mixed-integer programming formulation is presented in order to measure the performance of a heuristic with GA, PSO, and DE for small-sized instances. Hybrid genetic algorithm is designed, and the characteristics of the different examples and solution algorithms are further analysed to provide a reference for the solution of the order picking optimization problem in a dense mobile rack warehouse (Yang, Zhou, and Liu, 2020).

Yadon, Haiping, Mei, Sengang, and Xiaolei (2018) Proposes a simple multi population management strategy to dynamically adjust the subpopulation number indifferent evolution phases throughout the evolution. The proposed method makes use of individual distances in the same subpopulation as well as the population distances between multiple subpopulations to determine the subpopulation number, which is substantial in maintaining population diversity and enhancing the exploration ability. Furthermore, the proposed multi-population management strategy is embedded into popular EAs to solve real-world complex automated warehouse scheduling problems. Experimental results show that the proposed multi-population EAs can easily be implemented and outperform other regular single-population algorithms to a large extent.

Proposed Realizable Architecture of GA for MDVRP.

This section presented the architecture of Genetic algorithm for solving MDVRP. After several consultation of the theoretical literature of the processes involved in Genetic Algorithm and MDVRP Figure 2 was extracted as the proposed architecture of Genetic Algorithm for MDVRP.

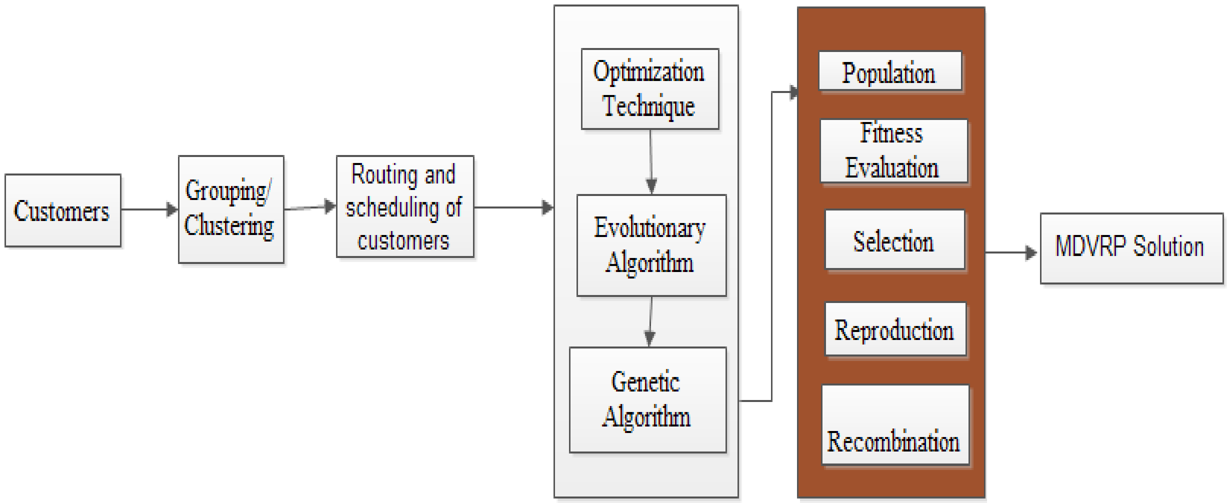

Figure 2: Proposed Realizable Architecture for GA in solving MDVRP

Description of the proposed realizable Architecture

This Section presents a description on the proposed architecture for the Multi Deport Vehicle routing problem. This entails identification of customer, specification of grouping or clustering algorithm, and process involved in routing and scheduling of customers.

Customers

In this step customers and their geographical locations are identified. Geographical location of each customer is identified using the map of a particular area defined by two coordinates, Latitude and Longitude. These two coordinates can be used to track the geographical locations independent of an outside location position.

Grouping/clustering

This stage requires specification and selection of clustering algorithm (K-means, nearest neigbour, shortest path, etc.) for grouping the customers based on the geographical location that is an algorithm that will track the travel distance of each customers and group the customers to appropriate depot.

