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Meta-Heuristics Algorithms of Intelligent Parking System on a Rush Hour Centre in Space Transport and Propulsion

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Abstract

The search for parking space is a time consuming process which not only affects the economic activities efficiency, but also the social interactions and cost. The need for efficient parking management systems especially during rush hour cannot be emphasized enough for such cities. Therefore, this study seeks to provide a solution to the issues by hybridizing two algorithms: Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) during rush hour in space transport and propulsion at a particular city Epe in Nigeria. This was measured by some metrics parameter such as Time-taken, Cost and User-satisfaction to solve the problem of premature convergence. The three algorithms: (GA-PSO, PSO and GA) using a Matric Laboratory (MATLAB) program in an intelligent parking system tried to allocate the route for the user vehicle in an optimal manner. GA-PSO solved the parking allocation problems by obtaining minima values in terms of the cost and time taken with high user satisfaction. The experimental results demonstrated an accurate and robust car parking space allocation algorithm. In return, a GA-PSO based car parking space allocation algorithm produced a reliable car parking allocation system.

Keywords: Genetic Algorithm (GA); Particle Swarm Optimization (PSO); Genetic Particle Swarm Optimization (GA-PSO); Matric, Laboratory (MATLAB) Program; Centre Space Transport and Propulsion (CSTP).

1. INTRODUCTION

Any parking lot offenses are kept under control by the parking enforcement. This makes it feasible to make the greatest use of the parking space in order to increase revenue and decrease the amount of time it takes to park a car in the parking lots. The parking system that is now in use is inefficient because parking is permitted without any restrictions and the parking facility cannot be utilized to its full potential [1]. The difficulty in managing has increased the need for intelligent solutions that will let vehicles choose the best alternative when identifying available parking spaces. The necessity for an effective parking system is brought on by factors like increased traffic, automobile pollution, driver annoyance, and exhaustion, to name a few.

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Mete-heuristics are computational approaches that are used to identify good and workable solutions to complex optimization problems (randomness or local search) [2][3] especially many real-world situations that are combinatorial in nature [4]. In order to solve the issue of car parking space, the genetic algorithm (GA) and particle swarm optimization method (PSO) are most frequently utilized.

In a GA, a population or collection of solutions would first be generated at random. The fittest solutions would then be chosen at the end of each iteration using a fitness function that is relevant to the issue area. Since the majority of these functions are stochastic, only a small percentage of the less-fit solutions would be chosen. This is done to maintain a diverse population and prevent an early convergence of subpar solutions. The chosen solutions are then checked to see if the best one is found; if not, recombination and mutation are used to breed the next new solution. This process is repeated until the best solution is identified or a predetermined number of generations has been reached [5][6].

PSO is a nature-inspired algorithm that takes cues from fish schooling, human social behaviour, and bird flocking. PSO, a meta-heuristic algorithm, was specifically motivated by the cooperative or swarming behaviour of biological populations [7]. One of the most significant swarm intelligence frameworks for tackling global optimization issues is PSO [8]. This method is suitable for technical applications and has a background of unfathomable intelligence. As a result, the PSO technique has garnered considerable interest from scholars working in the area of evolutionary computation and has produced several study findings over time [9].

In order to assess the accuracy of the developed system, this study focuses on the examination of the efficiency of hybridization of genetic particle swarm optimization (GA-PSO) for automatic assignment of parking space for cars based on specific assumptions and available parking space. It also demonstrated how well the GA-PSO methodologies worked when choosing the methods for the intelligent parking system. The work also concentrated on the application of real-time data collected during rush hour in a car parking space system being employed at the Centre for Space Transport and Propulsion (CSTP) in Epe Lagos State. The survey was conducted for two weeks, and the information acquired was utilized to test and assess how well the established system performed and how the results compared to earlier efforts.

2. RELATED WORKS

The length of time it takes a car to look for a parking spot is a time-consuming procedure that affects the effectiveness of economic activities as well as social interactions and financial implications [10]. The goal of the parking space allocation problem is to determine how to allocate a certain number of parking spaces among a specific number of vehicles while still maintaining certain criteria [11]. The allocation of parking spaces essentially has two goals: in order to effectively assign entities to spaces, it is first important to reduce space usage. Second, to reduce the punishment for breaking the problem's soft constraints. The hard constraint and the soft constraint are the two different categories of restrictions. The soft constraint should be punished because the hard constraint must be satisfied in order to find a workable alternative while the soft constraint does not [12].

