Intelligence Based Electric Vehicle Route Planning System

Safeera N, Chitharanjan K

Abstract— ***Now a day's Electric Vehicles (EVs) are popular all over the world. The drift towards electric vehicles is a result of severe environmental problems caused by the Internal Combustion Engine Vehicles (ICVs). EV posses performance weaknesses in case of transportation efficiency, such as low energy density of batteries, scarcity of public charging stops, long waiting and charging time, wastage of energy due to traffic, accident and blocking conditions. EV Routing Problem (EVRP) is relevant in the recent scenario to get the efficient route, assisted by coordinating distance travelled and availability of charging stops. Besides, it incorporates the traffic parameters, blocking conditions and accidents to bring this application in real world logistics. To make EVs as the future of personal transportation and to increase the user's acceptance, these problems should be considered. In congested areas, the concurrent and frequent recharging demands lead to high waiting time at the charging area, thus affecting both charging network and vehicle travel time. In this work, optimal route for the electric vehicles is computed that minimizes the associated cost, which is a combination of travel time, charging time and the energy consumption along the route. Inputs to the route planning system are the distance to be travelled, vehicle speed, states of charge and even sometimes the information about traffic conditions, blocks and accidents. The output of the energy management controller is to provide an optimal route that achieves best performance and overall system efficiency. As the stated problem is non-polynomial, the proposed work uses metaheuristic algorithms for finding an optimal route in a reasonable time. Genetic algorithm(GA) and Particle Swarm Optimization (PSO) are then used to solve the energy efficient routing problem for electric vehicles. These two metaheuristic methods are analyzed and studied and the results and performance of each are then compared and contrasted.***

Index Terms— ***EVRP, charging stations, GA, PSO***

I. INTRODUCTION

The use of ElectricVehicles (EVs) have recently become very popular due to the new regulations related to reducing the greenhouse gas emissions. The EVs do not only meet the emission standards but they may also reduce the energy costs. EV plays an important role in improving people's living standard and transport efficiency. From the environmental point of view EV reducing the environmental pollutions. In the point of transport efficiency EV faces many problems and weaknesses. Such as low energy density of batteries, scarcity of public charging stops, long waiting and charging time, wastage of energy due to the traffic, accident and blocking conditions. EV Routing Problem (EVRP) [1] is a great challenging recent problem to get the efficient route assisted by EV by coordinating distance travelled and availability of charging stops. In addition to this it also incorporates the traffic parameters, blocking conditions and accidents to bring this application in the real world logistics..There are few solutions already available on the market but none of these fulfils requirements for power users. Different control strategies [2] are usually proprietary solutions that do not have enough configuration options. Most of the control and journey planning systems do not consider the locations of charging stations and the factors influence the energy losses. There is no single system at all that would integrate all these features into one usable application. Therefore it was found that such solution is essential and could help to make EVs as universal as possible. Limited driving distance between battery charges is a fundamental obstacle to discourage the consumer for the use of EV. In order to eliminate this drawback and to improve the users acceptance, a sufficient number of charging stops are required. Wastage of battery energy due to the traffic conditions and blocking is a next disadvantage while using EVs. A better approach can eliminate it and choose a better route to reach at the destination. Waiting time for charging and queuing time are also affect the overall performance of the EV. So to avoid this a better approach is adopted. Several control strategies are proposed to minimize fuel consumption without compromising vehicle performance. Moreover, fuel economy and emissions minimization are conflicting objectives, a smart control strategy should satisfy a trade off among them.

This work is concentrated on finding a best energy path (i.e., paths with smallest energy related routing costs) between two locations using the following aspects: Minimizing vehicle energy consumption in general and Optimizing the selection of charging stations. Moreover, the main focus of these studies is to develop metaheuristic solution methods that provide suboptimal solutions with no guarantees on their quality. Such methods can be useful in practice, because they are typically significantly faster than other optimization techniques. This work presented in this paper uses GA and PSO. These metaheuristic optimization methods are applied to the EV example in order to find the most energy efficient route between two points.