Routing and Scheduling

Routing and scheduling of customers entails selection of efficient optimization technique and going through optimization process to ensure the required objective function is minimized or maximized subject to specified constraints.

Selection of Optimization Technique

Among the set of search and optimization techniques, the development of Evolutionary Algorithms (EA) has been very important in the last decade. EAs are a set of modern Meta heuristics used successfully in many applications with great complexity. It success on solving difficult problems has been the engine of a field known as Evolutionary Computation (EC). Benefits using EC techniques mostly come from flexibility gains and their fitness to the objective target in combination with a robust behavior. Now days, EC is consider as adaptable concept for problems solution, especially complex optimization problems. This vision is the alternative to some old descriptions that shows EC as a collection of similar algorithms ready to be used in any problem. Most of the present implementations of EA come from any of these five basic types: Genetic Algorithms (GA), Evolutionary Programming (EP), Genetic Programming (GP), Evolutionary Strategies (ES) and Differential Evolution (DE). Figure 3 represents the decompositions of Computational Intelligence

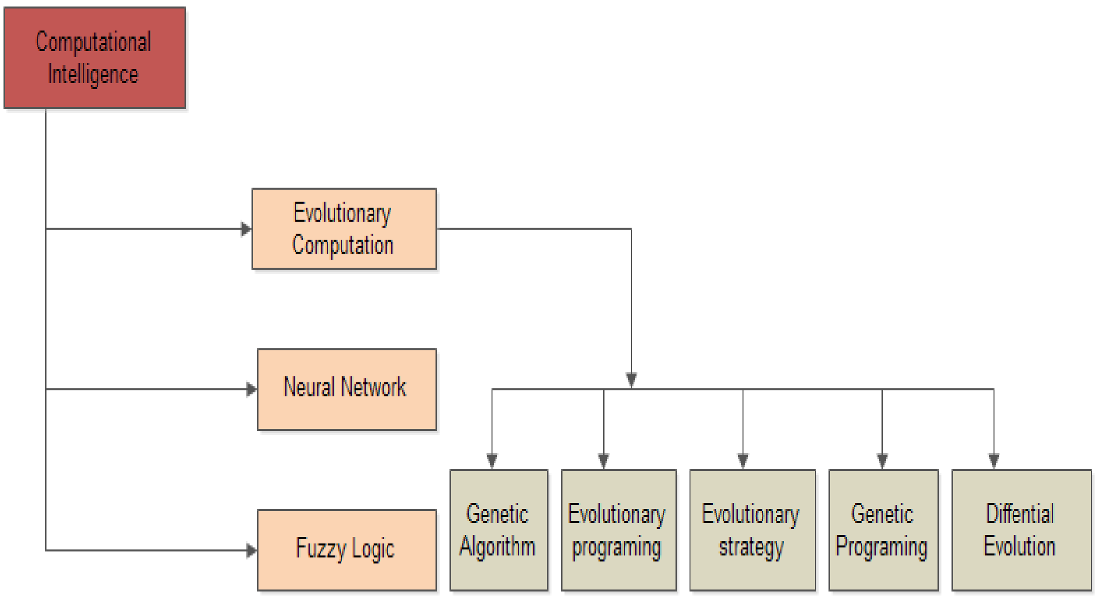

Figure 3: Evolutionary computation in Computational Intelligence (Extracted from weise, 2009).

Figure 3 shows the techniques used in computational intelligence to solve optimization problem. The advantages of Genetic Algorithms over other method such as Tabu search, Hill Climbing and simulated Annealing is shown in Table 1

Table 1: A Comparative Study of the Advantages of Genetic Algorithms over other methods

S/no.	Components	Tabu Search	Hill Climbing	Simulated Annealing	Genetic Algorithm
1	Parallelism				√
2	Efficiency	√	√	√	√
3	Effectiveness	√	√	√	√
4	Manageability	√		√	√
5	Simplicity		√		√
6	Robust to dynamic changes	√		√	√

The advantages of Genetic Algorithm were analyzed in Table 1 where parallelism and its robust to dynamic changes these among others makes it to be an outstanding method for solving large variety of combinatorial optimization problems. Genetic Algorithm was used as the search optimization technique. Genetic algorithm is part of evolutionary Algorithms which are inspired based on natural selection, genetic algorithm was chosen because of its large search space (it can accommodate large number of customers) and easy convergence (the fitness evaluation can be achieve in a shortest time compared with exact methods and other heuristics).