Finding parking can be a difficult problem in many places. If there are no parking spaces available where they are going to park, cars will begin to circle the blocks, contributing up to 30% of all traffic in congested urban settings [13]. A system, called S3, which is deployed in school zones, designed to detect and register vehicles driving at excessive speeds or parked in prohibited zones was described [14]; used in school zones and intended to detect and register vehicles traveling at excessive speeds or parking in banned areas. A wireless sensor network that is separated into two smaller networks makes up this system. One sub network detects parked cars in no-parking zones, and the other detects fast-moving cars. Anisotropic Magneto-Resistive (AMR) magnetic sensors are employed, and ZigBee establishes the wireless communication link.

A sophisticated parking system for cities. Parking detection, reservation assurance, and infrastructure-to-vehicle (I2V) or vehicle-to-infrastructure (V2I) communication are only a few of the system's features. The system assigns and reserves an appropriate parking space taking into account the needs of the 28 users, balancing proximity to the destination and parking fee, ensuring that the total parking capacity is effectively utilized. The system was put to the test in a Boston University garage [15]. It was suggested to develop an intelligent parking system that makes use of image-processing methods to address the issue of wasting time looking for a parking place in commercial parking lots.

Information about the available parking spaces is provided by the parking management system, as well as an automated payment system for registered users [16], while [17] suggested a low-cost service to provide information about the available parking spaces as well as an automatic payment system for registered users. This service is built on a central system that forecasts parking spaces using cellular automata and a smartphone app that employs a variety of technologies to direct vehicles to vacant spots. Hence, this work developed GA-PSO, which combined genetic algorithm (GA) and Particle Swarm Optimization (PSO) to generate the optimal solution

3. METHODOLOGY

3.1 Experiemental Setup of GA-PSO

Parking space allocation depends on dynamicity of parameters like traffic, free slots available, distance and cost; using route allocator to find the parking space along with the optimal route to reach the destination. GA-PSO adopted the simulation of a Particle Swarm Optimization (PSO) tuned with Genetic Algorithm (GA) to allocate parking space for vehicles using MATLAB program. The architecture is shown in Figure 1:

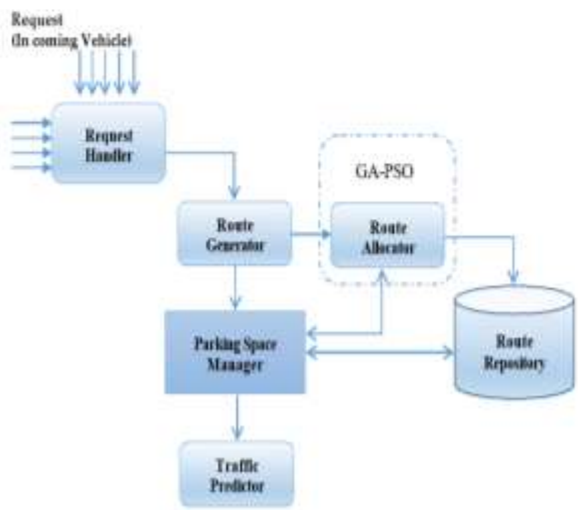

Figure 1: An enhanced system architecture of a car parking space

3.2 The System Design

An optimal allocation of route to user's request in the real time environment is a challenging task. The parking space allocation problem can be viewed as selecting a route from source to destination, which is optimal in terms of distance and time thereby minimizing the waiting time of the vehicle and maximizing satisfaction of users. The factors to be taken into account while choosing optimal route is given below as:

- Request handler receives the request from any number of homogenous vehicles (car) sat time *t*.
- Every vehicle V_k submitted by the user needs to be allocated a parking space P_{sj} which satisfies the parameters like distances, cost and time.
- Optimal allocation of a parking space P_{sj} or the vehicle V_k is viewed as constraint satisfaction problem and it formulated using integer linear programming.

Let the number of users be N_i, the number of parking spaces P_s while the source and destination of the i^{th} user given as S_i and D_j. The objective is to allocate the optimal route from source to destination, which saves time and cost. The route consists of set of paths from source to destination. The route network can be represented as a graph, where represents the set of parking spaces, and represents the edges between them.

i. Representation of user request: The vehicle V_k for the user is represented as:

$$V_k \leftarrow \{(V_k)_{id},\ Source_{Vk},\ Destination_{Vk},\ Deadline_{Vk},\ Budget_{Vk}\} \quad (1)$$

where $(V_k)_{id}$ represents vehicle id
$SourceV_k$ represents starting place of V_k
$DestinationV_k$ represents end place of V_k
$DeadlineV_k$ represents the maximum time before which the V_k should reach $DestinationV_k$ and $BudgetV_k$ represents the total cost required to process the user request.

ii. Representation of parking space: The parking space P_{si} is represented as:

$$P_{Sj} \leftarrow \{(P_{Sj})_{id},\ Cost_j,\ free\_slots\} \quad (2)$$

whereas $(P_{Sj})_{id}$, represents the parking space id $Cost_j$ represents the cost per hour for the vehicle V_k and *free_slots* represent the available free slots in parking space P_{Sj}

iii. Representation of route: A route R_k from source destination is represented as:

$$R_k \leftarrow (S_i - PS_a - PS_c - PS_d - PS_f - D_j) \quad (3)$$

whereas S_i and D_j represents the source and destination respectively and each PS_u represents the parking space, i.e. $PS_u \in \{PS\}$. Similarly, there are n numbers of routed available between source and destination.

