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OPTIMIZATION STRATEGY BASED ON GENETIC FUZZY LOGIC APPLIED IN PUBLIC TRANSPORTATION MANAGEMENT

Hadriel R. Santos
Danúbia S. Pires
Orlando D. R. Filho
Kayon V. L. Lopes
hadrireis@gmail.com
danubiapires@ifma.edu.br
orlando.rocha@ifma.edu.br
kayonvinicius222@gmail.com
Federal Institute of Maranhão
Av. Getúlio Vargas, 04, Monte Castelo, 65030-005, São Luís, MA, Brasil.

Abstract. The search for the implementation of intelligent systems that provide greater effectiveness in urban planning, especially urban mobility, in order to facilitate the development of metropolises, has grown in recent years. The real world is too complicated to get accurate descriptions, therefore the approximation or inaccuracy must be introduced to get a reasonable model. In view of this, fuzzy logic presents itself as a powerful tool, since it is able to deal with systems that present problems for conventional techniques, mainly the nonlinearity and the lack of precise knowledge about these systems. Initially it was only approached the quantitative population of a given region and o timetable as input variables. The objective of cluster analysis is to classify objects according to the similarities between them and the organization of data in groups. Therefore, the Fuzzy C-Means (FCM) fuzzy clustering algorithm can be used to work with the initial collected data. The centers of the clusters provided by FCM correspond to the parameters of the rules of the proposed Takagi-Sugeno model. In order to guarantee the characteristics of performance, robustness and stability, the use of hybrid systems, it is necessary, specifically, to include the genetic algorithm to aid and optimize the fuzzy system, having as a function of suitability the output of the Takagi- Sugeno system. Consequently, the current routes are evaluated according to their cost of implementation, since they include as many people as possible, in order to validate or even reformulate existing routes.

Keywords: Genetic Algorithm,Fuzzy Logic, Public transportation.

1 Introduction

The search for the implementation of intelligent systems that provide greater effectiveness in urban planning, especially urban mobility, aiming to facilitate the development of the metropolises has grown in recent years. Urban evolution will always be conditional on a circulation channel scheme in accordance with available transport technologies. Thus, Intelligent transit control and monitoring systems can reduce of the disorder related to at the same. These systems are usually based on lagged data collection and provide a signal to the control core where it makes the appropriate decision for the region.

Urban mobility can be optimized by systems that use appropriate devices capable of managing the amount of public transport through functions that measure the cost of their implementation, when considering variables such as timetable, location and population density. Given this, a fuzzy genetic algorithm presents itself as a powerful tool for the development of intelligent systems for of the transit control and monitoring.

2 Motivation

Certain parts of metropolitan spending are for public transport. Amid a worldwide trend seeking alternatives to improve its quality, there is a big effort from the scientific community, along with government spheres, to provide viable means to this end. It is observed that the use of intelligent systems in the Urban Plans is inoperative, which contributes to an ineffective and troubled process. Current systems are unable to determine the population quantity of a given region according to the time and day of the week, it does not indicate what type of transport would be appropriate for a particular region, do not evaluate current routes.

With this in view, urban mobility becomes one of the most challenging issues in large urban centers, since traffic congestion is a daily problem. Discussions on urban mobility can be seen in various area-related research, [1], [2], [3] . However, existing approaches do not consider an essential factor: population information [4]. If space on the street is limited and demand constantly increases, it is essential to optimize its use. For this, there is no way to escape investments in more efficient public transport systems and enjoyable to its users.

3 Methodology

3.1 Formulation of the Takagi-Sugeno fuzzy model.

The potential of clustering algorithms reveal structures in data to be explored, not only through the classification or organization of the data, as well as reducing complexity in modeling and optimization. [5]. An effective approach in identifying nonlinear systems is to partition the experimental data of the system into subsets, taking into account the similarity between the data, approximating each subset to a simple model. [6]. Depending on the objective, various grouping definitions can be formulated. Fuzzy clustering algorithms are used when a data partition is desired where the transition between subsets occurs gradually. There are several fuzzy clustering algorithms. Among them, the traditional Fuzzy C-Means (FCM) is used to work with the initial data collected. FCM is based on minimizing the following objective function:

$$J_m = \sum_{i=1}^{c} \sum_{k=1}^{N} \mu_{ik}^{m} ||z_k - v_i||^2 \tag{1}$$

where c is the number of data samples, N refers to the number of clusters, m corresponds to fuzzy partition matrix. The center of clusters, v_i, refers to the center point of a given area and is represented by an X in the figure 1, which is calculated as follows:

$$v_i = \frac{\sum_{k=1}^{N} \mu_{ik}^{m} z_k}{\sum_{k=1}^{N} \mu_{ik}^{m}} \tag{2}$$