II. RELATED WORK

Very few works have been proposed in literature which try to address the routing problem by considering various parameters, characteristics and optimization criteria. Most researchers study about the Vehicle Routing Problem(VRP). After that some studies explicitly consider the specific characteristics of alternative fuels and adopt them to VRPs. Goncalves et al [7] consider a VRP with Pickup and Delivery (VRPPD) with a mixed fleet that consists of EVs and vehicles using internal-combustion engines. The objective is to minimize total costs, which consist of vehicle related fixed and variable costs. They consider time and capacity constraints and assume a time for recharging the EVs, which they calculate from the total distance travelled and the range using one battery charge. However, they do not incorporate the actual location of recharging stations into their model. Thus, they basically propose a mixed fleet

Revised Version Manuscript Received on August 28, 2015.

Safeera N, Department of Computer Science, SCT College of Engineering, University of Kerala, Trivandrum, India.

Mr. Chitharanjan K, Department of Computer Science, SCT College of Engineering, University of Kerala, Trivandrum, India.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

VRPPD with an additional distance-dependent time variable.

In [8] [9] the EVRP formulated consists on finding a set of minimum cost routes, such that the demand of the consumer is satisfied. In addition, some new constraints are introduced to take into account the capacity of the battery of the EVs. In [10] [11] the model of EVRP also considers the refueling and the recharging time of EVs. Nevertheless, the costs of recharge and battery degradation have not been taken into account in these works. To the best of my knowledge, [10] are the first to combine a VRP with the possibility of refuelling a vehicle at a station along the route. They are mainly motivated by vehicle fleets operating on a wide geographical region and driving with biodiesel, liquid natural gas or CNG. For these fuels only a limited refuelling infrastructure exists, but refuelling times may be assumed to be fixed. The proposed Green VRP(G-VRP) considers a maximum route duration and fuel constraint. Fuel is consumed with a given rate per travelled distance and can be replenished at Alternative Fuel Stations (AFSs). In principle, the G-VRP is modeled as an extension to the Multi-Depot VRP with Inter Depot Routes(MDVRPI) and authors in [10] propose two heuristics to solve the new problem. The first heuristic is a Modified Clarke and Wright Savings algorithm (MCWS) which creates routes by establishing feasibility through the insertion of AFSs, merging feasible routes according to savings and removing redundant AFSs. The second heuristics is a Density Based Clustering Algorithm (DBCA) based on a cluster first and route second approach.

Other papers such as [12] [13] discuss the recharging control in order to minimize the cost of energy recharge. Both works address the recharging control for large fleets of EVs. The control strategy obtained minimizes generation costs and the recharge cost of the EVs fleet. Also, it highlights that the strategy is not centralized, allowing to preserve the autonomy of each vehicle. However, these works do not consider the energy consumed by each EV and the fact that the optimal charging profiles obtained may lead to an increased degradation of the battery.

III. Route Planning System

This section describes the problem definition and the overview of the system developed. The overall route planning system consists of different steps. These are reflected on the Figure1. Optimal route planning is the core of the this work.

A. Problem Definition

EV routing problem addressed in this work is defined as the selection of a best route satisfying charging, distance and time constraints. This is done in such a way that it is feasible with respect to the energy consumption while travelling due to the certain factors such as traffic, block and accident and the charging parameters such as charging time and queuing time.

The problem can be stated as follows:

$$\min_{z_{ij}^k} \sum_{k=1,i=1}^{n} \sum_{j=1}^{R} C_{ij} \,.\, z_{ij}^k + C_{ij}.T_{ij} \;\ldots\ldots\ldots\ldots (1.1)$$

subject to

$$e_{ij}.z_{ij}^k \le E_k \;\ldots\ldots\ldots\ldots (1.2)$$

$$\sum_i z_{ij}^k = 1, \forall k, i = start(N_k) \;\ldots\ldots\ldots\ldots (1.3)$$

$$\sum_i z_{ij}^k = 1, \forall k, i = end(N_k) \;\ldots\ldots\ldots\ldots (1.4)$$

$$\sum_{j,k} z_{ij}^k \le R_k + 1, \forall k \;\ldots\ldots\ldots\ldots (1.5)$$

$$\sum_{j,k} z_{ij}^k \le C_i, \forall i \;\ldots\ldots\ldots\ldots (1.6)$$

$$\sum_j z_{ij}^k \le \sum_j z_{ji}^k, \forall i, k, i \ne start(N_k), i \ne end(N_k) \;\ldots\ldots\ldots\ldots (1.7)$$