3.3 GA-PSO Formulation

The mathematical formulation of the space allocation problem is defined as:

$$Minimize \sum_{i}^{n}\sum_{j}^{m} C_{ij} X_{ij} \qquad (4)$$

$$\sum_{i}^{n} X_{ij} \le T_j \forall j = 1,..,m \qquad (5)$$

$$L_i \le \sum_{i}^{m} X_{ij} \le U_i \forall j = 1,..,n \qquad (6)$$

where $i = 1,...,m$ is the set of entity indices, $j = 1,..,n$ is the set of space area indices, C_{ij} is the cost of assigning an entity i to a space area j, T_j is the total space capacity, L_i and U_i are the lower and upper bounds of the number of entities to be allocated. Equation (5) indicates that the total number of allocations must not exceed the space area capacity and Equation (6) represents the constraints of the lower and upper bounds.

PSO has a faster convergence rate but its allocation solution cannot be global optima in space allocation. Therefore, GA-PSO will get a more optimized space allocation when PSO has already converged; which helped this study to get a solution closer to global optima or global optima in adaptive space resource allocation. Algorithm for GA-PSO is given below:

Step 1: Generate random population of N, set adaptive parameter according to equation 10, 11 and 12

Step 2: Initialize population of particles havinf positions X_j and velocities V_j using 7, 8 and 9.

Step 3: Set itersation $k = 1$

Step 4: Calculate fitness of particles $F_{ij}(t) = f \vec{x}_{ij}(t))$and find the index of the best particle *b*.

$$\vec{x}_{ij}(t) = Minimize \sum_{i}^{n}\sum_{j}^{m} e^{C_{ij}X_{ij}}\ subject\ to$$

$$\sum_{i=1}^{n} X_{ij} \le T_j \forall\ j = 1,.,m\ L_i \le \sum_{j}^{m} X_{ij} \le U_i \ \forall\ j = 1,,n$$

where i = 1,..,m is the entity indices, j = 1,...,n is the set of space area indices, C_{ij} is the cost of assigning an entity i to a space area j, T_j is the total space capacity; L_i and U_i are the lower and upper bound of the number of entities to be allocated.

Step 5: Select $Pbest_{ij}(t) = \vec{x}_{ij}(t)$ and $Gbest_{ij} = x_{bj}(t)$.

Step 6: $\omega = \omega_{max} - k * \frac{\omega_{max} - \omega_{min}}{Max_{no} - \omega_{min}}$

where current iteration, ω_{max} is the final weight, ω_{min} is the initial weight, ω is the inertia weight employed to overcome the problem of premature convergence.

Step 7: Update velocity and position of particles*:* $\vec{v}_{ij}(t+1) = X\omega\vec{v}_{ij}(t) + c_1r_1\left(P_{best} - \vec{x}_{ij}(t)\right) + c_2r_2\left(P_{best} - \vec{x}_{ij}(t)\right) + c_3r_3\left(G_{best} - \vec{x}_{ij}(t)\right)\vec{x}_{ij}(t+1) = \vec{x}_{ij}(t) + \vec{v}_{ij}(t+1)$

Step 8: Evaluate fitness $F_{ij}(t) = f(\vec{x}_{ij}(t+1))$ and find the index of the best particle b_1

Step 9: Update Pbest of population: $if F_{ij}(t+1) < F_{ij}(t)\ then\ Pbest_{ij}(t+1) = \vec{x}_{ij}(t+1) else\ Pbest_{ij}(t+1) = Pbest_{ij}(t)$

Step 10: Update Gbest of population: $if F_{bj}(t+1) < F_{bj}(t) then\ Gbest_j(t+1) = Pbest_{bj}\,(t+1)\ and\ set\ b = b_1\ else\ Gbest_{bj}(t+1) = Gbest_t(t)$

Step 11: If $k < Max\_no$ then k = $k + 1$ and go to Step 2 else go to Step 11

Step12: Output optimum solution as $Gbest_{bj}$.$Gbest_{bj}=x_{bj}(t)$.

3.4 Performance Measure

The performance of the developed intelligent car parking system was evaluated in terms of cost, user satisfaction and time taken. User satisfaction: User was satisfied, if the vehicle reaches the destination within the deadline with minimum completion time. User satisfaction is calculated as follows:

$$User\ Satisfaction = \frac{|VS|_{si}}{|V|_{si}} \qquad (13)$$

where $|V|_{si}$ represents the total number of vehicles arrived for the i^{th} schedule S_i. $|VS|_{si}$ represents number of vehicles reaches the destination on time for the i^{th} schedule S_i.