From the system input and output data, FCM estimates the antecedent parameters (operating regions), and the number of rules of the proposed Takagi-Sugeno fuzzy model. Identifying the main areas of origin of the students according to the coordinates collected through the initial research. This method presents itself as an alternative of reformulation when analyzing the areas of a city, avoiding limitation by neighborhoods and using the designation by population incidence area.

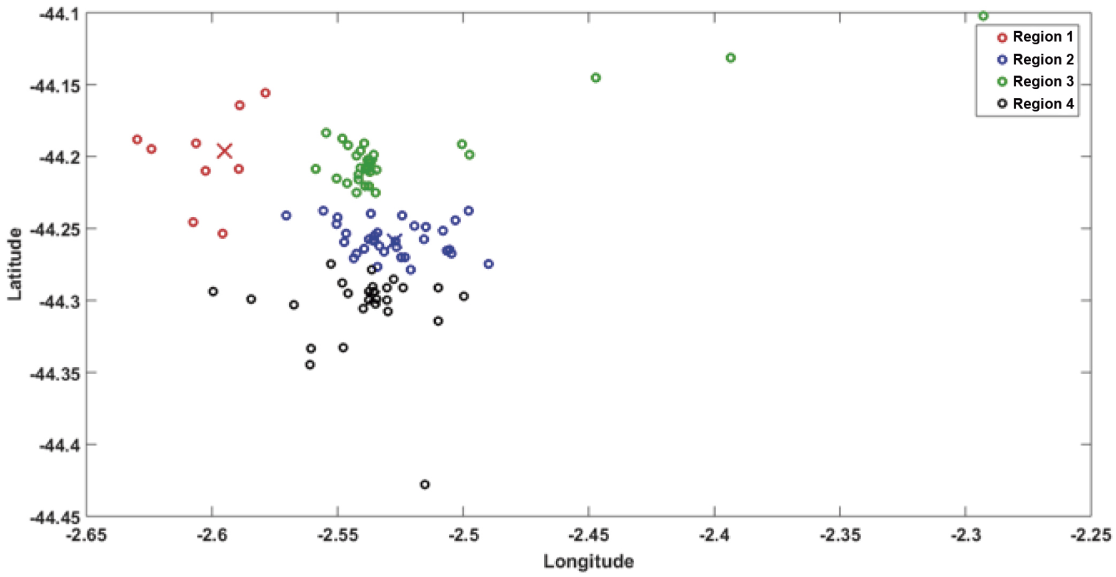

Figure 1. Data clusters by concentration area

By organizing a set of patterns (usually represented as attributes or points in multidimensional space - attribute space) into clusters, according to measure of similarity, bringing together the nearest locations, as shown in Figure 1. Clustering is usually associated with exploratory analysis, because it involves problems where there is little a priori information about the data, and itself can provide new hypotheses about the interrelationship of the same and their intrinsic structure. Minimization of functional Fuzzy C-Means represents a nonlinear optimization problem that can be solved using a variety of available methods, ranging from minimization grouped coordinates, up to genetic algorithms (GA).

3.2 Genetic Algorithm Analysis

In order to guarantee the characteristics of performance, robustness and stability, the use of hybrid systems [7], [8], [9], it becomes necessary, specifically, the inclusion of the genetic algorithm to aid and optimize the fuzzy system, having as function of aptitude the output of the Takagi-Sugeno model.

The development of the proposed GA was based on data analysis of the input variables (chromosome). The initial population is represented by a dimension matrix 100×2: each row corresponds to a chromosome and each column corresponds to values assigned to the time and quantitative populational. The evolution of GA depends on processes of *crossover* and mutation, whose rates, in the GA implemented by the authors, are of 50% and 20%, respectively. The first it consists the selection of chromosomes with the lowest implementation cost, resulting from matrix of the initial population after the selection fee is applied. The two lowest cost chromosomes are selected for the operation of *crossover*, the chromosomes resulting from this operation replace the of higher cost [10]. Mutations expand the cost surface search area by randomly modifying chromosomes with each iteration performed by the algorithm.

