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Improving Travels of the Public Transport System of Guadalajara Using ACO

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Abstract. This paper presents the application of ant algorithm to improve public transport route in the metropolitan area of Guadalajara. We use a methodology with an eight-step sequence in which it is possible to: 1. Identify the problem, 2. Identify the sources of information, 3. Prepare the census to collect the data. 4. Raise the information, 5. Analyze the data, 6. Treat the information, 7. Implement the algorithm and 8. Analyze the results. We use a methodology with an eight-step sequence in which it is possible to: 1. Identify the problem, 2. Identify the sources of information, 3. Prepare the census to collect the data. 4. Raise the information, 5. Analyze the data, 6. Treat the information, 7. Implement the algorithm and 8. Analyze the results. The contribution is to improve the routing Public transport in the ZMG through the implementation of Bio-inspired algorithms that will shorten the distance and the time of Travel from origin to destination.

Keywords: C++, Instances, Traffic, Ant Colony Optimization.

1 Introduction

In the last population census of 2010, conducted by the INEGI, identified in the area of mobility growth rates in terms of vehicle fleet it has been increasing: the rate of motorcycles increased by 30% annually between 1990 and 2010, from 16,000 to 177,000. In the same period, the rate grew to 7.31% cars, and trucks and cargo vans to 7.66%. The lower rate is that of passenger buses -3.49% - certainly closer to the growth of housing in the state. ZMG concentrated two-thirds of the vehicle fleet with 65%.

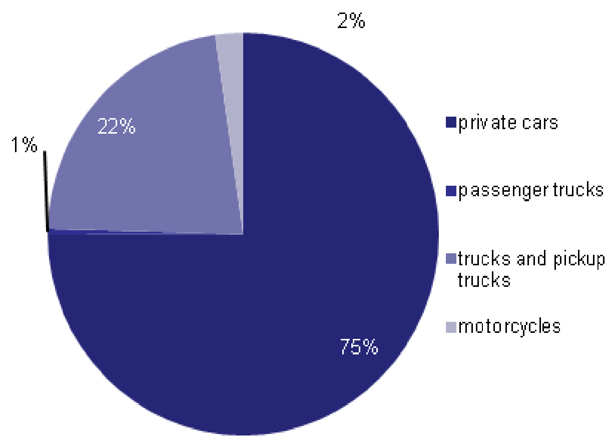

Fig. 1. ZMG Vehicle fleet [1].

In the figure above 4 types of transport are shown. It is identified as the predominant percentage use of private cars and the least dominant is represented by passenger trucks [1].

A bio-inspired algorithm based on ant colony is proposed for the optimization of the routing problem.

According to the literature reviewed, the following elements were found:

- Application of ant algorithm

The ant algorithm is a powerful implementation to solve complex problems; is based on the application of heuristics and probability for decision making [2].

It is possible to use ACO to estimate the traffic flow paths, as established in [3], where the application is shown to a specific case of Havana.

ACO is used in pharmaceutical industry to analyzing proteins for the study of AIDS [4].

Various routing optimization systems can be found in the market using bio-inspired algorithms, among which the following can be found:

- SOSACO

It is a search engine for social networks. The algorithm identifies new paths easier without breaking the original graphs [5]. This intelligence is useful in the application of GPS systems and in the precision they offer [6].

- MIDACO

Mixed Integer Distributed Ant Colony Optimization is an innovative optimization software for continuous and combinatorial problems. A special feature of MIDACO is its parallelization capability. The MIDACO parallelization option is based on the concept of reverse communication and can be used in all common distributed computing support architectures (including HPC and GPU). This function aims to parallel the evaluation (expensive CPU time) of the objective functions and constraints. It is designed for time consuming applications, where a single evaluation requires seconds, minutes or even hours [7].

- Vehicle routing problem

The original assumption of VRP is the problem of vehicle routes of a city; the problem is in the distribution of routes, times and load for each unit. The goal is to achieve [8]:

- that all nodes are visited exactly by a vehicle once,
- that all routes begin and end at a depot,
- For each unit, the load does not exceed the capacity of vehicles,
- For each unit, the distance does not exceed the given limit.

