Review based on static routing of hybrid car

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Abstract: Vehicle routing problem has been always a point of discussion in many research papers focusing on static and dynamic aspects of routing and its implementation through optimization techniques like genetic algorithm . Hybrid nature of routing problem is also exploited emphasizing on duality of fuels to be used and also fuel conservation. Several business oriented and environment friendly companies like Tesla have focussed on developing hybrid vehicles or those operating completely on electricity only because they have realized the need for the preservation of non-renewable fuels like petrol and diesel. Google have been designing an efficient network for routing of vehicles based on road maps of the particular country. Current research works are based on designing of static routes, dynamic routes or they completely emphasize the working of a hybrid car to effectively govern the environmental emission of gases and also on the operation of the vehicle. But the important aspect is that focus has to be shifted on the automation of route designing of these hybrid cars according to the roadmaps.

In this paper, the collaborative concept of static routing and hybrid cars is used. Our static routing scheme analyses the various roadmap characteristics and keeping up to the concept of a hybrid car that is it can operate in two fuel mode, petrol and electricity and also focusing on the user satisfaction based on the four parameters cost, time, petrol and electricity.Results show that the genetic algorithm turns out to be very effective in designing the routes and side by side also maintaining the fuel modes between the intermediate destinations and also works for user satisfaction.

Keyword:static,dynamic,VRP,hybridvehicles,genetic algorithm,routing,gene,allele,chromosome, selection,crossover,mutation,offsprings

Introduction: There has been the tremendous importance of effective routing algorithms and hence comes the need for exploiting various graph-based algorithms which gives the best route according to user satisfaction. Google has an immense contribution in designing the networks of various countries using the technology Googlemaps[1].

Routing algorithms are of two types -:

1. Which can give the best path.
2. Which can give an optimal path.

Further, these can be divided as static and dynamic. In the traditional vehicle routing problem (VRP) without backhauling, a depot has to serve the demands of a set of customers with a fleet of vehicles. The objective is to determine the vehicle routes in order to minimize the total travelling time/cost of the vehicles. There is a vast literature on the VRP describes that the problem as NP-Hard. The basic VRP/VRPB is static in the sense that all the information on customers, their demands, distances between locations, travelling times/costs and so on are available with the decision maker in the beginning of the planning period so that the solution to the problem, i.e. the vehicle routes remain static until the end of the planning period. However, in practice, most of the information may not be available at the time of decision-making, which may be revealed dynamically over time such as customer demands, travelling times and so on. This set of problems is referred to as dynamic VRP/VRPB, which has produced a significant amount of research since about the last one-and-a-half decades. Dynamic VRP may consist of customers with delivery-only or pickup-only demands, dynamic customer requests and/or dynamic travel/service times, real-time diversions of vehicles en route to a customer or replaning of vehicle routes only when vehicles reach their next destinations, capacitated or incapacitated vehicles, single time period or multiple time periods, single objective or multiple objectives, and so on [2-3].In current paper ,the concept of the hybrid car vehicle routing(HCVR) has been used. This problem is an extension of the classical VRP in which vehicles can work both electrically and with traditional fuel. The vehicle may change propulsion mode at any point of time. The unitary travel cost is much lower for distances covered in the electric mode. An electric battery has a limited capacity and may be recharged at a recharging station (RS). A limited number of RS are available. Once a battery has been completely discharged, the vehicle automatically shifts to traditional fuel propulsion mode. Furthermore, a maximum route duration is imposed according to contracts regulations established with the driver [4].

Motivation: Depletion of the renewable resources has led to a provoking thought of how to improve the journey via a vehicle and also preserving the fuels like petrol, diesel and CNG. HYBRID CAR is meant to solve the purpose which can run on electricity and a particular renewable fuel. In the current research paper, the concept of the hybrid car in combination with routing problem is implemented using the genetic algorithm.