4. RESULTS AND DISCUSSION

The survey taken lasted for two weeks and the following data were gathered. The total number of spaces in the car park is 340, a total of 10 schedules were taken spanning for two weeks for 10 working as shown in Table 1 below and the simulation results obtained by GA-PSO, PSO and GA techniques were presented for the validation of intelligent car parking system using MATLAB.

Table 1: Frequency of vehicles coming into the car park at CSTP Epe between 7th -18th December 2020

Date and Time	Frequency of Vehicles in the Car Park)	Total Frequency
Monday 7th Dec. 2020 (8.00-9.00am)	235	322
(9.00-10.00am)	87	
Tuesday 8th Dec. 2020 (8.00-9.00am)	214	304
(9.00-10.00am)	90	
Wednesday 9th Dec. 2020 (8.00-9.00am)	195	258
(9.00-10.00am)	63	
Thursday 10th Dec. 2020 (8.00-9.00am)	208	292
(9.00-10.00am)	84	
Frinday 11th Dec. 2020 (8.00-9.00am)	97	188
(9.00-10.00am)	91	
Monday 14th Dec. 2020 (8.00-9.00am)	254	327
(9.00-10.00am)	73	
Tuesday 15th Dec. 2020 (8.00-9.00am)	244	328
(9.00-10.00am)	84	
Wednesday16th Dec. 2020 (8.00-9.00am)	237	311
(9.00-10.00am)	74	
Thursday 17th Dec. 2020 (8.00-9.00am)	204	278
(9.00-10.00am)	74	
Friday 18th Dec. 2020 (8.00-9.00am)	167	241
(9.00-10.00am)	74	

The model was evaluated based on computation time, cost and user satisfaction with respect to a fixed packing dimension of the parking space at a point in time as seen in Table 2 to Table 4 respectively. The GUI of the three techniques is depicted in appendices A-C, also the system was simulated using numbers of cars of 100 ranging from 10-1000 can be seen in Appendices D-F respectively.

Table 2: Simulation results using GA-PSO 10 schedules during rush hour at CSTP Epe

Sc-hed ule	No of Vehi-cles	No of Parki-ng Spaces	Time Take-n	Cost	User Satis-fac-tion
1	322	340	85.25	2.13	0.48
2	304	340	87.75	2.19	0.45
3	258	340	50.07	1.52	0.48
4	292	340	57.57	1.42	0.49
5	188	340	56.04	2.23	0.54
6	327	340	59.42	2.09	0.53
7	328	340	48.54	2.40	0.48
8	311	340	94.34	2.54	0.46
9	278	340	70.77	2.27	0.51
10	241	340	68.72	2.06	0.53

Table 3: Simulation results using PSO 10 schedules on a rush hour at CSTP Epe

S/ N	No. of Vehi-cles	No of Park-ing Space	Time Taken	Cost	User Satisf-action
1	322	340	136.49	3.87	0.35
2	304	340	185.49	3.06	0.30
3	258	340	134.24	2.89	0.30
4	292	340	174.51	4.09	0.30
5	188	340	119.78	3.97	0.36
6	327	340	192.86	3.23	0.36
7	328	340	140.05	3.75	0.33
8	311	340	148.58	4.34	0.35
9	278	340	122.33	2.83	0.33
10	241	340	177.85	3.69	0.33

Table 4: Simulation results using PSO 10 schedules during rush hour at CSTP Epe

Sc-hed ule	No of Veh-icles	No of Park-ing Spac-es	Time Taken	Cost	User Satis-fac-tion
1	322	340	254.96	5.52	0.32
2	304	340	275.90	6.62	0.28
3	258	340	253.37	5.97	0.34
4	292	340	281.85	6.10	0.30
5	188	340	256.94	6.15	0.31
6	327	340	263.74	5.57	0.29

7	328	340	221.14	5.92	0.34
8	311	340	261.69	5.77	0.27
9	278	340	300.29	5.49	0.32
10	241	340	250.62	6.17	0.31

Table 5 depicted the results evaluation in terms of the computation time, cost value and user satisfaction for PSO, GA and GA-PSO based intelligent car parking system during rush hour were presented in this section. In GA technique, time taken for the vehicle from source to destination was the highest, since it chose the shortest route as the best route. In the case of PSO technique, the time-taken for the vehicle to reach destination was higher than in GA-PSO while time taken for vehicles to reach destination was minimum in GA-PSO.

