Cultural Algorithm to improve the generation of paths for the Public Transportation in Leon City

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Abstract. In the last years the population of Leon City, located in the state of Guanajuato in Mexico, has been considerably growing, causing habitants to occupy most of their time in public transportation. As a consequence of the demographic increase and bottleneck traffic, users deal with the daily problem of optimizing their time to get on time to their destiny. To give a solution to this problem of obtaining an optimized route between two points in a public transportation, a method based on the cultural algorithms technique is proposed. Cultural algorithms are used in the generated knowledge in a set of time periods for a same population, using a belief space. These types of algorithms are a recent creation and as far as we know, there is not a registration of its application in the solution of the traffic problem. The proposed method seeks a path that minimizes the time of traveling and the number of transfers. The results of the experiment show that the technique of the cultural algorithms is applicable to these kinds of multi-objective problems.

Keywords: Cultural Algorithms, Evolutionary Algorithms, Optimization, Transport, Population, Beliefs, Agent.

1 Introduction

The population growth has increased the traffic jam and, as a result, the demand of public services, such as transportation, is rising rapidly. In these circumstances, an effective public transportation is a necessity. To move from one place to another users are faced with the problem of optimizing resources in a transport system with many kinds of goals; for example, to minimize the number of stations, path length, travel mode, and travel time. Many times, solving this routing problem involves conflicts in goals. A solution with the fewer number of visited stations and the highest travel time is an example of conflict in goals.

Fort the multi-objective nature, the public transportation problem can be solved through evolutionary computation. The use of evolutionary algorithms has increased to solve several problems of multi-objective optimization which occur in the society, among the public transportation optimization.

A wide bibliographical revision revealed that Cultural Algorithms (CAs) have not been applied yet to the public transportation problem. Reynolds developed the cultural algorithms as a complement to the metaphor which inspired the evolutionary algorithms (natural selection and genetic concepts) [3]. CAs are an evolutionary computation technique, that uses the knowledge that has been generated in several times (same individuals, but in different time-space), for the same population, using a belief space, this characterizes to CAs, and they make an area of great interest for research. Two problems that have been implemented CAs are: Diorama's Representation using a Mosaic Image [5] and Public Security System [7].

For the previously exposed, in this article is presented a solution method for the public transportation problem based in CAs. The proposed method looks for a path that minimizes the travel time and the number of transfers, which are objectives in conflict. The Public Transportation Problem is presented as a case of study. On one hand system users save money using the path with less transfers and the other hand, they save time using the path of shortest travel time. When looking for the optimal path, first the algorithm considers the path with the least travel time, and then minimizes the number of transfers.

2 Problem description

Instance: Given a transport network formed by a directed graph $G= \{V, E\}$, where V is a set of vertexes that represent the bus stations. And a set of edges E that represent the routes that connect the stations. The V contains the information of the previous and next stop. The E is identified with the route number NR that joins the stations, the sense that follows the route and the time T required between two stations.

An initial station v_0, an end station v_n, a time t_0 and a date of consultation is provided. The search begins from v_0, covering the edges $v_0 + i$ that allows it to arrive v_n, accumulating $t_a= t_a+i$ that took to arrive and the number of route changes or transfers done $nr= nr+1$. The process finishes when $v_i = v_n$.

Objective: To Find a set of routes NR and continuous terminals for going from v_0 to v_n, in such a way, that minimizes t_a and NR, to arrive v_n.

3 Description of Cultural Algorithms

Cultural algorithms employ a basic set of knowledge sources, each related to knowledge observed in various social species. These knowledge sources are then combined to direct the decisions of the individual agents in solving optimization problems [1]. Cultural algorithms consist of two main components: a population space, belief space and a communication protocol [2]. It is the following:

Population space, this space maintains a set of individuals, which represent potential solutions to the problem. Each individual possesses its characteristics, and these characteristics define its fitness in the environment. Through different time periods called generations, individuals can be replaced by their descendants, obtained by means of the application of the operator that somehow affects the population [3].

Belief space is the space where the knowledge acquired by the individuals through the generations will be stored, and this must be accessible to any individual in the population, and can be used to influence its behavior, for example to modify its characteristics and then modify its fitness [3].

Communication protocol describes the way in which the knowledge is exchanged between the population space and belief space [2]. It states the rules about the individuals that can contribute to the belief space with their experiences through the acceptance function. The influence function through the belief space can influence to the new individuals [6].

Algorithm 1. Pseudo code of a cultural algorithm [3].

```
1       initialize(P = {x_1, . . . , x_μ})
2       evaluate(P)
3       initialize(B)
4       repeat
5               update(B, accept(P))
6               P' = influence(operators(P))
7               evaluate(P')
8               P = selection(P')
9       until the termination condition is achieved
```

The Algorithm 1 shows the main steps of a Cultural Algorithm. Most of the steps of a cultural algorithm are similar to those of a standard evolutionary algorithm, for example lines 1 and 2. The novel thing of these algorithms is the use of a belief space *B*. The line 3 is the initialization of the belief space. The details of this procedure depend on the structure of the belief space, and may be different in each case.