The four major parameters has been used in fitness function for the static routing problem discussed in the paper-:

- Cost
- Time
- Electricity (fuel mode 0)
- Petrol (fuel mode 1)

Prior work: The Vehicle Routing Problem (VRP) is a complex combinatorial optimization problem that belongs to the NP-complete class. Due to the nature of the problem it is not possible to use exact methods for large instances of the VRP. Genetic algorithms provide a search technique used in computing to find true or approximate solution to optimization and search problems.

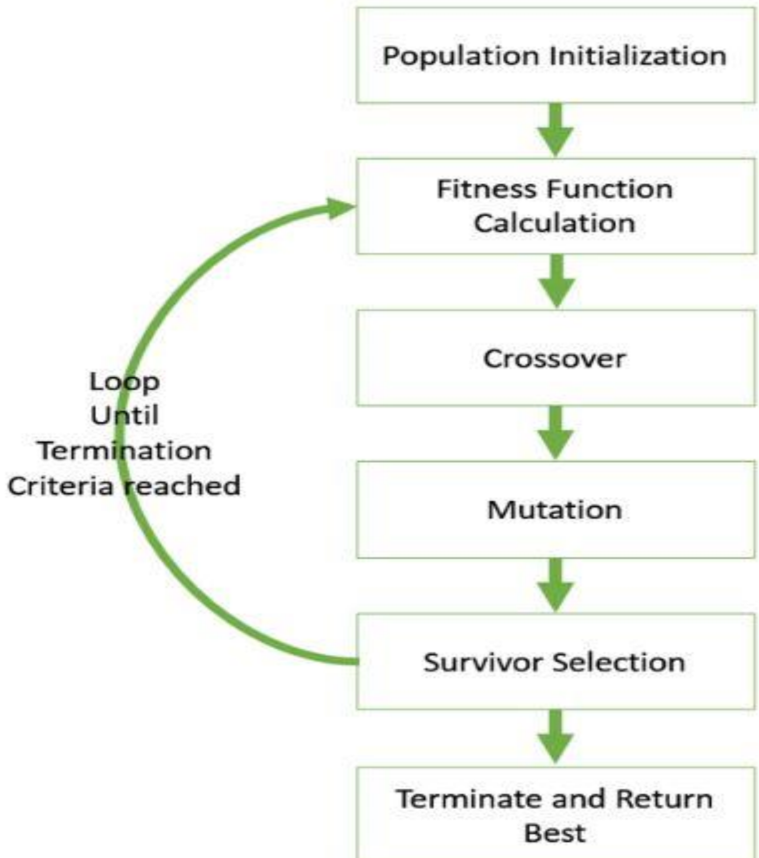
However some heuristic is also used in this paper in addition during crossover or mutation for tuning the system to obtain better result. The static vehicle routing is implemented here with the backhauling and penalty system used during fitness function calculation and parent selection [5].

DVRP(Dynamic vehicle routing problem) is more practical in real world situation .In this new Customers orders can apper over time and significant reconfiguration of routes takes place dynamically while executing the current solution.Because of the NP hardness of DVRP it is widely used in real world situations with combination of proper meta-heuristic used.Practical applications includes dial-a-ride services(door to door services over small areas) [6] , reapir and courier services(which involves single insertion in the tours with time constraints and express mail delivery(which involves pickup and delivery of the item at different locations) [7].

Hybrid vehicle serves a important purpose of preservation of renewable fuel and in combination with dynamic vehicle routing produces tremendous results. The method has also been tested on a simplified version of the HVRP already presented in the literature, the Green Vehicle Routing Problem (GVRP), and very good results have been obtained. A reduction in pollution can be obtained in two different ways: through a better exploitation current resources, and by using new, environmental friendly technologies. The first step in this process is to make a better use of available resources. This could be obtained by applying more efficient and sophisticated routing planning optimization methods and adopting smart distribution systems, [8], [9], which would help to decrease the traveling distance of vehicles and hence emissions. However, this generally results in a decline of emissions of only a few percent and the emission level of trucks and vans remains high. A more promising strategy is the use of zero emission electric battery vehicles. One emerging research area concerns pollution emission minimization.