Table 5: GA-PSO, PSO and GA during rush hour in a car parking with a maximum of 340 parking spaces

S/N	Techniques	Time Taken	Cost	User Satisfaction
1	GA-PSO	67.85	2.09	0.50
2	PSO	I53.22	3.57	0.33
3	GA	262.05	5.93	0.31

Figure 5 demonstrated how GA-PSO achieved minimum result compared with PSO and GA techniques. The result of GA-PSO technique when compared with PSO and GA techniques had the least value in terms of cost. As GA-PSO chose the route based on minimum distance and cost of the parking space per second, the cost incurred was less in GA-PSO. GA arbitrarily allocated the user request for the route, thus maximizing the time and cost of the request. PSO picked the first route as the best route irrespective of cost and produced high cost compared with GA-PSO while GA had the highest cost. Figure 6 ddisplayed GA-PSO, having the minimum cost than PSO and GA techniques.

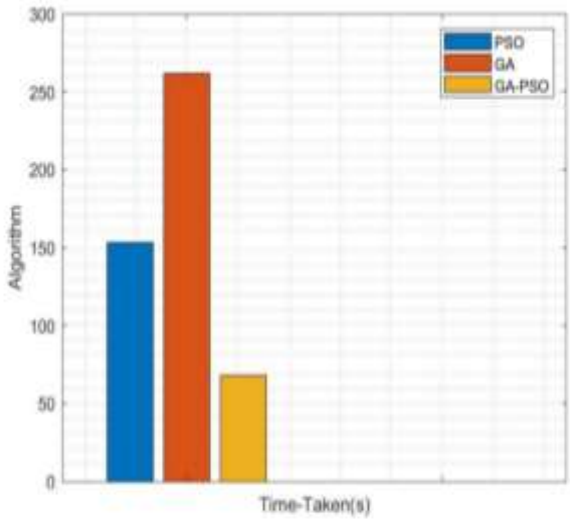

Figure 5: Graph showing time taken by GA, PSO and GA-PSO during Rush hour in a car park

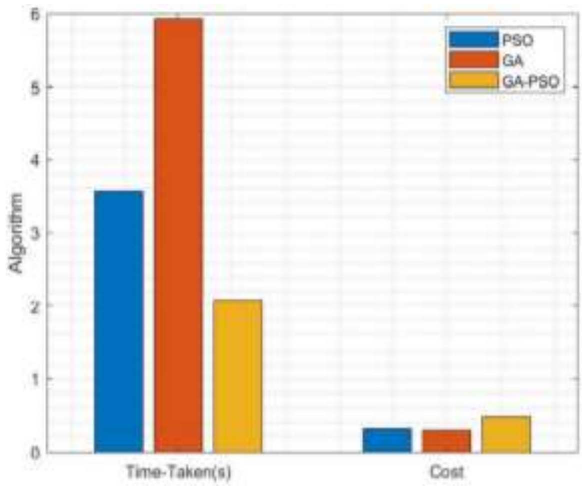

Figure 6: Graph showing time taken and cost by GA, PSO and GA-PSO during rush hour in a car park

5. CONCLUSION

This study evaluated the essential features of GA-PSO, PSO and GA techniques as route allocator in intelligent car parking system. A model of car parking space with respect to parking scale dimension was simulated using MATLAB program. The experimental results demonstrated an accurate and robust car parking space allocation technique. The three optimization techniques try to allocate the route for the user vehicle in an optimal manner. Therefore, GA-PSO solved the parking allocation problem by obtaining minima values in terms of the cost and time taken with high user satisfaction. In view of this, a GA-PSO based car parking space allocation technique would produce a reliable car parking allocation system and also favours rush hour over GA and PSO in terms of cost, computation time and user satisfaction just as seen from the simulation results.

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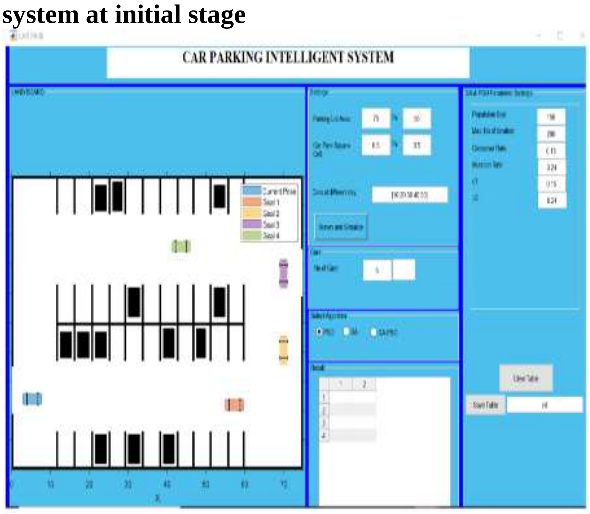
APPENDICES

Appendix A: Graphic user interface showing car system at initial stage



Appendix B: Graphic user interface showing car parking system at processing stage

