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One approach for application of geographic information systems and fuzzy logic in business decision-making

Krasimir Slavyanov
Department Computer Systems and Technologies
"Vasil Levski" National Military University
Shumen, Bulgaria
k.o.slavyanov@gmail.com

Abstract. **Computer information systems are applied in all areas of human activity and their main purpose is information analysis and forecasting to make effective and optimal management decisions. Geographic Information Systems (GIS) are modern computer information systems for processing, mapping, and analyzing geospatial information. The creation of new projects in a GIS environment to support management decisions could be combined with artificial intelligence technologies such as fuzzy logic, so that different dimensional input geographic and business parameters can automate to some extent some logically based management decisions. This report explores the possibilities of fuzzy logic technologies to process geographic and statistical economic data for making adequate business decisions. Data on localities, distances to a specific site, demographic profile of the population and historical sales reference for a given region were used to generate output variable values for frequency of advertising campaigns, selection of product range and logistics parameters. The environment for developing the Fuzzy inference system is Matlab, and the software for the geographic information system is ArcView.**

Keywords: fuzzy inference system, geographic information system, membership function.

I. INTRODUCTION

Modern geographic information systems have a toolkit designed to support various spheres of human activity. The relationships between different statistical data and objects on different types of maps can contribute to the analysis and making of important management decisions, then supported by artificial intelligence [1], [2]. Any company that operates with service and resource providers or uses its branch offices and facilities in a system of locations in different places organizes a complex structure for planning and building its logistics. The application of artificial intelligence to minimize errors and comply with various rules and norms is increasingly necessary in our time, because the final financial indicators of companies are largely determined from the correct planning of the consumption of resources. The application of fuzzy logic to various tasks related to planning in the economy [3] has various fields of application and in this report both the capabilities of GIS to obtain analytical data and their subsequent use as input data for a Fuzzy Inference System (FIS) are discussed. An example objective for a given company is explored - to support decision-making for a given area such as frequency of advertising campaigns, distribution of certain classes of goods, type of means of transport and value of transport costs.

II. MATERIALS AND METHODS

For the purposes of this study, ArcGIS 10.8 software and demo GIS databases included in ArcView software were used. The experimental scenario is taken in which a company needs to expand its branch network with a new site and is looking for GIS-based locations. The research examined whether output data for analysis could be obtained from GIS related to the population of an area of interest, distance from a central warehouse (hub), statistics on the company's product sales, and average annual income per person in the area. Based on the input data, reasonable decisions ought to be made about the frequency of advertising campaigns, the classes and range of products to be offered, the type of delivery vehicles, and the expected company's transport costs in the area.

The aim of this research is to support the search for these solutions by a fuzzy logic decision-making system, where, based on the fuzzy input variables, pre-set rules are followed and reasoned values of the fuzzy output variables are obtained [4] [5], which in this case should be the sought parameters of the investment.

GIS, with its built-in features for searching a population database of cities in a country, can select a target group of

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cities that meet certain criteria. As a query result, a map with cities with a population of more than 100,000 in the United States are shown on fig. 1.

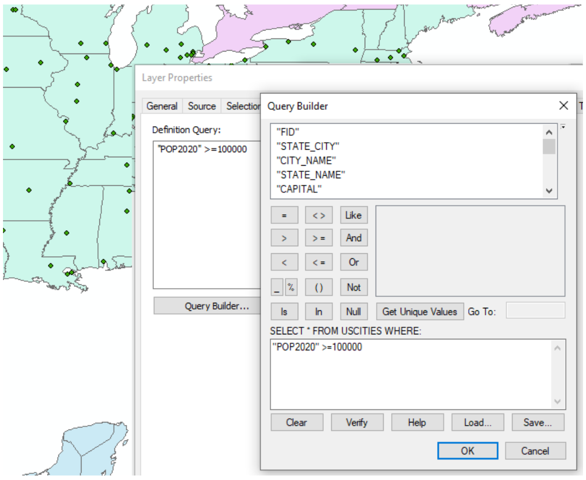

Fig. 1. A query for cities with more than 100 000 citizens.

In a next step, a specific city can be located, as well as neighbouring cities up to 300 miles away (Fig. 2 and Fig. 3).