In [10], the authors introduced the Pollution-Routing Problem (PRP), an extension of the classical Vehicle Routing Problem with Time Windows, which consists in routing a number of vehicles to serve a set of customers, and determining their speed on each route segment in order to minimize a function that includes fuel, emission and driving costs. The same problem has been addressed in [11] where an Adaptive Large Neighborhood Search based heuristics approach is proposed. A time-dependent version of the PRP has been addressed in [11], while [12] introduced the bi-level pollution routing problem. In [13] the recharging vehicle routing problem (RVRP) was introduced, in which vehicles were allowed to recharge directly at customer locations, adding a time penalty to the route duration. Erdogan and Miller Hooks, [9] were the first to combine a VRP with the possibility of refueling a vehicle at a station along the route. They considered a limited number of refueling infrastructures located along the network and a fixed recharging time (independent of the remaining level of battery charge). The proposed Green Vehicle Routing Problem (GVRP), considers a maximum route duration and fuel constraint. Fuel is consumed with a given rate per traveled distance and is tank is totally replenished at recharging stations. Schneider et al., [22], present the Electric Vehicle Routing Problem with Time Windows and Recharging Stations (E-VRPTW), which can be seen as an extension of the GVRP in which time windows are considered. An extension of the E-VRPTW, where partial recharging are allowed, has been studied in [4]. Finally, multiple recharging technologies, characterized by different recharging times and costs, have been introduced in [10].

Basic framework of genetic algorithm:

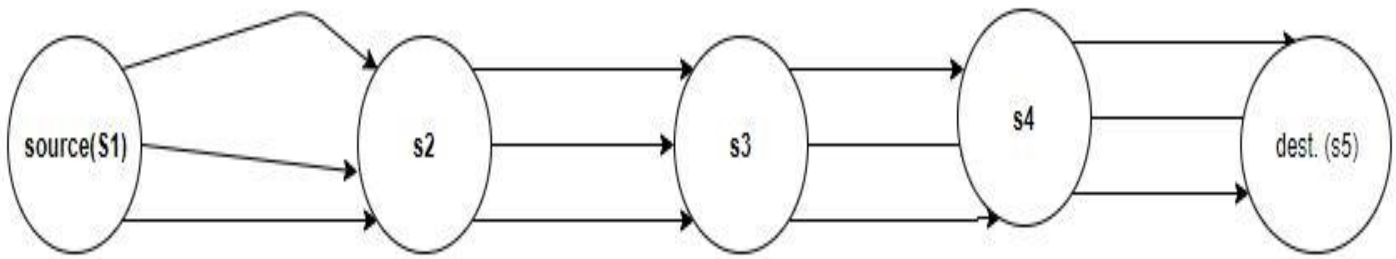


Basic algorithm of the genetic algorithm used -:

```
GA()
   initialize population
   find fitness of population

   while (termination criteria is reached) do
      parent selection
      crossover with probability pc
      mutation with probability pm
      decode and fitness calculation
      survivor selection
      find best
   return best
```

Basic structure of the problem to be implemented :

Data representation is shown below as figure 1 -:



- **This problem is to calculate the static optimized route from source s1 to destination s5 with intermediate destinations as s2,s3 and s4 to satisfy the user requirements based on discussed parameters in sixth point.**
- **Now assumption is that car has to travel each of the intermidiate sub_destinations that is s2,s3 and s4.**
- **Car is hybrid that means it can switch mode of operation between petrol and electricity during change of path from one to another.**
- **Dataset of the paths is generated and information of all paths available between two intermediate destination is fetched and recorded in a data structure on which GA is applied.**
- **Each path can either be traversed via petrol mode 0 or elctricity mode 1**
- **for each mode , for each path , there are 3 sub_paths to reach a sub_destination and details of these paths are given as-: the cost incurred , time spent , petrol used and electricty used.¶**
- **The goal is to give a static route from source to destination satisfying user requirements according to the priorities given to each of the four factors listed in above point.**

Chromosome analysis-:
Geneotype information -:

Encoding used : Binary encoding in combination with integer value encoding ie., hybrid combination of binary encoding with integer value encoding.