Population Initialization

Population initialization is the first step in GA implementation where random chromosome where generated, each string generated is then evaluated and assigned a fitness value, generated population of chromosome were partitioned into 16 Islands of subpopulations (the population must be divisible by 16) using an Island Evolution in which isolated GAs are executed on separated processor runs. Occasionally, some individuals from an island migrate to another island, thus allowing subpopulations to share genetic material.

Fitness Evaluation

Fitness function quantifies the optimality of a solution (chromosome) so that a particular solution may be ranked against all the other solutions. The function depicts the closeness of a given solution to the desired result. Each individual in the subpopulation is assigned a fitness value which is used to evaluate how fit each individual is, the most fittess individual is selected for reproduction. The Fitness function transforms the measure of performance into an allocation of reproductive opportunities. The fitness of each individual was evaluated using $fi/\bar{f}$

where fi represent the fitness of individual and $\bar{f}$ represent an average fitness value for all the population.

Selection Mechanism

The common selection mechanisms used are roulette wheel, rank selection, stochastic sampling, tournament selection, truncation selection, etc. Each selection mechanism selected will require selection operator for selecting potentially useful solutions for Reproduction and Recombination. For example in roulette wheel selection mechanism the chance of an individual's being selected is proportional to its fitness, greater or less than its competitors' fitness. Out of many methods for selecting the best chromosomes, roulette-wheel selection mechanism was used because of its ability to work efficiently on larger set of data, in this method the population was mapped onto a roulette wheel, where each individual is represented by a space that proportionally corresponds to its fitness by repeatedly spinning the roulette wheel, individuals are chosen using stochastic sampling with replacement, to fill the intermediate *population.*

Reproduction

Crossover mechanism is used for reproduction; crossover is a genetic operator that combines (mates) two chromosomes (parents) to produce a new chromosome (offspring). The idea behind crossover is that the new chromosome may be better than both of the parents if it takes the best characteristics from each of the parents. Crossover occurs during evolution according to a user-definable crossover probability. Crossover selects genes from parent chromosomes and creates a new offspring. The crossover used for this research is route based crossover. A child inherits most of the traits (routes) from the recipient, but also gets a small portion of genetic material (sub-route) from another parent, which is called a donor. Sub-route is chosen in such a way that no conflict emerges.

Recombination

Recombination is usually carried out through a process known as Mutation, after a crossover is performed, mutation takes place. Mutation is a genetic operator used to maintain genetic diversity from one generation of a population of chromosomes to the next. Mutation is an important part of the genetic search, helps to prevent the population from stagnating at any local optima. Mutation is intended to prevent the search falling into a local optimum of the state space. The mutation value was set 0.02 from which the chromosome will flip; flip mutation operator simply inverts the value of the chosen gene. i.e. 0 goes to 1 and 1 go to 0. After flipping it, will slide and swap and swap the genes.

Conclusion

Genetic Algorithm is a meta-heuristic inspired by the process of natural selection that belongs to the larger class of Evolutionary Algorithms. It takes the form of biological genetic processes. This paper proposed realizable architecture for solving MDVRP with GA. The proposed architecture will be a road-map to the researchers willing to adopt a genetic algorithm to solve variant of MDVRP. The realizable architecture captures the various components needed in the genetic algorithm. This architecture yielded an effective result when applied in solving MDVRP with greater convergence of the fitness function. The future research should focus on optimization of the clustering algorithms, fitness function as well as clear mechanism for using efficient Genetic operators in selection of the best route.

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