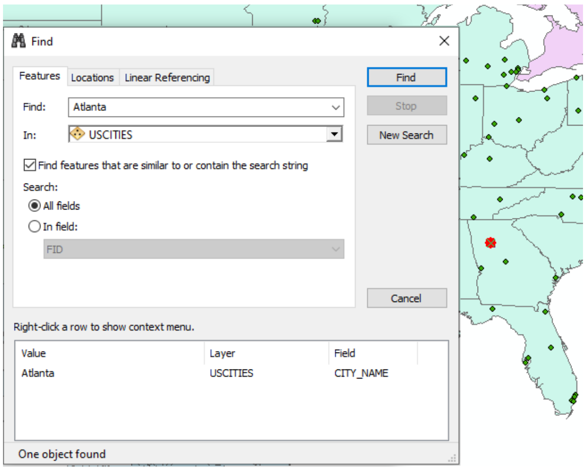

Fig. 2. Query to find a specific location on the map.

Localization of objects of a given type can also be done by querying the database (Fig. 4).

Each of the results for the types of objects of interest can be further ordered depending on specific information that must be available in the database, in this case the stores can be ordered by the amount of their orders from the company (fig. 5 and fig. 6).

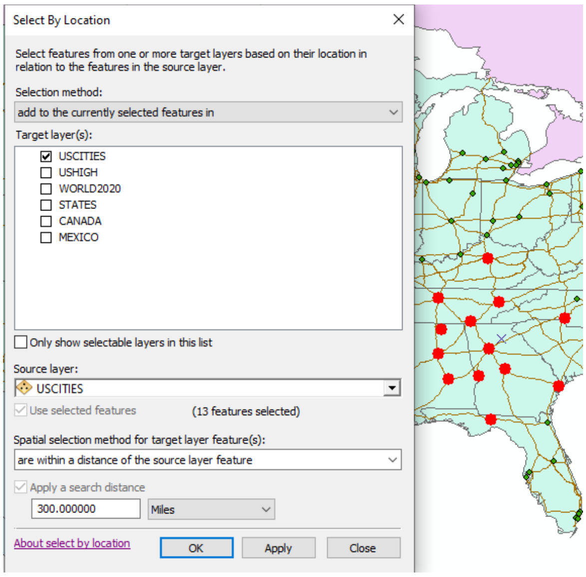

Fig. 3. Query to find neighboring cities up to 300 miles in distance.

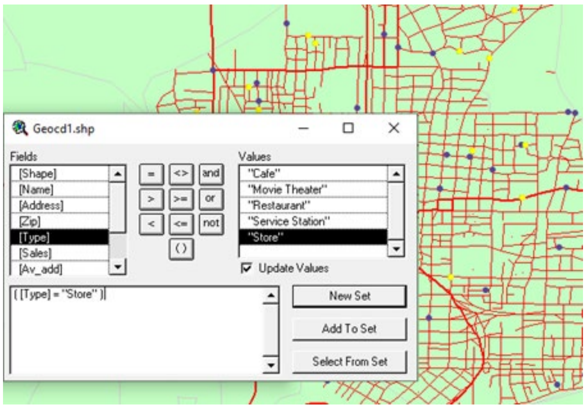

Fig. 4. A selection of stores in a given city where the company has contracts.

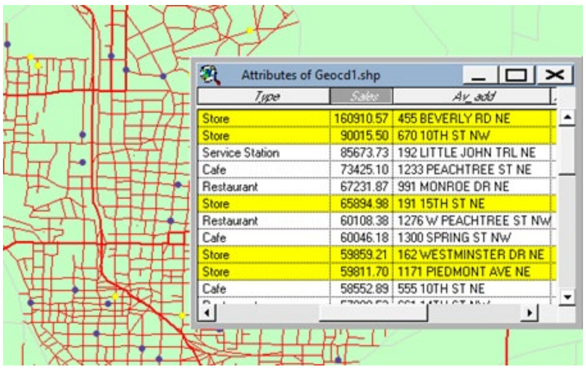

Fig. 5. Objects with orders for over 50,000 USD.

Using the study-specific GIS functionalities, exported values for the Mamdani-type [6] FIS input fuzzy variables can be generated with the structure previously described, depicted in Fig. 7.

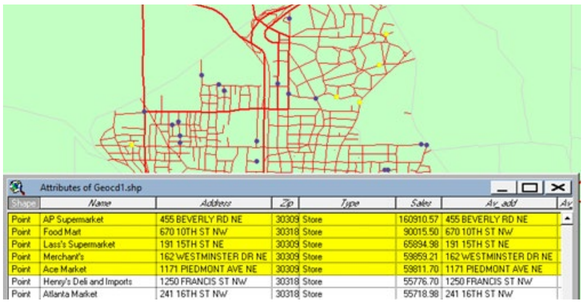

Fig. 6. Fuzzy inference system with GIS data designed to be used for fuzzy input variables.