F1	**F2**	**F3**	**F4**
R1	**R2**	**R3**	**R4**

Binary part of a gene-:

- The set of **F ={F1,F2,F3,F4…FN}** denotes fuel mode to be taken**.**
- F can take a binary value(0 or 1).0 denotes pterol fuel mode and 1 denotes electricty mode.
- N is the size of chromosome

Integer value part of gene-:

- The set of **R={R1,R2,R3,R4…RN}** denotes the route to be taken for a path
- R can take values ={1,2,3} which denotes route number which can be followed.

Phenotype representation-:

- Let us take a population of size **P=8.**
- Phenotype is lised below.
- It comprises of two populations in the form of two matrices -:fuel_pop for fuel modes and path_pop for route to be taken.

```
[[0 0 1 0]
 [0 0 0 0]
 [1 0 0 1]
 [0 0 1 1]
 [0 1 0 1]
 [0 1 1 0]
 [0 1 1 1]
 [0 1 1 0]]
```

```
[[2 2 2 1]
 [2 3 1 1]
 [2 2 2 2]
 [3 2 1 1]
 [1 2 2 3]
 [3 2 1 2]
 [1 1 2 3]
 [2 2 1 2]]
```

- First matrix shown is fuel_path [i,j] which denotes random fuel mode to be used by car in i^{th} population for the j^{th} path.

- Second matrix shown is path_pop[i,j] which denotes random route(j) to be taken in i^{th} polulation for the j^{th} path.
- For example fuel_path [0,0]=0 and path_pop [0,0]=2 denotes that from s1 to s2 car travels with fuel mode “0” ie., petrol and has taken route number “2”.
- The above generated two populations are generated randomly using numpy library in python.

Fitness calculation -:

- Four parameters are used for each of the four factors that are -: cost ,time, petrol and electricity
- Strict assumption is that any one of these factors cannot be derived from each other that is ,cost during journey depends on fuel used either petrol or electricity but there is no direct formula to get exact cost as various taxes and other costs can occur in a particular path travelled by car.
- Four parameters are constants which represent the priorities or the weights given to each of the above listed factors.
- **Parameters=[k1,k2,k3,k4]** where {k1,k2,k3,k4} € set of constants.
- {k1, k2 ,k3, k4} represents weights of cost, time, petrol and electricity respectively.
- Let the list **factors =[cost, time, petrol, electricity].**

Objective function used -:

$$F(objective)=\sum(Parameters_i)*(factors_i) \text{ and i loops from 0 to 3.}$$

$$\Rightarrow k_1*cost+ k_2*time+ k_3*petrol+ k_4*electricity.$$

Parent selection -:

- Here the **x** best parents are selected which are selected for crossover and mutate to produce the offsprings.
- x= no_of_parents in the implimentation.
- Various other policies of parent selection can be used as listed below-:
- Roulette wheel selection, Stochastic Universal Sampling(SUS),Tournament Selection ,Rank selection and Random selection.

Crossover -:

- Various policies of crossover that can be used are listed below -:
- One point crossover, multi point crossover, uniform crossover , Whole arithmetic recombination and Davis’ Order crossover.
- In the problem crossover followed is one pint crossover and is shown below -:

Crossover example -:

First chromosome -:

0	**1**	**1**	**0**
2	**2**	**3**	**1**

Second chromosome -:

0	**1**	**0**	**1**
3	**3**	**3**	**1**

Resultant crossover chromosome after crossover at mid point -:

0	**1**	**0**	**1**
2	**2**	**3**	**1**

Mutation -:

- It is used to maintain and introduce diversity in the genetic population and is usually applied with a low probability – $\boldsymbol{p_m}$. If the probability is very high, the GA gets reduced to a random search.
- Various mutation operators used are listed below -:
- Bit flip mutation, Random resetting , Swap mutation ,Scramble mutation ,Inversion mutation.