$$z_{ij}^k = \{0,1\}, \forall i, j, k \;\ldots\ldots\ldots\ldots (1.8)$$

Eq.(1.1) defines the non-linear minimization function. The variable z_{ij}^k k represents if the k^{th} route uses the edge between the i th and the j th nodes. Eq.(1.1) is the nonlinear cost function composed by two terms. The first represents the cost involved to traverse an edge between two nodes whereas the second represents the cost associated in the concurrent usage of charging station by different vehicles at the same charging station. Eq.(1.2) is the energy constraint for the trip between two nodes, where e_{ij} is the energy requirement between node i and node j , whereas, Eq.(1.3) and Eq..(1.4) are used to represent starting and end points of the k-route. Eq.(1.5) is a limit on the number of charging station visited by each vehicle, where within route k, at the most R_K charging stops are allowed. Eq.(1.6) considers explicitly the limit on the number of vehicles that can be charged at the i th charging station. Eq.(1.7) is used to model the movement of vehicles requiring each vehicle entering into a node to exit from it, except for the starting and end node. Eq.(1.8) is the set of value given to the charging stops. If the route uses charging stop then value is taken as 1 (true) else (false). Traffic, accident and block are taken the values 0 & 1.

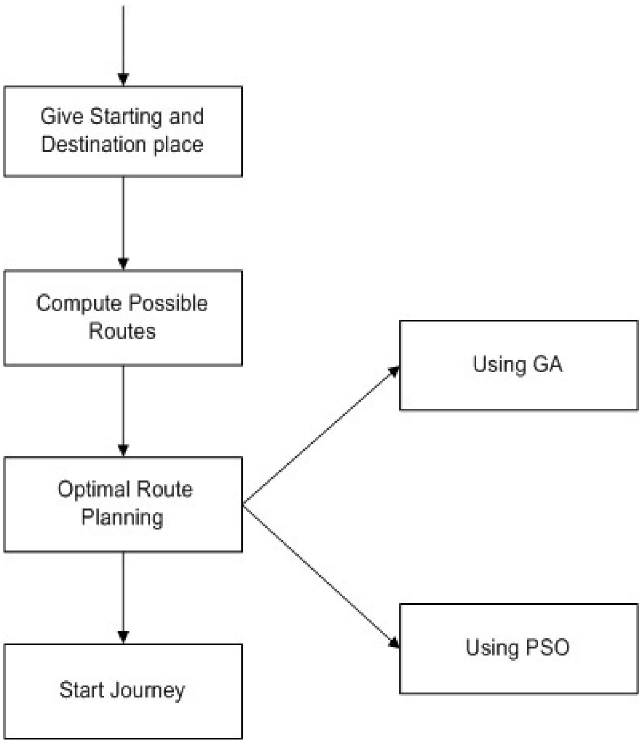

Figure1: Route Planning System

B. Optimal Route Planning

Optimal route can be find out using GA and PSO. The input is the set of routes and calculated parameters in the Routes Finding parts. Output is the set of routes or cheapest route (Routes with minimum energy cost).

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

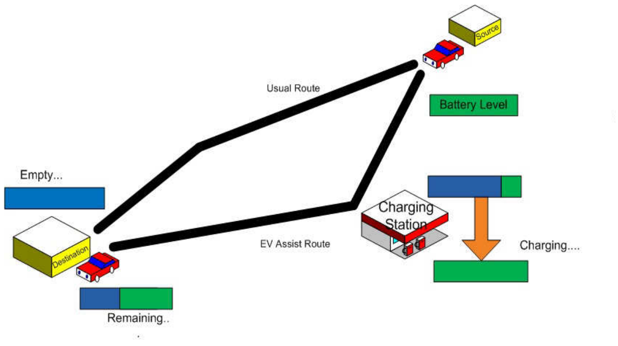

Figure 2: Route Assisted by EVRP solution

1) *Genetic Algorithm(GA)*

The GA is a method, based on the example of the natural selection in the "real natural world". Genetic algorithm with its extension to heuristics and meta heuristics are a common tool used to resolve non polynomial problems [14]. GA uses several algorithms and methodologies to create better and better approximate solutions for a given problem, using the older solutions (parents) to create new ones (children). GA would like to create an artificial model for the previously written steps to be able to solve problems which could not be solved in the classical way of computing. The algorithm is started by obtaining an initial population of chromosomes (the name given to solutions) randomly or incorporating some previous knowledge of the problem.