Appendix C: Graphical user interface showing car parking system at final stage

Appendix D: Simulation result using GA-PSO 100 schedule

Schedule	No of Vehicles	No of Parking Spaces	Time Taken	Cost	User Satisfaction
1	10	5	33.94	1.50	0.50
2	20	10	34.21	2.46	0.45
3	30	15	34.70	1.84	0.47
4	40	20	40.66	2.13	0.45
5	50	25	30.58	2.44	0.50
6	60	30	51.67	2.14	0.53
7	70	35	41.18	2.28	0.51
8	80	40	47.10	1.39	0.51
9	90	45	35.02	1.45	0.53
10	100	50	43.46	1.47	0.47
11	110	55	41.49	1.64	0.54
12	120	60	50.25	2.35	0.50
13	130	65	32.30	2.07	0.53
14	140	70	41.61	1.73	0.46
15	150	75	42.07	2.09	0.53
16	160	80	29.87	2.02	0.48
17	170	85	36.83	2.04	0.52
18	180	90	44.94	1.41	0.52
19	190	95	37.71	2.14	0.49
20	200	100	46.32	1.78	0.51
21	210	105	28.70	1.38	0.47
22	220	110	51.79	2.04	0.48
23	230	115	28.59	2.27	0.47
24	240	120	47.39	2.35	0.50
25	250	125	28.15	2.18	0.48
26	260	130	41.80	1.90	0.46
27	270	135	29.20	1.53	0.51
28	280	140	44.01	1.38	0.51
29	290	145	32.98	1.49	0.53
30	300	150	30.21	2.53	0.48
31	310	155	42.54	2.46	0.50
32	320	160	32.97	1.61	0.53
33	330	165	27.41	1.41	0.50
34	340	170	37.41	1.96	0.51
35	350	175	31.45	1.91	0.47
36	360	180	42.38	2.42	0.47
37	370	185	28.49	1.76	0.51
38	380	190	31.64	2.43	0.46
39	390	195	28.85	2.47	0.48
40	400	200	47.76	1.53	0.46
41	410	205	27.42	1.76	0.48
42	420	210	50.15	1.87	0.46
43	430	215	39.28	2.08	0.54
44	440	220	33.89	2.43	0.53
45	450	225	28.14	1.66	0.48
46	460	230	34.92	2.18	0.53
47	470	235	37.81	1.82	0.50
48	480	240	33.16	2.11	0.51
49	490	245	34.85	1.92	0.46
50	500	250	38.88	1.80	0.45
51	510	255	51.34	1.60	0.50
52	520	260	29.82	1.62	0.53
53	530	265	31.17	1.68	0.49
54	540	270	32.43	1.45	0.53
55	550	275	49.42	2.01	0.51
56	560	280	48.29	2.02	0.47
57	570	285	49.87	2.03	0.46
58	580	290	30.73	2.14	0.47
59	590	295	36.84	1.56	0.47
60	600	300	36.08	2.04	0.45
61	610	305	35.33	2.34	0.49
62	620	310	42.21	1.86	0.54
63	630	315	43.92	2.54	0.48
64	640	320	28.43	2.54	0.51
65	650	325	30.55	1.42	0.47
66	660	330	40.31	1.57	0.50
67	670	335	52.08	1.51	0.51
68	680	340	29.34	2.29	0.47
69	690	345	29.31	2.21	0.49
70	700	350	45.27	2.41	0.48
71	710	355	31.84	1.64	0.49
72	720	360	33.04	2.22	0.52
73	730	365	47.59	1.99	0.47
74	740	370	43.23	1.75	0.47
75	750	375	45.31	1.83	0.49
76	760	380	29.31	2.43	0.48
77	770	385	40.12	2.18	0.50
78	780	390	28.12	2.55	0.54
79	790	395	32.10	1.59	0.46
80	800	400	47.43	2.33	0.46
81	810	405	28.72	1.85	0.47
82	820	410	38.40	1.48	0.50
83	830	415	42.85	2.45	0.54
84	840	420	51.10	2.43	0.51
85	850	425	29.69	2.40	0.51
86	860	430	47.49	1.83	0.52
87	870	435	43.56	1.88	0.50
88	880	440	46.97	2.06	0.46
89	890	445	50.66	2.31	0.51
90	900	450	40.57	1.51	0.45
91	910	455	46.28	2.35	0.48
92	920	460	43.25	1.43	0.46
93	930	465	28.59	1.95	0.50

94	940	470	43.03	1.51	0.49
95	950	475	50.35	2.06	0.49
96	960	480	47.09	1.79	0.50
97	970	485	34.42	1.70	0.47
98	980	490	46.07	2.07	0.52
99	990	495	46.39	1.92	0.52
100	1000	500	33.38	2.27	0.47
Average	**505**	**252.5**	**38.58**	**1.96**	**0.49**