VRP extends its variants to suit different road problems [9]:

- CVRP (Capacitated Vehicle Routing Problem)

The units have uniform capacity and must meet customer demands known for a single product from a common warehouse at a minimum cost of transit. That is, CVRP is like VRP with the additional limitation that each unit must equal the uniform capacity of a single product.

- VRPTW (Vehicle Routing Problem with Time Windows)

Each of the clients, as well as the deposit, has several time windows of delivery or delivery [10].

2 General Objective

In Jalisco the number of vehicles has grown over the last thirty years by 7.29% per year, this amount is above the percentages of population and housing; motorcycles have 30%, cars with 7.66% and finally public transportation with 3.49%.

The ZMG contains two-thirds of total vehicles with 65% [11]. One of the main problems, when talking about mobility in public transport, is the time it takes to reach a unit from the origin to the destination, caused by ignorance of the route, inaccessibility to roads, climate issues, traffic load (peak hour / hour valley).

Our goal is to implement ACO to a problem of public transport in the metropolitan area of Guadalajara with the aim of improving travel.

3 Process

As defined at the beginning of the present study, the proposed methodology is composed of eight stages which are shown in the Figure 2.

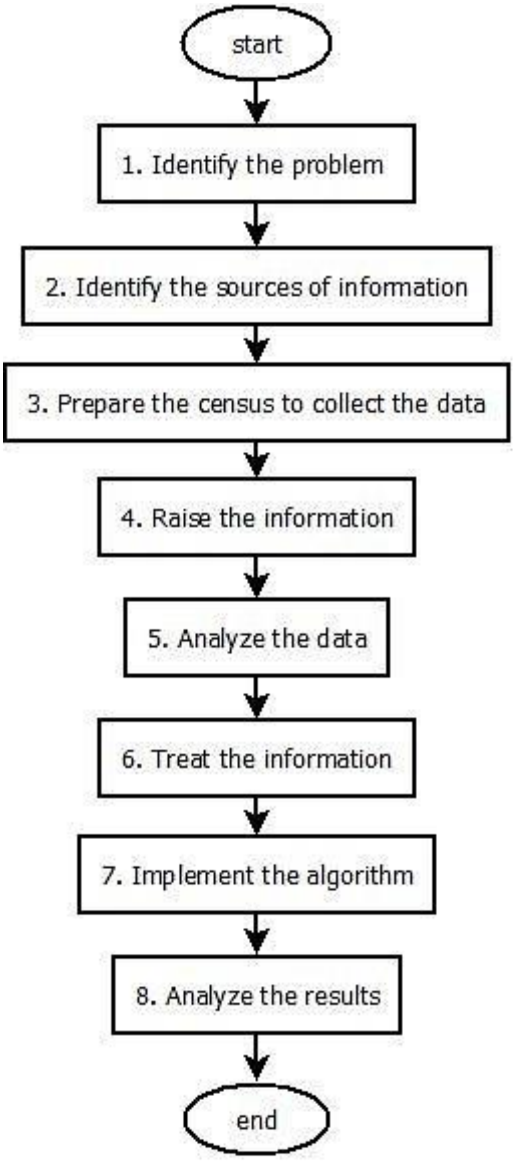

Fig. 2. Process.

The total distance is calculated, the number of routes for each execution and the number of vehicles, with the inputs 25 cities (nodes).