Algorithm 1: EVRP using GA

Input: Set of available routes containing different stages.
Output: Set Of Cheapest Routes.
Initialize a population $P=\{r_1, r_2, r_3 .... r_n\}$ to start at the starting point *S* ,*Weight=0;*
for *i*<P
    $route_i$ = random Route Selection ($route_i$)
  Do selection process
  Do the cross over process
  Do Mutation Process
Calculate overall fitness value of each route($\{r_1, r_2, r_3 .... r_n\}$) in P using eqn. (2) and (3)
If not satisfy energy
    Weight=Weight+100000;
else
Weight=Weight+100*Charging. size
End If
Select set of routes with small fitness value as Best Routes

$$Weight = Weight + \frac{Block}{Block_{Max}} + \frac{Distance}{Distance_{Max}} + \frac{Traffic}{Traffic_{Max}} \dots\dots\dots\dots (2)$$

$$Weight += \frac{ChrQueue}{ChrQueue_{Max}} + \frac{ChrTime}{ChrTime_{Max}} \dots\dots\dots (3)$$

These are then evaluated according to a fitness function that measures their adaptability to the problem's environment, which corresponds to the cost function of the problem being optimized. From there, some are selected to become parents (usually the fitter individuals have a higher chance of becoming parents) of the next generation and mate. This reproduction, or crossover, is done by creating two or more new chromosomes that contain part of the parents' genetic material. Doing this for all pairs of selected parents will result in a new generation and the process can then be repeated, with some descendants possibly being identical to the best parents to preserve solution quality (elitism). Mutation, just like in natural organisms, can occur and operate a minor change on a chromosome. This usually occurs randomly on a low percentage of chromosomes and is useful to explore new regions of the solution space that might not have been covered by the population's current genetic material [15].

2) *Particle Swarm Optimization (PSO) Algorithm*

PSO was introduced by Kennedy and Eberhart in the mid-1990s. It is a population-based stochastic approach which has been grouped under swarm intelligence [16-18] and evolutionary computation [19].

Input: Set of available routes containing different stages.
Output: Cheapest Route.
1. Initialize N particles at the starting point *S* ,*Weight=0;*
2.**for** *i*<N
3.   *route=S*
4. **while !** Destination point *D* **do**
5    $route_i$=randomRouteSelect($route_i$)
6 **end**
7   *i=i+1*
8 **end**
9.**for** each route
10.Calculate X_i and G_{min} using eqns. (4) and (5)
11. **while** ! defined number of iterations **do**
12. **for** *i<N*
13.   **if** $route_i$!=G_{min}_*route*
14.   **while !** Destination point *D* **do**
15.   Calculate velocity using Eqn.(6) and (7)
16.   **end**
17. Calculate Weight using Eqn.(2)
18. **if** *Weight*<G_{min} then
19. G_{min}=*Weight*
20.   **else continue**
21. **end if**
22. i=i+1
23. **end for**
24. **end while**
25.cheapest route is the route generated by G_{min}

Algorithm 2: EVRP using PSO

$$X_i^* = \begin{cases} f(r_i), \forall r_i thatreachedpointD \\ \infty, otherwise \end{cases} \dots\dots\dots\dots (4)$$

$$G_{min} = \begin{cases} min\,\{f(r_i)\}, \forall r_i thatreachedpointD \\ \infty, otherwise \end{cases} \dots\dots\dots\dots (5)$$

$$TotalChargingTime + ChargingTime * (1 + ChargingQueue) \dots\dots\dots\dots (6)$$

$$Velocity += TotalChargingTime \dots\dots\dots\dots (7)$$

PSO was derived from a concept of a flock of birds which fly everywhere to find food. Each bird is illustrated as a particle. Each particle moves stochastically in search space for a feasible solution. Each of the particles has its own velocity and position. PSO can indicate the velocity and position of particles in a multi-dimensional space. By updating both

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

velocity and position, a feasible solution can be achieved. The fitness values comprise of global and local best derived from the simulated behaviour of a group of particles [20]. local best is the solution offered by each of the particle while the global best is the best solution obtained from all particles.