Appendix E: Simulation result using PSO 100 schedule

Schedule	No of Vehicles	No of Parking Spaces	Time Taken	Cost	User Satisfaction
1	10	5	79.66	3.47	0.30
2	20	10	90.44	3.04	0.30
3	30	15	92.16	3.19	0.30
4	40	20	96.68	4.41	0.33
5	50	25	68.50	3.43	0.34
6	60	30	80.23	3.44	0.35
7	70	35	94.88	3.54	0.31
8	80	40	60.08	3.98	0.31
9	90	45	81.14	3.12	0.34
10	100	50	76.55	2.89	0.34
11	110	55	62.27	2.69	0.34
12	120	60	65.01	4.17	0.31
13	130	65	78.13	3.91	0.33
14	140	70	56.86	3.14	0.35
15	150	75	88.74	3.31	0.30
16	160	80	54.55	2.87	0.35
17	170	85	52.12	2.98	0.36
18	180	90	57.59	3.70	0.32
19	190	95	74.17	4.10	0.33
20	200	100	74.43	3.29	0.34
21	210	105	68.30	3.83	0.31
22	220	110	53.36	4.13	0.30
23	230	115	61.38	3.29	0.31
24	240	120	78.07	4.29	0.32
25	250	125	72.38	3.87	0.36
26	260	130	97.41	3.62	0.32
27	270	135	84.18	3.49	0.36
28	280	140	80.33	4.09	0.33
29	290	145	69.93	3.46	0.32
30	300	150	65.55	3.19	0.34
31	310	155	83.35	4.04	0.35
32	320	160	55.59	2.67	0.32
33	330	165	68.61	2.94	0.30
34	340	170	51.82	4.46	0.33
35	350	175	98.95	4.16	0.30
36	360	180	81.24	3.11	0.36
37	370	185	53.38	3.90	0.35
38	380	190	66.32	3.30	0.31
39	390	195	70.32	2.71	0.35
40	400	200	55.29	3.52	0.35
41	410	205	91.02	3.01	0.34
42	420	210	78.77	3.2	0.34
43	430	215	93.18	2.65	0.30
44	440	220	80.53	4.36	0.33
45	450	225	51.31	2.82	0.34
46	460	230	80.17	4.47	0.33
47	470	235	62.86	2.61	0.33
48	480	240	52.05	3.92	0.35
49	490	245	87.10	3.59	0.33
50	500	250	94.02	3.18	0.35
51	510	255	65.78	3.28	0.31
52	520	260	62.90	3.35	0.36
53	530	265	88.50	3.29	0.32
54	540	270	53.57	4.47	0.34
55	550	275	58.06	4.14	0.35
56	560	280	64.14	3.92	0.33
57	570	285	85.75	3.16	0.32
58	580	290	85.30	4.34	0.31
59	590	295	78.74	3.41	0.34
60	600	300	90.52	4.13	0.32
61	610	305	64.04	4.11	0.36
62	620	310	83.83	4.41	0.34
63	630	315	77.90	3.37	0.34
64	640	320	70.21	4.25	0.31
65	650	325	84.03	3.90	0.34
66	660	330	94.67	3.24	0.32
67	670	335	57.93	2.86	0.33
68	680	340	72.65	3.42	0.33
69	690	345	91.62	4.42	0.31
70	700	350	51.34	3.62	0.30
71	710	355	52.34	4.03	0.31
72	720	360	82.55	4.45	0.35
73	730	365	93.81	3.96	0.31
74	740	370	80.65	3.56	0.34
75	750	375	52.00	3.82	0.36
76	760	380	88.28	3.80	0.36
77	770	385	53.43	3.10	0.34
78	780	390	65.69	2.85	0.34
79	790	395	65.31	3.36	0.33
80	800	400	61.45	2.65	0.31
81	810	405	57.45	4.31	0.36
82	820	410	64.71	3.51	0.35
83	830	415	79.64	3.00	0.34
84	840	420	52.60	3.03	0.33
85	850	425	72.73	2.81	0.35
86	860	430	79.80	3.88	0.33
87	870	435	82.50	2.90	0.32
88	880	440	66.67	4.13	0.34
89	890	445	88.10	3.80	0.30
90	900	450	66.72	2.87	0.36
91	910	455	67.07	3.66	0.35
92	920	460	92.18	2.80	0.37
93	930	465	75.87	3.79	0.32
94	940	470	89.29	3.37	0.32
95	950	475	78.05	4.14	0.35
96	960	480	67.66	4.12	0.34
97	970	485	90.24	4.38	0.30
98	980	490	81.62	3.34	0.31
99	990	495	72.30	4.48	0.36
100	1000	500	92.15	3.10	0.30
Average	**505**	**252.5**	**73.65**	**3.57**	**0.33**