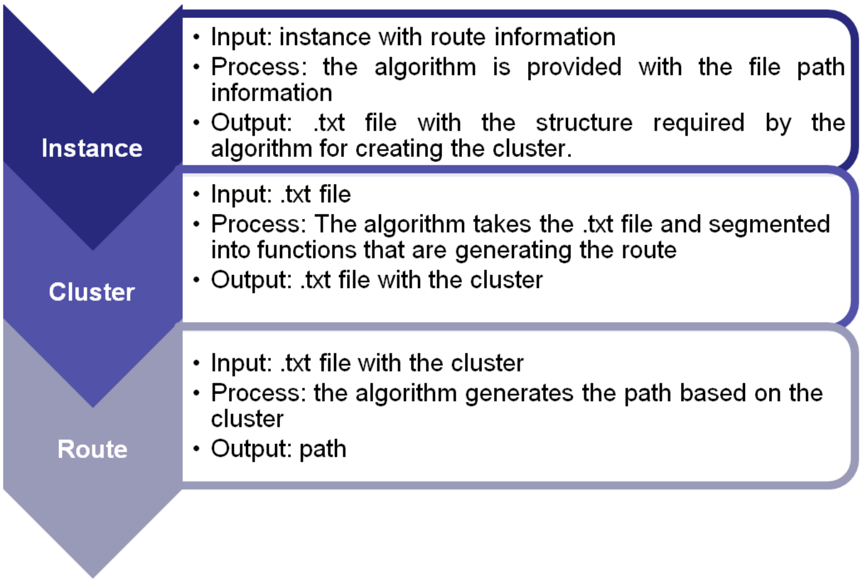

Fig. 3. Stages of processing.

The process consists of three elements; an instance as input, clusters are created and finally the route is created.

4 Experiment

The complete path consists of the following data:

The following data is used in the experiment:

- 33 units,
- 71 drivers,
- 37 points,
- Daily average per unit:
  - Passengers: 528,
  - Laps: 4,
  - Time of turns: 50 minutes.

The experiment consists of:

1 Identify points along the route.

Table 1. Control points.

trip	number	punto	lat	long	X	Y
	1	Base 214	20.63128	-103.272	95	73
	2	Farm GDL	20.63564	-103.276	92	68
	3	Rio Nilo	20.63904	-103.277	92	63
	4	Curva Malecon	20.64367	-103.278	92	56
	5	Templo Malecón	20.64762	-103.274	94	50
	6	Pizzería 61	20.65312	-103.28	90	43
	7	Bolería	20.6552	-103.294	80	40
	8	Ramón Val-Pensador	20.65748	-103.309	70	37
	9	Arena Jalisco	20.66469	-103.317	64	26
going	10	Cuartel colorado	20.67049	-103.334	52	18
	11	Zapatería prado	20.67298	-103.342	46	15
	12	Pque. Sn. Fco.	20.67357	-103.348	42	14
	13	8 de julio- la paz	20.67216	-103.353	38	16
	14	Paztolsa	20.66566	-103.36	34	26
	15	Lab. Piza	20.66386	-103.365	30	28
	16	Retorno 61	20.658	-103.378	20	36
	17	Isla Gomer	20.63682	-103.392	11	66
	18	Reyes Heroles	20.62875	-103.391	12	77
	19	Zansibar-Imss	20.62631	-103.391	11	82
	20	Contestación	20.62345	-103.4	6	84

trip	number	punto	lat	long	X	Y
	1	contestación	20.62345	103.3999	6	84
	2	Zansibar-Imss	20.62631	-103.391	11	82
	3	Reyes Heroles	20.62875	-103.391	12	77
	4	Isla Gomer	20.6368	-103.392	11	66
	5	Retorno 61	20.65792	-103.377	20	36
	6	Enrique D/Washing	20.66463	-103.364	32	33
	7	Paztolsa	20.66651	-103.359	34	26
return	8	Pque. Sn. Fco.	20.67286	-103.347	44	22
	9	Med 56	20.67099	-103.341	48	25
	10	Cv Ruiz Sanchez	20.66268	-103.32	63	37
	11	Vinos la playa	20.65814	-103.308	72	42
	12	Mercado Osos	20.65281	-103.294	82	49
	13	Templo Malecón	20.64762	-103.274	94	50
	14	Subida malecón	20.64169	-103.277	94	65
	15	Santa Rosalia- Mal	20.63678	-103.279	93	72
	16	Farm GDL	20.63516	-103.275	92	68
	17	Base 214	20.63128	-103.272	95	73

2 Identify the number of passengers moving from one point to another.

Table 2. Instances.