IV. PERFORMANCE ANALYSIS

The performances of these algorithms are analyzed based on the objective function to find the minimum total travelling time for vehicles from vehicle source to destination. The comparison involves two aspects: total travelling time for a vehicle and the processing time. This section discusses the results for the datasets of South Indian Route map. The experiments for those datasets used similar set up as applied with sequence number 6 and round 10. The performance of the algorithms is based on the total travelling time (fitness value) obtained by all the travelled vehicles and processing time. Average of the total travelling time and processing time is calculated based 20 experiments. The results are plotted as a graph shown in Figure 3. Figure 3 compares the results of the travelled vehicles . It is apparent that PSO outperformed the other algorithms at different Kilo Meters. As can be seen in the Figure 4, although shows that there is very little difference in terms of processing time.

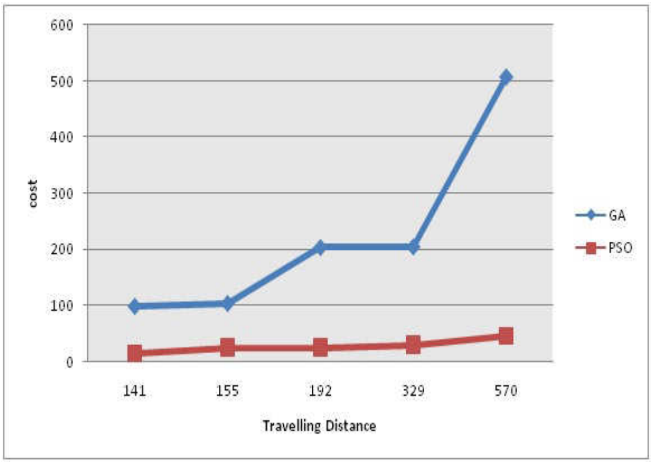

Figure 3.Travelling Distance against Cost

This confirmed that the PSO has a capability of finding optimal solution and fast convergence compared to the GA. The calculation of velocity involving exploitation, and exploration of particles in PSO has contributed to the solution. The exploitation presents means of particles to perform a local search while the exploration is globally finding the best solution, which was gathered from the selection of global best

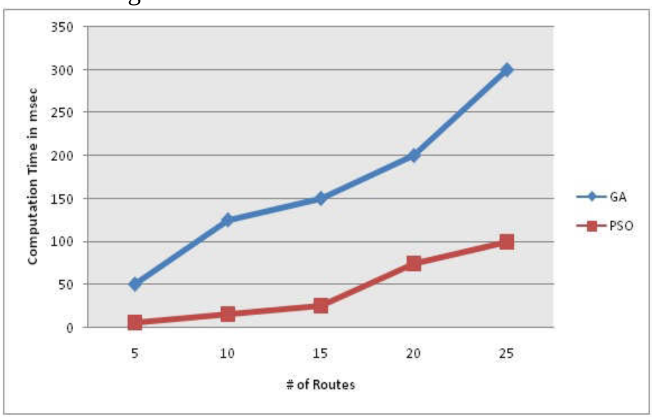

Figure 4.Analysis based on Computation time

V. CONCLUSION AND FUTURE WORKS

In this paper, A formulation to the solution of the source-to-destination energy efficient routing for EVs has implemented. Distance , time and charging criteria are the major constraints to select a cheapest route. This work also incorporates traffic ,block, and accident parameters to find an optimal path with less cost and energy loss. In this work two metaheuristic algorithms such a GA and PSO are used to find out the solutions. Analyzed the performance of these two and result shows that these two have comparatively same performance. But the computation time and travelling time are minimum in PSO than GA. An additional constraint added to PSO leads to a better performance than GA.