The update (also called `adjust`) function of the belief space is in the main loop (line 4 to line 9). The algorithm incorporates new experiences to the belief space, from a selected group of individuals *P*. In the line 5 the function `accepted,` selects the individuals of this group which are chosen from the population.

In the line 6, the variation operators of the algorithm are modified by the function `influence`. Finally in the line 7, the population influenced by the belief space is evaluated to choose the best option.

The `selection` function generates a solution to the search space. It is influenced from five sources of knowledge basic [7]. The best solution will be part of the belief space; this step is shown in line 8.

The Cultural knowledges of any cultural evolution model are: situational, normative, topographic, historical or temporal, and domain knowledge [8].

A representation of the interactions in the elements of Cultural Algorithms is shown as a diagram in Figure 1 [3].

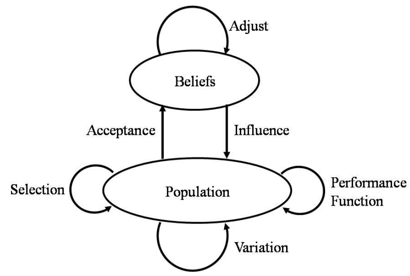

Fig. 1. Representation of Cultural Algorithms.

4 Experiments and Results

The transport net is represented by a graph G, and for modeling had been employed 3 tables described bellow:

tbase_rutas: contains general information about the routes. This table is formed by an identifier field that is used to link other tables; a field that contains the route name that is used to indicate the user the number of the route (bus) that he must take; a field that stores the route type as an additional information that identifies the bus for the user and finally a field that contains the route direction that is used in the intern process of solution construction, this information also presented to the user.

tparadas: contains information about the realized stations for each route that is important for the tour's construction, from which is taken the specification about the places of the needed stations for the transfers that are suggested to the user. This table is formed by an identifier field of the route that is used to link other tables to obtain additional information; a field that contains the name of each station that the bus does; a field that contains the previous station to the current station; a field that contains the next station to the current station and finally a field that stores the necessary time for arriving from the current station to the next station with the current route.

thorarios: contains schedule information of the beginning and end daily departures for each route. This table is formed by an identifier field for the route, with the object to obtain additional information; a field to store the place of the route departure; a field that contains the first departure hour of the route; a field to store the last departure hour of the route; a field to store an interval time for the departure of each route; a field that contains the working days for that route and finally a field to specify if the route departs from the origin or the destination of the route.

For the data base development, a route map of the city and the service schedule for the routes are provided; using for the table's filling the information described before. A part of the map that was included in the application is in the Figure 2.

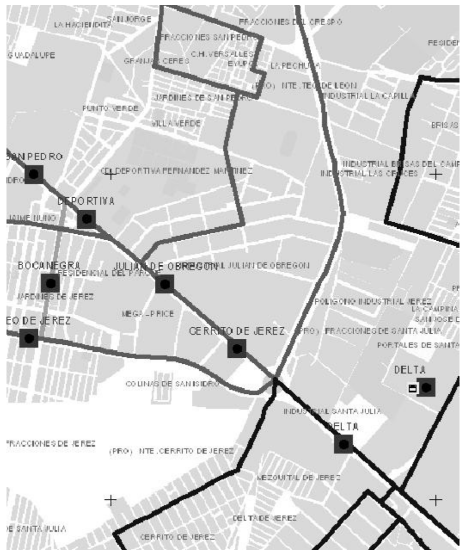

Fig. 2. Map of the used quadrant for the test and prototype elaboration. The brought out lines with dark color are the streets where the public transportation bus passes by.

After we have filled the tables, the next step is the construction of waypoints (routes). "Algorithm 2" shows the main steps to construct a waypoint (route).

Algorithm 2. The main steps for constructing a waypoint (route).

```
GenerateRoute (Origin, Destination, Time, Date)
1    initialize pActual=Origin, pPrior=Origin, Routes="",
     Stations=""
2    do
3          consult existence of routes that pass through
           p_Actual and Destination and available for time
           and date requested.
4     IF exist
5          route=selectQueryPath()
6    ELSE
7          consult if routes that pass through pActual exist
           and available for time and date requested.
8          route=selectQueryPath()
9    pActual=next(pActual)
10   pPrior_next=next(pPrior)
11   IF(pActual=pPrior)
12         route=routePrior
13   IF change of route {
14         Routes=routes+route
15         Stations=Stations+pActual }
16   until pActual=Destination
```

In the algorithm, a consult is made (lines 3 and 5) with the table *tparadas* to check the existence of any route that passes through the actual stop and that it also passes through destination stop. If several routes exist, you choose one of them; we execute the opposite case (lines 7 and 8), where we verify again the table *tparadas* to see routes that pass through that stop and we select any of those routes. By means of the table *tparadas* (lines 9 to 12) a search for the next stop according to the chosen route is done. If in the selected route, its next stop is the same as the next stop from the previous route, then the previous route is selected, this is done to reduce the number of transfers. The solution keeps storing every time a transfer occurs (lines 13 to15); this process repeats itself until we arrive to the destination that checks in line 16.