Number	X	Y	Demand
1	95	73	14399
2	92	68	9763
3	92	63	9892
4	92	56	5029
5	94	50	16833
6	90	43	23515
7	80	40	25165
8	70	37	13695
9	64	26	30269
10	52	18	12624
11	46	15	9037
12	42	14	21949
13	38	16	30900
14	34	26	29200
15	30	28	31100
16	20	36	33461
17	11	66	6754
18	12	77	5020
19	11	82	4794
20	6	84	0

Number	X	Y	Demand
21	6	84	0
22	11	82	45261
23	12	77	16684
24	11	66	48247
25	20	36	147
26	32	33	59589
27	34	26	40230
28	44	22	36416
29	48	25	20500
30	63	37	16673
31	72	42	21461
32	82	49	10546
33	94	50	16833
34	94	65	10300
35	93	72	7200
36	92	68	928
37	95	73	0

For the experiment, three factors were selected: Shifts, Units and Days to determine the route. The turns are identified in three moments: M, T and N where M = Morning (8 a.m.), T = Late (12 p.m.) and N = Night (6 p.m.).

The selection of the shifts seeks to identify which route is the most demanded and in which shift. Three units (r5, r12 and r23) are analyzed. Finally we consider the days of the week from Monday to Friday (d1, d2, d3, d4 and d5) where d1 = Monday, d2 = Tuesday, d3 = Wednesday, d4 = Thursday and d5 = Friday.

The Figure 4 shows the analysis mentioned.

Turn
M = 8 a.m.
T = 12 p.m.
N = 6 p.m.

Unit
r5
r12
r23

Day
d1 = Monday
d2 = Tuesday
d3 = Wednesday
d4 = Thursday
d5 = Friday

Fig. 4. Factors for analysis.

The next step is to prepare the matrix in Excel with the data for analysis in Statgraphics Centurion XVI. The result is shown in Image 4:

	U5				
	d1	**d2**	**d3**	**d4**	**d5**
M	335	288	286	307	285
T	205	294	291	284	149
N	202	128	101	156	178

	U12				
	d1	**d2**	**d3**	**d4**	**d5**
M	207	32	246	299	292
T	84	168	135	113	113
N	252	341	246	0	130

	U23				
	d1	**d2**	**d3**	**d4**	**d5**
M	292	332	286	228	164
T	255	295	258	261	205
N	207	189	183	164	0

Fig. 5. Data for the Matrix.

The data in each table represent the sum of the loads that are defined by time as the case for M, T and N.

In total there are 45 records identified by time, unit, day and capacity.

The matrix generated with the above information is shown in Table 3:

Table 3. Result matrix.

time	Unit	day	capacity
T	r23	3	258
M	r12	5	292
T	r12	1	84
T	r23	2	295
T	r23	1	255
M	r5	2	288
M	r23	3	286
T	r5	2	294
N	r5	2	128
T	r12	3	135

N	r12	4	0
N	r12	3	246
M	r5	4	307
M	r12	3	246
T	r23	5	205
N	r5	4	156
N	r5	3	101
T	r5	1	205
T	r12	5	113
N	r23	2	189
T	r23	4	261
N	r23	5	0
N	r23	1	207
M	r5	3	286
T	r5	5	149
N	r5	5	178
T	r5	3	291
N	r5	1	202
T	r12	4	113
M	r12	1	207
N	r12	5	130
M	r12	4	299
T	r5	4	284
N	r12	1	252
M	r12	2	32
M	r23	2	332
M	r5	1	335
M	r23	1	292
N	r23	3	183
M	r23	5	164
N	r23	4	164
N	r12	2	341
T	r12	2	168
M	r5	5	285
M	r23	4	228

The experiment seeks to analyze the variable capacity and identify which shift has the highest demand. The summary for the capacity variable is shown in Table 4:

Table 4. Result matrix.

Count	45
Average	210.356
Median	207.0
Variance	7722.69
Standard deviation	87.8788
Coeff. of variation	41.7763%
Minimum	0
Maximum	341.0
Range	341.0

The capacity variation is shown in Figure 6:

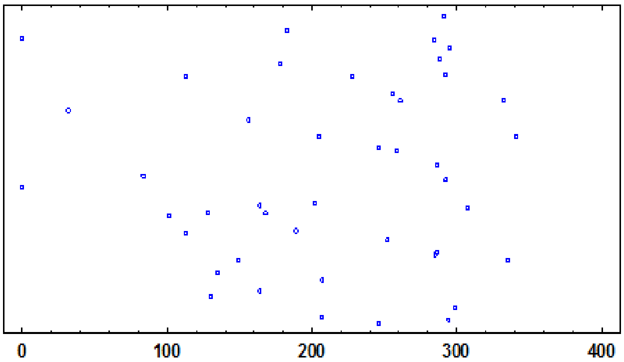

Fig. 6. Capacity variation.