Mutation used in the problem -:

- Combination of bit flip mutation in fuel part that is F and random resetting in route part that is R.

Let us take the crossover chromosome obtained in above case -:

- Let us take the mutation point as 2 that is 2^{th} index or the third allele or the third column of chromosome
- On flipping the fuel part and random resetting the route part , mutated chromosome is shown below -:

0	**1**	**1**	**1**
2	**2**	**1**	**1**

Survivor selection -:

- Varous policies used for survivor selection are listed below -:
- Age based selection and fitness based selection.

Termination conditions -:

- When there has been no improvement in the population for X iterations
- When we reach an absolute number of generations.
- When the objective function value has reached a certain pre-defined value.

Experimental Results -:

- Let us consider a organised dataset for figure 1.
- For each of the two intermediate and consecutive sub_destinations that is from S_i to S_{i+1} three paths are given.
- Each of these path can either be travelled with electricity or petrol as fuel mode.

- For each of these path values of cost ,time, petrol and electricity will be given in respective units.
- There are four paths one between S_1 to S_2 , S_2 to $S_{3,}$ S_3 to S_4 and S_4 to S_5.
- Dataset for each path is shown below as 2D matrix(M) where M_{ij} represents list of four factors that is cost(in INR), time(in mins) , petrol(in litres) and electricity(units) repectively, i represents fuel mode taken and j is the route number to be taken.

Datasets -:

Matrix 1 for path 1-:

Fuel mode as row Route number as column	Route 1	ROUTE 2	ROUTE 3
0(Petrol mode)	**[100,40,3,0]**	**[90,35,3,0]**	**[67,25,2,0]**
1(electricity mode)	**[80,45,0,5]**	**[70,40,0,6]**	**[45,35,0,5]**

Matrix 2 for path 2-;

Fuel mode as row Route number as column	Route 1	ROUTE 2	ROUTE 3
0(Petrol mode)	**[120,50,5,0]**	**[100,40,4,0]**	**[75,35,4,0]**
1(electricity mode)	**[80,65,0,8]**	**[70,50,0,7]**	**[45,45,0,6]**

Matrix 3 for path 3-:

Fuel mode as row Route number as column	Route 1	ROUTE 2	ROUTE 3
0(Petrol mode)	**[70,30,3,0]**	**[90,35,3,0]**	**[67,25,2,0]**
1(electricity mode)	**[80,45,0,5]**	**[70,40,0,6]**	**[45,35,0,5]**

Matrix 4 for path 4 -;

Fuel mode as row Route number as column	Route 1	ROUTE 2	ROUTE 3
0(Petrol mode)	**[150,50,8,0]**	**[90,35,3,0]**	**[67,25,2,0]**
1(electricity mode)	**[100,70,0,11]**	**[70,40,0,6]**	**[45,35,0,4]**

Example 1 -:

Variables -:

- pop_size(size of population)=8
- chromosome_size(size of chromosome)=4
- no_of_generations(size of generation)=10
- no_of_parents(size of parents)=4
- crossover_point(crossover point)=2
- crossover rate=0.25
- mutation rate=0.6
- mutation_point(mutation point)=2
- constants(parameters)=[1,2,3,3]