The proposed GA was implemented by the authors in order to obtain the global minimum cost within a cost surface. [5], This overall minimum cost corresponds to the best solution for distribution of the quantity of transport available. The function that represents the degree of aptitude, $f(x)$, of each solution is given by the equation (3).

$$f(x) = \sum_{i=1}^{N} P(i) A_i \tag{3}$$

at where N represents the area total in which the algorithm will be used, A_i is the chosen region to be optimized and $P(i)$ corresponds to the relative weight of that region, being defined by the quotient between the population quantity of a given region and the total initial population.

4 Results

A data base was developed to store the information regarding the worked variables, namely: timetable and population quantity, from this it became possible to develop a mapping by area of population incidence, in which four clusters were chosen to represent the main areas, besides identifying the centers of each region. In 2 can be visualized a graph related to the pertinence of the collected coordinates, referring to students from the Federal Institute of Maranhão, in relation to the center of clusters determined by the FCM. From the identified regions can be defined the way in which public transport will be distributed to a given region, through the GA, where the algorithm can be fed and defined to act according to the areas and coordinates defined in the clustering, after the last iteration of the algorithm, the answer correponds to a family of solutions, which presents the best forms of distribution of the public transport according to the region's needs.

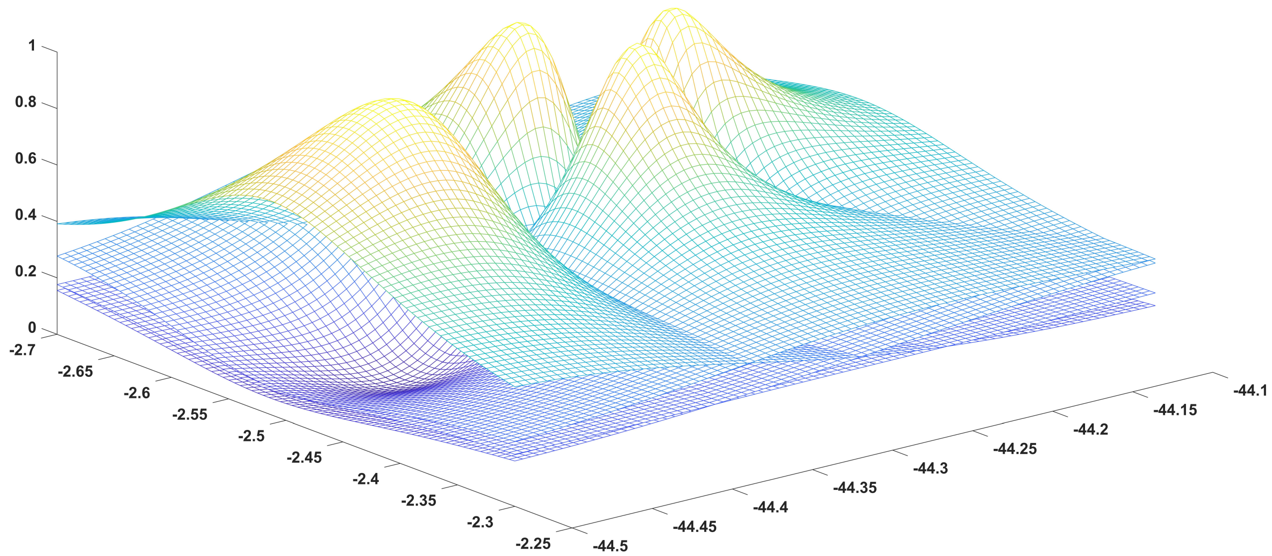

Figure 2. Pertinence of the coordinates relative to the center of the clusters.

5 Conclusion

The application of a hybrid system was adequate to the proposed problem. The organization and identification of data through clustering has made optimization more accurate, using the data from this step it was possible to develop and inform through the genetic algorithm the appropriate distribution function, thus reducing the processing lag, given that current distribution systems use obsolete data. Computational results show the efficiency of the proposed methodology, given that it has proved superior to current methods, in determining how public transport should be distributed to a given region, contemplating the largest number of people and having a lower implementation cost.

Acknowledgements

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