In the figure 7 you can see in which shift there is more load:

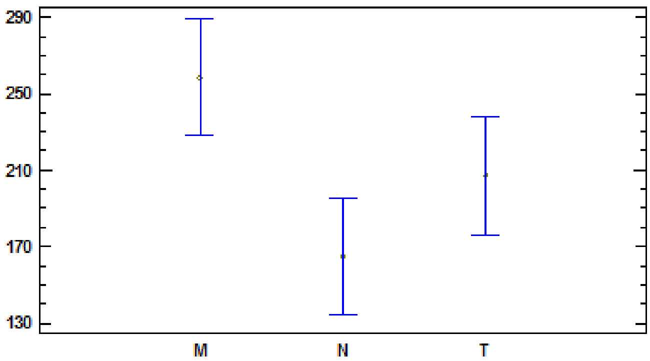

Fig. 7. Shifts.

The graph shows that the lap where most charges are in the M, approximately 290, followed by T, it is the turn of 12 pm with 200 and less load is N, that is to say that at 8 pm people do not even require one unity.

The Figure 8 shows a larger capacity per shift, identifying M with greater capacity for unit r5 while for the same turn of unit r12 is the one that has less demand.

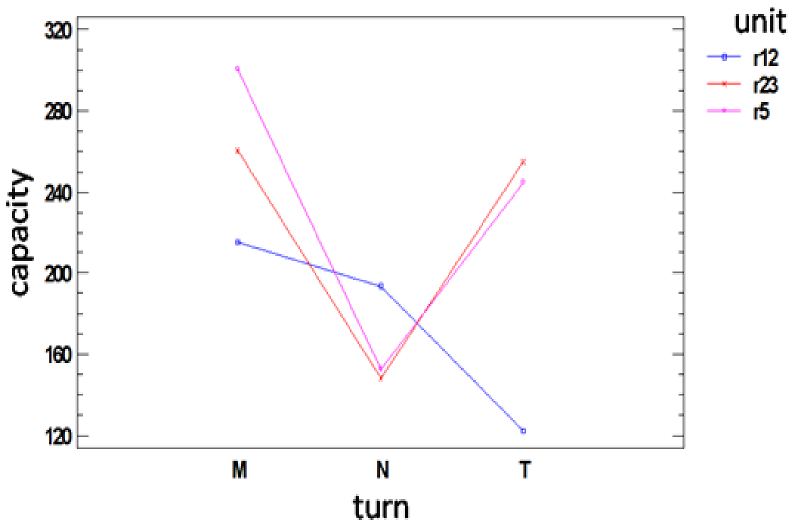

Fig. 8. Capabilities Per Turn.

We take the unit that has the most demand in the shift that more request and with greater capacity as case of application of the algorithm to determine an improvement. The case is for unit 5, at time M on day 1, i.e. unit 5 has more demand and therefore moves more people on Mondays; In the Table 5 the analysis can be appreciated:

Table 5. Result matrix.

time	unit	day	capacity
M	**r5**	**1**	**335**
M	r5	4	307
M	r5	2	288
M	r5	3	286
M	r5	5	285

Points by passing the unit M are 12, as shown in the Table 6:

Table 6. Crossing points.