Technical output after generations -:

```
Generation  0  results:


fitness values are :
[595 732 821 711 778 627 715 655]

best cost is:  595

Generation  1  results:


fitness values are :
[595 627 655 711 619 615 652 755]

best cost is:  595
```

```
Generation  2  results:


fitness values are :
[595 615 619 627 579 657 621 656]

best cost is:  579

Generation  3  results:


fitness values are :
[579 595 615 619 621 579 630 553]

best cost is:  553




Generation  4  results:


fitness values are :
[553 579 579 595 550 553 621 579]

best cost is:  550

Generation  5  results:


fitness values are :
[550 553 553 579 577 579 550 579]

best cost is:  550

Generation  6  results:


fitness values are :
[550 550 553 553 579 579 579 577]

best cost is:  550

Generation  7  results:


fitness values are :
[550 550 553 553 577 577 577 577]

best cost is:  550

Generation  8  results:
```

```
fitness values are :
[550 550 553 553 577 577 579 579]

best cost is:  550

Generation  9  results:


fitness values are :
[550 550 553 553 577 579 577 579]

best cost is:  550
```

User interactive output using genetic algorithm -:

```
best path available is :

fuel on which car needs to operate on path  1  is:
electricity
route to be taken for path  1  is:  3

fuel on which car needs to operate on path  2  is:
petrol
route to be taken for path  2  is:  3

fuel on which car needs to operate on path  3  is:
petrol
route to be taken for path  3  is:  1

fuel on which car needs to operate on path  4  is:
electricity
route to be taken for path  4  is:  3


cost for this optimum path is:  550
```

Comparision with researched algorithm -:

- **This problem can be solved by Brute force approach with exponential complexity**
- **Complexity =O(pow(6,4))=O(1296)**
- **Generalized complexity -:**
- **If route numbers are 1 to R and there are N no. of paths that is there are N+1 places including source and destination ,complexity =O(pow(2*R,N)).**
- **It will halt the system.**

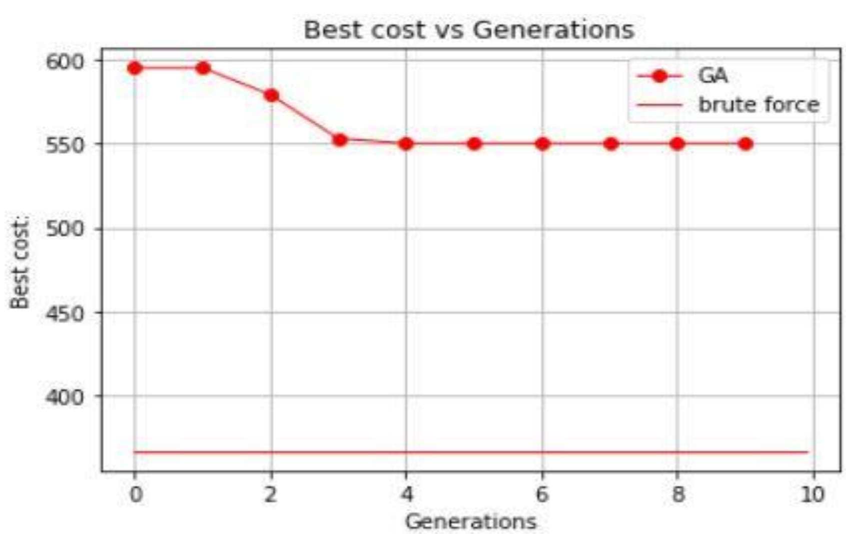
Comparison of two algorithms outputs -:

- **Output from brute force is always the best possible output but takes exponential time as explained**

User interactive output from brute force approach is as follows-;

```
fuel on which car needs to operate on path  1  is:
electricity
route to be taken for path  1  is:  3


fuel on which car needs to operate on path  2  is:
electricity
route to be taken for path  2  is:  3


fuel on which car needs to operate on path  3  is:
petrol
route to be taken for path  3  is:  1


fuel on which car needs to operate on path  4  is:
electricity
route to be taken for path  4  is:  3


best_cost is: 367
```

Analysis through plot-:



Example 2 -:

Variables -:

