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Optimization of Police Contingent Management Based on a Genetic Fuzzy System

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Abstract. In a worldwide trend for technologies development that assist in the efficient management of people and resources, there is a great effort by the scientific community to provide viable ways to atach this goal. In this way, to insert in these approaches the analyses of variables that influence the public safety administration assists in the decision making of an intelligent system. This paper proposes a software development based on Genetic Fuzzy system to help authorities in police contingent management in order to reduce crime in urban centers. Were selected indicators that have a greater impact on the planning and management of public security and, from this perspective, was searched for data that best represent the real situations and correlate with the study object. The data used in the modeling and training of the algorithm were extracted from a database that shows the occurrence of Intentional Lethal Crimes in São Luís, Brazil. The Fuzzy C-Means (FCM) algorithm was used as a fuzzy grouping and unsupervised learning tool to estimate the performance regions (antecedent parameters) and the rules number of the Takagi-Sugeno (TS) inference model. The genetic algorithm is a search and optimization technique based on the principles of genetics and natural selection. A fitness function is used in each generation of the algorithm to gradually improve the solutions. Since the output of Takagi-Sugeno model is the weighted sum of functions of the consequent rule, the local models parameters are optimized from a fitness function. With the algorithm convergence, the answer given is a family of solutions wich representing the best police force distribution scenarios within the optimized areas. This feature is important for the proposed system operation, because it allows this software to function as a tool to aid decision-making, contributing to the responsible authorities. The use of the structure of a Genetic Fuzzy system has been shown to be efficient to the proposed problem. It can be noted as advantages of using this method in solving problems of resource management and people the possibility of acting on continuous or discrete variables, efficiency in the treatment of multiple variables, possibility of working with numerical data, experimental and analytical functions. Computational results demonstrate the efficiency of the methodology developed.

Keywords: Optimization, Fuzzy Logic, Genetic Algorithm, Fuzzy C-Means, Hybrid Algorithm.

1 Introduction

Many are the authors and policing specialists who draw attention to the fact that the last three decades have been characterized, on the subject of public security, by the construction of an international conjuncture marked by remarkable innovations and considerable reforms of the police institutions themselves. In a relatively short period, most European, and even American, police have radically rethought their attributions, training, strategies, and relationships with the communities to which they should render their services. In this process central innovations in safety were introduced. These include the model of community policing and problem-oriented policing, georeferencing, and the set of technologies for mapping of crime and violence that identify hot spots, the collaborative approach between police and social service agencies, evidence-based policing, crime prevention approaches through environmental projects. [1]

In a worldwide trend for technologies development that assist in the efficient management of people and resources, there is a great effort by the scientific community to provide viable ways to attach this goal. In this way, to insert in these approaches the analyses of variables that influence the public safety administration assists in the decision making of an intelligent system. A police officer management system emerges as a powerful tool to assist authorities in the planning of strategic actions and distribution of police officers throughout the city, contributing to the intensive fight against crime through the prevention and monitoring of areas flagged as priorities.

2 Methodology

2.1 Data Treatment

For the development of this project, it was first necessary to define which indicators would have the greatest impact on the planning and management of public safety, then was sought the data that best represents the real situations and correlate properly with this research. This choice was made based on the literature dealing with public safety in Brazil. Throughout the study it was possible to observe the existence of indicators that relate properly to each other, namely: type of crime, place of occurrence, type of weapon, day and time of occurrence, victim profile, number of police officers available. For the development of the algorithm it was decided, based on the researchers' experience, that the variables **type of crime**, **place of occurrence**, **day and time of occurrence** and **number of available police officers** would be used first due high degree of correlation. Therefore, restrictions were imposed on the indicators that are reflected in the mathematical modeling of the fitness function used by the system.

Once the indicators were defined, a partnership was established with the statistics sector of the Public Security Secretariat of Maranhão, which made it possible to obtain these data. The database used in this research provides information about Intentional Lethal Violent Crimes (CVLI) during the year of 2017, in São Luís. In analyzing the database, adjustments and manipulations were made in the format of the data so that they could be completely compatible with the structure of the algorithm and follow the standards set in the "Methodology for Measuring Intentional Lethal Violent Crime (CVLI) and Other Deaths". A part of this information is used, firstily, to model, feed and train the algorithm. Later, another part of the data is used to avaliable the proposed methodology. A sample of the database is shown in the table 1.