Demand	Point	unit	time
13	PAZTOLSA	5	04/04/2016 08:03
47	8DEJULIOLAPAZ	5	04/04/2016 08:10
10	PQUE.SN.FCO	5	04/04/2016 08:13
27	ARENA COLISEO(LUCHA)	5	04/04/2016 08:16
45	CRUZ VERDE RUIZ SANCHEZ	5	04/04/2016 08:22
11	VINOS LA PLAYA	5	04/04/2016 08:26
38	MERCADO DE LOS OSOS	5	04/04/2016 08:32
41	TEMPLOMALECON	5	04/04/2016 08:40
35	SUBIDAMALECON	5	04/04/2016 08:43
9	STA,ROSALIA MAELCON	5	04/04/2016 08:45
35	FARMACIA GUADALAJARA	5	04/04/2016 08:47
24	BASE214	5	04/04/2016 08:51

The instance generated from the previous points is shown in Table 7:

Table 7. Instance IM12.

number	x	y	demand
1	34	26	13
2	38	16	47
3	42	14	10
4	64	26	27
5	63	37	45
6	72	42	11
7	82	49	38
8	94	50	41
9	94	65	35
10	93	72	9
11	92	68	35
12	95	73	24

3 Apply the algorithm [12].

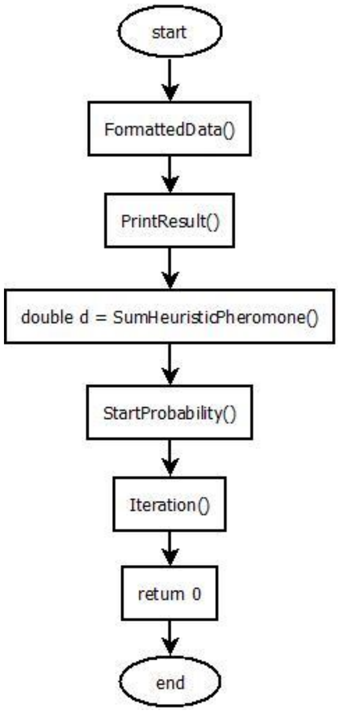

Fig. 9. The algorithm.

The main method consists of 5 functions in which processing algorithm is performed, as shown previously.

5 Results

The results derived from the execution of the algorithm with the instance IM12 are shown in the Table 8:

Table 8. IM12 results.

cluster	cost	iterations	route					
cluster-r5-clu1-3.vrp	81	9	0	2	1	0		
cluster-r5-clu2-4.vrp	128	14	0	2	3	1	0	
cluster-r5-clu3-3.vrp	145	100	0	1	2	0		
cluster-r5-clu4-5.vrp	170	8	0	1	4	2	3	0

A cluster is generated by each array that creates the algorithm; It was decided to section in cluster to facilitate the analysis to a point more granular and not so general.

The cluster column contains the generated instances, the cost column is the result of the algorithm processing, the iterations column contains the cycles and finally the route column contains the suggested route.

The following images show the results of the execution

cluster-r5-clu1-3.vrp

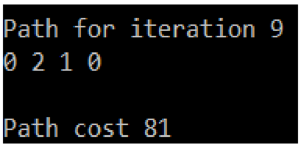

Fig. 10. Execution result cluster-r5-clu1-3.vrp.

cluster-r5-clu2-4.vrp

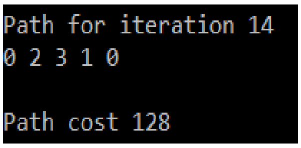

Fig. 11. Execution result cluster-r5-clu2-4.vrp.

cluster-r5-clu3-3.vrp

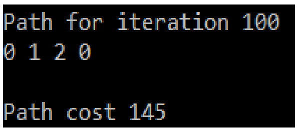

Fig. 12. Execution result cluster-r5-clu3-3.vrp.

cluster-r5-clu4-5.vrp

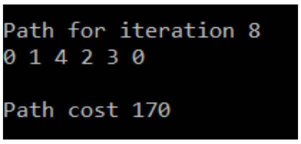

Fig. 13. Execution result cluster-r5-clu4-5.vrp.

6 Conclusions

It is possible to improve the conditions under which units of public transport work by applying the ant colony algorithm.

The sequential ACO algorithm was implemented and the results were promising in terms of performance in response times and distribution of the units at different points and this suggests a reduction in the units needed to cover the sections.

It is possible to visualize the route geographically since the 37 control points of the route are identified and located.

This work shown the importance of real instances to solve specific problems supported by information technologies and metaheuristics.

7 Future Work

Future work is expected to apply parallelism using CUDA to further improve the algorithm and apply the present approach to MATLAB and Smart Cities.

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