- pop_size(size of population)=8
- chromosome_size(size of chromosome)=4
- no_of_generations(size of generation)=10
- no_of_parents(size of parents)=4
- crossover_point(crossover point)=2
- crossover rate=0.45
- mutation rate=0.55
- mutation_point(mutation point)=2
- constants(parameters)=[1,2,3,3]

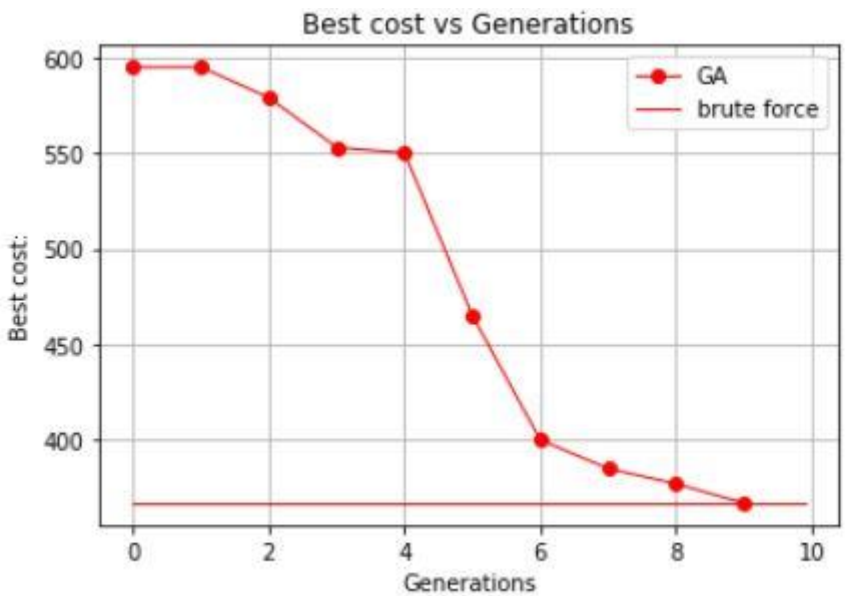
Technical output after generations -:

```
Generation  0  results:


fitness values are :
[595 732 821 711 778 627 715 655]

best cost is:  595

Generation  1  results:


fitness values are :
[595 627 655 711 619 615 652 755]

best cost is:  595



Generation  2  results:


fitness values are :
[595 615 619 627 579 657 621 656]

best cost is:  579

Generation  3  results:


fitness values are :
[579 595 615 619 621 579 630 553]

best cost is:  553
```

```
Generation  4  results:


fitness values are :
[553 579 579 595 550 553 621 579]

best cost is:  550

Generation  5  results:


fitness values are :
[550 465 466 467 553 463 470 471]

best cost is:  465

Generation  6  results:


fitness values are :
[465 400 402 500 451 443 445 446]

best cost is:  400

Generation  7  results:


fitness values are :
[400 399 398 385 388 390 396 392]

best cost is:  385

Generation  8  results:


fitness values are :
[385 382 377 388 390 395 392 396]

best cost is:  377

Generation  9  results:


fitness values are :
[377 369 382 385 390 392 388 367]

best cost is:  367
```

User interactive output using genetic algorithm -:

```
best path available is :

fuel on which car needs to operate on path  1  is:
electricity
route to be taken for path  1  is:  3

fuel on which car needs to operate on path  2  is:
electricity
route to be taken for path  2  is:  3

fuel on which car needs to operate on path  3  is:
petrol
route to be taken for path  3  is:  1

fuel on which car needs to operate on path  4  is:
electricity
route to be taken for path  4  is:  3


cost for this optimum path is:  367
```



Conclusion-: This research paper is an attempt to focuss on environmental pollution and depletion of the renewable resources (fuel).It does not focuss on the entire substitution of the petrol as a fuel but algorithm finds a collaborative solution comprising of using both petrol and electricity as fuel and also satisfies the user requirements.

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