The analysis of the indicators stored in the database was performed with a georeferencing system. Therefor the relative contribution of each variable was obtained and, consequently, the crime hotspots identifyed. Figure 1 shows the result of plotting crime map for variable "crime type" using the *Google Maps*® platform.

Table 1. Database of Intentional Lethal Violent Crimes in São Luís

Date	Hour	Latitude	Longitude	Kind of crime
1-jan-2017	00h21	-2,527837	-44,285545	Murder
1-jan-2017	06h00	-2,538813	-44,193256	Murder
...	...	...	...	...
12-dec-2017	19h22	-2,533775	-44,19008	Murder

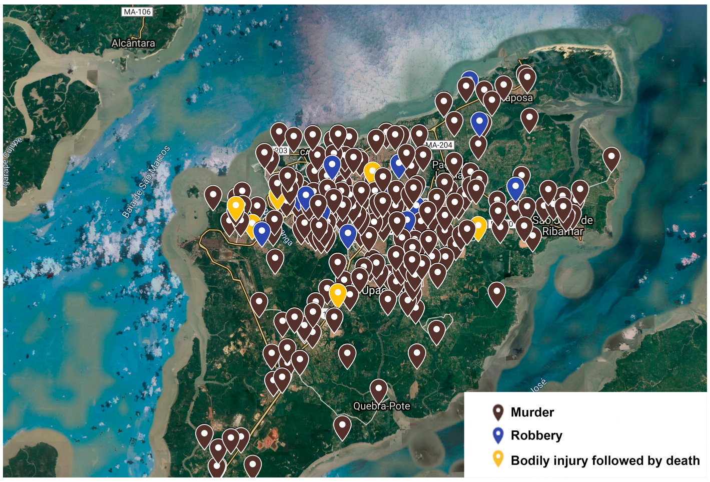

Figure 1. Crime Map

2.2 Techniques

Since it is a nonlinear system, the most effective identification approach arises from partitioning the experimental data concerning the system into subsets, taking into account similarities between the data, bringing each subset closer to a simple model [2]. Depending on the purpose, many cluster definitions can be formulated. A cluster, also known as clustering, can be understood as a group of objects in which each object is more similar to objects within the cluster than any object outside the cluster. [2] [3]

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). Fuzzy C-Means can be equated by an iterative algorithm, based on the minimization of a performance index, which indicates the adequacy of the generated data partition, ie, the adequacy of the obtained clustering.

In Takagi-Sugeno (TS) fuzzy model only the rule antecedent is formed by a fuzzy proposition. The consequent is expressed by a linear function of the values observed in the fuzzy system inputs. [4] [5] [6] The TS fuzzy model inference mechanism defines the degree of activation of each rule for a characteristic input vector, which in turn determines the degree of firing of a rule according to the values of the input variables.

Evolutionary Computing (EC) is an area of study derived from artificial intelligence based on the Natural Selection principles to find the best solutions to certain problems. The Genetic Algorithm (GA) is a type of EC algorithm in which symbols (often called "genes" or "chromosomes") representing possible solutions are "created". This "reproduction" of symbols typically includes the use of a mechanism analogous to the crossover process in genetic recombination and an adjustable mutation rate. A fitness function is used in each algorithm generation to gradually improve solutions, in analogy with the natural selection process.

In this paper was used a hybrid algorithm that combine Fuzzy C-Means, Genetic Algorithm and

Takagi-Sugeno Fuzzy Model . The main advantages of developing hybrid algorithms is that one technique, due to limitations or shortcomings, may not be able to solve a given problem, so combining various techniques can lead to a more robust and efficient solution [7]. Figure 2 shows the flowchart of proposed system.

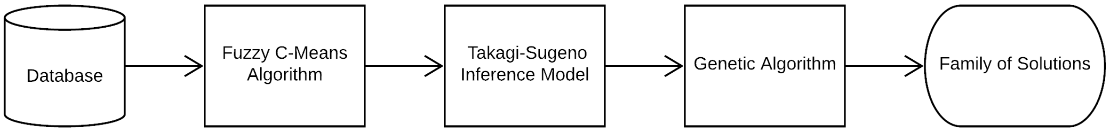

Figure 2. System Flowchart

2.3 Proceedings

In the first step, FCM was used as a fuzzy clustering and unsupervised learning tool to estimate the performance regions (antecedent parameters) and the rules number of the TS inference model. FCM input parameters used was the number of clusters, c, the distance measurement , $m \in (1, \infty)$, and a small number ($e > 0$) that works like a stop criteria.