For the elaboration of the tests, we took in count the next requests as instances. In Table 1, we only show an example of a request. The requests were selected for these tests due to the traveled distances for getting to the original destiny are long, besides that in this places many options of routes pass through, this is why that possibilities of arriving to the destination are plenty. We carry on 5 executions of the application per instance. We made requests for 3 different hours so to observe the results accomplished in each execution.

Table 1. Instance Request example.

Origin:	EYUPOL.Popular
Destination:	PASEO DE JEREZ
Hour:	12:00
Date:	01/08/2009
Agents:	3
No. improvement periods:	9

After the execution of the application with the previously described data, we obtain the results shown in Table 2. This results show us estimated time in minutes and the number of used buses, after executing the instance example 5 times. In Table 3 we can observe the evolution of periods and how their solution improves by measuring estimated time in minutes and the number of used buses, for the instance example and only one execution.

Table 2. Results of 5 executions of the application for the instance example

Origin	Destination	Time stimated in minutes	Number of used buses
EYUPOL.Popular	PASEO DE JEREZ	15	2
EYUPOL.Popular	PASEO DE JEREZ	15	2
EYUPOL.Popular	PASEO DE JEREZ	15	2
EYUPOL.Popular	PASEO DE JEREZ	15	2
EYUPOL.Popular	PASEO DE JEREZ	15	2

Table 4 shows a concentrate of all requests executing 5 times each. Using the same Origin and Destination but changing the hour of request. Obtaining the average of time in minutes and used buses. After the result analysis we observe at what hour the request is a meaningful factor for the experiment's efficiency.

Table 3. Results by period of the first execution for the instance example

Period	Origin	Destination	Time stimated in minutes	Number of used buses
1	EYUPOL.Popular	PASEO DE JEREZ	39	8
2	EYUPOL.Popular	PASEO DE JEREZ	33	6
3	EYUPOL.Popular	PASEO DE JEREZ	15	2
4	EYUPOL.Popular	PASEO DE JEREZ	15	2
5	EYUPOL.Popular	PASEO DE JEREZ	15	2
6	EYUPOL.Popular	PASEO DE JEREZ	15	2
7	EYUPOL.Popular	PASEO DE JEREZ	15	2
8	EYUPOL.Popular	PASEO DE JEREZ	15	2
9	EYUPOL.Popular	PASEO DE JEREZ	15	2
10	EYUPOL.Popular	PASEO DE JEREZ	15	2
11	EYUPOL.Popular	PASEO DE JEREZ	15	2

Table 4. Test results with different instances and hours

Origin	Destination	Date	Hour	Time Avg in minutes	Avg of used buses
San Pedro	Industrial Delta.Beta	01/08/2009	06:00	14.4	2.6
San Pedro	Industrial Delta.Beta	01/08/2009	12:00	14.6	2.4
San Pedro	Industrial Delta.Beta	01/08/2009	22:00	14.2	2.6
CERRITO DE JEREZ.Cerrito de Jerez	ITL.Prol.Españita	01/08/2009	06:00	26.6	4
CERRITO DE JEREZ.Cerrito de Jerez	ITL.Prol.Españita	01/08/2009	12:00	25.8	4
CERRITO DE JEREZ.Cerrito de Jerez	ITL.Prol.Españita	01/08/2009	22:00	27	3.6
EYUPOL.Popular	PASEO DE JEREZ	01/08/2009	06:00	15	2
EYUPOL.Popular	PASEO DE JEREZ	01/08/2009	12:00	15	2
EYUPOL.Popular	PASEO DE JEREZ	01/08/2009	22:00	16	2.5
DEPORTIVA	DELTA.Estacion	01/08/2009	06:00	9.6	1.4
DEPORTIVA	DELTA.Estacion	01/08/2009	12:00	9.4	1.6
DEPORTIVA	DELTA.Estacion	01/08/2009	22:00	9.2	1.8

5 Conclusions and future work

For solving the path generating problem of public transportation is proposed a Cultural Algorithm. The motivation for using Cultural Algorithm lies on the multi-objective problem nature and the literature review that reveals that these algorithms had not been applied to the public transportation.

In general, the Cultural Algorithms consist of three elements: population space, belief space and the communication protocol. The proposal is centered in the adaptation of the belief space. The algorithm takes the best proposed path in each period. The experimentation results show that this path has a big influence in the generation of new paths for subsequent periods. Because of that, we can assure that the belief space is a decisive factor for finding the best solution. The proposed algorithm obtains good results comparing these with handbook estimates, that had done by experts in the area of generating transportation paths.

In addition, this analysis confirms that the parameter of application time is a significant factor to generate the problem solution, because when this parameter changes the solution changes considerably too.

As future work It is intended to expand the case study, because it was considered only one quadrant of the Leon City, Guanajuato. For this study is necessary to extend the database to include all Public Transportation Infrastructure of the City. Another line of work is the extension of the Cultural Algorithm to incorporate objectives and restrictions that are also present in the system in study.

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