Appendix F: Simulation result using GA 100 schedule

Schedule	No of Vehicles	No of Parking Spaces	Time Taken	Cost	User Satisfaction
1	10	5	134.53	6.33	0.30
2	20	10	122.97	5.79	0.35
3	30	15	112.53	5.54	0.27
4	40	20	134.60	5.51	0.35
5	50	25	112.60	5.75	0.32
6	60	30	112.26	5.99	0.33
7	70	35	108.95	5.55	0.30
8	80	40	149.76	5.70	0.31
9	90	45	108.57	6.05	0.28
10	100	50	137.36	5.96	0.35
11	110	55	127.80	6.12	0.33
12	120	60	124.00	6.52	0.28
13	130	65	111.39	5.34	0.30

14	140	70	123.55	5.35	0.31
15	150	75	128.24	5.72	0.31
16	160	80	132.18	6.48	0.32
17	170	85	112.92	6.59	0.27
18	180	90	117.45	6.10	0.31
19	190	95	140.55	5.92	0.32
20	200	100	143.34	6.27	0.35
21	210	105	120.02	5.40	0.28
22	220	110	146.01	6.30	0.31
23	230	115	115.85	6.64	0.27
24	240	120	118.33	6.65	0.28
25	250	125	122.37	5.74	0.34
26	260	130	153.30	5.25	0.33
27	270	135	121.06	5.41	0.35
28	280	140	128.82	6.49	0.33
29	290	145	121.20	5.74	0.28
30	300	150	114.51	6.01	0.29
31	310	155	126.86	5.98	0.27
32	320	160	149.86	5.88	0.30
33	330	165	127.20	6.30	0.28
34	340	170	145.55	5.30	0.32
35	350	175	121.87	5.98	0.35
36	360	180	109.47	5.45	0.28
37	370	185	118.49	5.50	0.34
38	380	190	112.17	6.02	0.33
39	390	195	119.36	6.46	0.30
40	400	200	140.33	5.40	0.31
41	410	205	113.05	6.66	0.31
42	420	210	121.56	3.20	0.37
43	430	215	109.25	6.60	0.27
44	440	220	148.73	5.98	0.31
45	450	225	152.19	6.02	0.28
46	460	230	107.54	6.18	0.29
47	470	235	148.66	6.37	0.29
48	480	240	123.43	5.54	0.30
49	490	245	127.30	6.11	0.33
50	500	250	127.92	6.48	0.30
51	510	255	117.78	6.30	0.30
52	520	260	142.52	5.43	0.28
53	530	265	118.57	5.30	0.35
54	540	270	142.13	5.31	0.31
55	550	275	150.64	6.07	0.30
56	560	280	147.82	5.39	0.34
57	570	285	138.45	5.93	0.34
58	580	290	113.14	6.42	0.28
59	590	295	126.28	6.58	0.29
60	600	300	141.67	6.09	0.29
61	610	305	143.17	6.20	0.33
62	620	310	150.90	5.37	0.30
63	630	315	150.44	6.07	0.29
64	640	320	151.20	6.42	0.28
65	650	325	112.57	6.09	0.31
66	660	330	126.22	5.68	0.34
67	670	335	131.75	6.61	0.27
68	680	340	119.23	5.25	0.34
69	690	345	128.79	5.99	0.35
70	700	350	132.77	5.41	0.28
71	710	355	107.47	5.80	0.34
72	720	360	146.83	6.46	0.30
73	730	365	137.10	6.01	0.32
74	740	370	109.02	5.73	0.28
75	750	375	147.24	6.09	0.28
76	760	380	128.19	6.18	0.31
77	770	385	129.71	6.43	0.31
78	780	390	151.56	6.32	0.31
79	790	395	146.19	5.51	0.29
80	800	400	142.54	5.56	0.28
81	810	405	139.04	6.27	0.27
82	820	410	140.44	6.45	0.30
83	830	415	134.60	5.64	0.30
84	840	420	144.64	5.63	0.31
85	850	425	111.84	5.32	0.32
86	860	430	132.58	6.63	0.35
87	870	435	124.73	6.07	0.33
88	880	440	122.02	5.75	0.28
89	890	445	147.71	5.61	0.34
90	900	450	127.53	6.62	0.30
91	910	455	150.88	6.64	0.30
92	920	460	138.55	5.82	0.30
93	930	465	124.27	5.84	0.29
94	940	470	117.24	6.16	0.29
95	950	475	120.47	6.50	0.33
96	960	480	129.30	5.30	0.29
97	970	485	139.34	6.52	0.35
98	980	490	108.94	5.58	0.29
99	990	495	148.26	6.11	0.29
100	1000	500	111.91	5.38	0.33
Average	**505**	**252.5**	**129.54**	**5.96**	**0.31**