Figure 3 shows the FCM output for $c = 4, m = 2, e = 10^{-6}$.

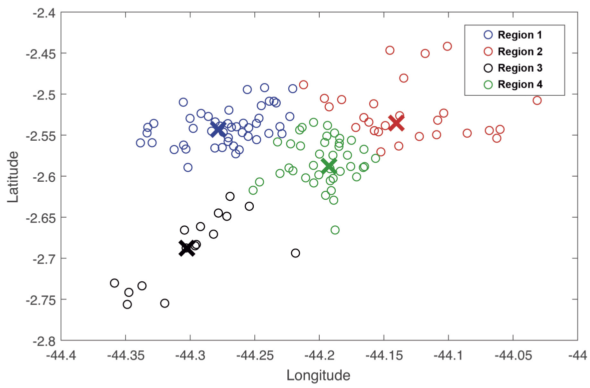

Figure 3. Fuzzy Clustering

For the TS system, the fuzzy rules(R_i) of a fuzzy set (B) have the shape of the Equation 1.

$$R_i : IF \quad x_1 \quad IS \quad B_1^i, \quad ... \quad , \quad x_n \quad IS \quad B_n^i, \quad THEN \quad y^i = P(x_i) \tag{1}$$

where the output function for each rule, y^i, is a function of numerical variables of inputs $x = (x_1, ..., x_n)^T$. Generally, this model decomposes the input space into fuzzy regions and approximates system output in each region by local models. The Figure 4 shows the membership function, result of TS model inference.

Once the TS model output is the weighted sum of rule consequent, this parameters are used like the weight of fitness function, required by GA. The expression that represents the aptitude degree,$f(x)$, of each solution is given by Equation 2.

$$f(x) = \sum_{i=1}^{N} P(x_i)A_i \tag{2}$$

where N represents the number of areas of algorithm activity, A_i represents each area that will be optimized and $P(x_i)$ represents the weight of each area.

With the convergence of the algorithm, the answer given is a family of solutions that represents the best scenarios of police distribution within the optimized areas. This feature is important for the operation

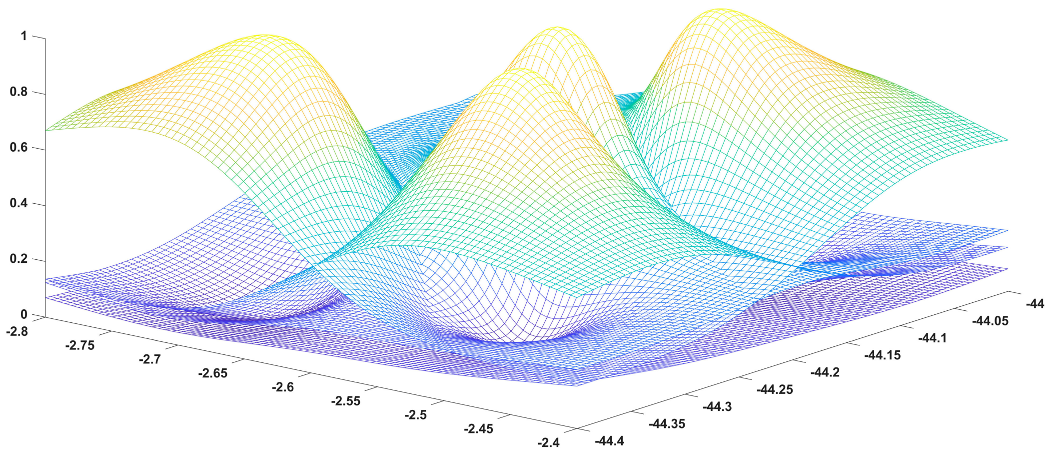

Figure 4. Membership Function

of the proposed system, as it allows this software to works like a decision-making aid, contributing to the responsible authorities.

2.4 Conclusions

In this paper was proposed a methodology based on a hybrid algorithm resulting from the combination of GA and TS Fuzzy inference model to optimize the management of the police force. In fact, these techniques are suitable for people and resource management and, above all, as a tool to aid decision making, provided they are properly constructed. Computational results demonstrate the efficiency of the proposed method.

Acknowledgements

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