REFERENCES

1. N. Touati and V. Jost, “About green vehicle routing and scheduling problem, in proc. 2,” in 4th European conf. operational research, Lisbon, Portugal, July 2010.
2. C. G. A. M. C. G. V. Pillac, “Dynamic vehicle routing problems: State of the art and prospects,” 2011.
3. X. Yang, Engineering Optimization: An Introduction with Metaheuristic Applications. Wiley, 2010.
4. M. Zbigniew, and D. Fogel. How to solve it: modern heuristics. Springer, 2004.
5. J. Brownlee, Clever Algorithms: Nature-Inspired Programming Recipes.Jason Brownlee, 2011
6. Y. Shi, "Particle swarm optimization: developments, applications and resources." Evolutionary Computation, 2001. Proceedings of the 2001 Congress on. Vol. 1. IEEE, 2001.
7. R. S. F.Goncalves, S.R Cardoso and A. P. Barbosa, “Optimization of distribution net-work using electric vehicles: A vrp problem.technical report,ceg-ist,utl,lisboa,” 2011.
8. N. Touati-Moungla and V. Jost, “Combinatorial optimization for electric vehicles management,” in Proc. Int. Conf. Renewable Energies Power Quality, 2011.
9. M. L. A. Artmeier, J. Haselmayr and M. Sachenbacher, “The optimal routing problem in the context of battery-powered electric vehicles,” in Proc. Workshop: CROCSCPAIOR-10, 2nd Int. Workshop Constraint Reasoning Optimization ComputationalSustainability, Bo- logna, Italy, 2010.
10. E.-H. S.Erdogan, “A green vehicle routing problem,transportation research parte:logistic and transportation review 48 100–114.,” (2012).
11. A. S. M. Schneider and D. Goeke, “The electric vehicle routing problem with time windows and recharging stations,” Univ. Kaiserslautern, Germany, Tech. Rep., Jan. 30, 2012.
12. I. A. H. Z. Ma, D. S. Callaway, “Decentralized charging control of large populations of plug-in electric vehicles, ieee transactions on control systems technology 21 (1) (2013) 67 –78, issn 1063-6536, doi: 10.1109/tcst.2174059.,” 2011.
13. S. H. L. L. Gan, U. Topcu, “Optimal decentralized protocol for electric vehicle charging, ieee transactions on power systems pp (99) 1–12, issn 0885-8950,doi:10.1109/tpwrs.2012.2210288.,” (2012).
14. D. E. Goldberg et al. Genetic algorithms in search, optimization, and machine learning. vol. 412. Reading, MA: Addison-Wesley, 1989.
15. Adam Marczyk. Genetic algorithms and evolutionary computation. April 23, 2004.
16. J. Kennedy, Swarm intelligence, in Handbook of Nature-Inspired and Innovative Computing, 2006, pp. 187-219.
17. A. P. Engelbrecht, Computational intelligence: An Introduction, 2nd ed. West Sussex: John Wiley & Son, 2007.
18. K. E. Parsopoulos and M. N. Vrahatis, Parameter selection and adaptation in unified particle swarm optimization, Mathematical and Computer Modelling, vol. 46, 2007, pp. 198-213.
19. I. C. Trelea, The particle swarm optimization algorithm: convergence analysis and parameter selection," Information Processing Letters, vol. 85, 2003, pp. 317-325.
20. A. R. Guner and M. Sevkli, A Discrete Particle Swarm Optimization Algorithm for Uncapacitated Facility Location Problem, Journal of Artificial Evolution and Applications, vol. 2008, pp. 1-9, 2008.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Safeera N, is currently doing her MTech in Computer Science and Engineering at Sree Chitra Thirunal College of Engineering under Kerala University, Trivandrum, Kerala, India. She received her B Tech Degree in Computer Science and Engineering under Kerala University, India in 2011. She concentrates mainly on image processing, optimization and data mining .

Mr. Chitharanjan K, is working as Asst. professor at the department of computer science and engineering, Sree Chitra Thirunal College of Engineering, Trivandrum, Kerala. . He did his B. Tech degree from Adoor Engg College and M.E. degree from National Institute of Technology, Trichy Now he is doing his research work in Cloud computing. He has 15 years of teaching experience. He concentrates mainly on networking and cloud computing.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.