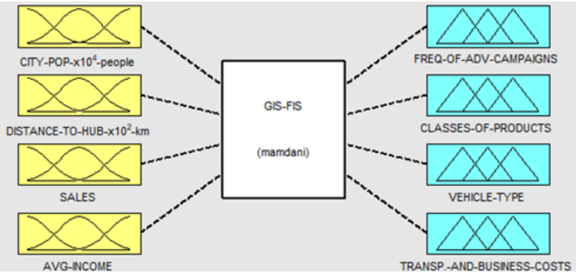

Fig. 7. Fuzzy inference system with GIS data designed to be used for fuzzy input variables.

The fuzzy input variables with their membership functions are designed as follows:

- Population of the city (smallest - up to 10,000; small - up to 25,000; middle - up to 50,000; big - up to 100,000 and biggest - over 100,000).
- Distance to the central warehouse - transport time (up to 2 hours - up to 150 km; up to 3 hours - up to 200 km; up to 4 hours - up to 300 km, over 4 hours - over 300 km).
- Sales history (up to 50,000 USD; up to 100,000 USD; over 100,000 USD).
- Average annual income (up to 50,000 USD; up to 100,000 USD; over 100,000 USD).

Membership functions for the population of the city were created by gaussian combination type, for distance to the warehouse – trapezoidal, for sales history – pi-shaped, for the average annual income – triangular [7]. The input fuzzy variable "Distance to hub", designed to have four sections from zero to 500 km is shown on fig. 8.

The fuzzy variables for the output linguistic variables are designed, with membership functions as follows:

- Frequency of advertising campaigns (1-3 per year; 4-6 per year; 7-10 per year).
- Classes of products to offer (middle class; high class; premium class).
- Type of vehicle to the site (utility van; box-truck; semi-truck).
- Transport and work costs (small; average; large).

The membership functions for the classes of offered products are generalized bell-shaped, depicted in Table 1. The functions of the remaining fuzzy variables are triangular.

Fig. 8. Membership functions for the input variable "Distance to hub".

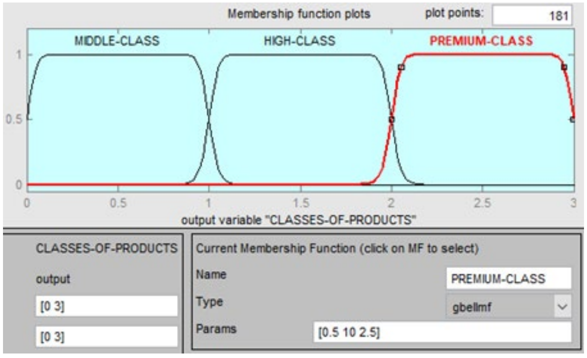

Fig. 9. Membership functions for the product classes to be offered at the new company site.

To study experimental performance of the system, 20 fuzzy rules are synthesized (shown in Table 1).

TABLE 1 FUZZY RULES

Rule №	IF				THEN			
	Popul.	Dist.	Sales	Income	Freq.Adv.	Pr.Class	Vehicle	Tr.Cost
	Options pool				Options pool			
	<10k <25k <50k <100k >100k	<2h <3h <4h >4h	<50k <100k >100k	<50k 50-100k >100k	1-3 4-6 7-10	MID HIGH PREM	VAN Box-T Semi-T	SMALL AVG LARGE
1	<10k	<2h	<50k	<50k	4-6	MID	VAN	SMALL
2	<10k	<2h	<50k	50-100k	7-10	HIGH	VAN	SMALL
3	<10k	<3h	<50k	50-100k	4-6	HIGH	Box-T	AVG
4	<10k	<4h	<100k	>100k	1-3	PREM	Box-T	AVG
5	<25k	<2h	<50k	<50k	4-6	MID	VAN	SMALL
6	<25k	<2h	<50k	50-100k	4-6	HIGH	Box-T	AVG
7	<25k	<3h	<50k	50-100k	4-6	HIGH	Box-T	AVG
8	<25k	<4h	<100k	>100k	1-3	PREM	Box-T	AVG
9	<50k	<2h	<50k	<50k	4-6	MID	VAN	SMALL
10	<50k	<3h	<100k	50-100k	7-10	HIGH	Box-T	AVG
11	<50k	<4h	<100k	50-100k	7-10	HIGH	Box-T	AVG
12	<50k	>4h	>100k	>100k	1-3	PREM	Semi-T	LARGE
13	<100k	<2h	<50k	<50k	4-6	MID	Box-T	AVG
14	<100k	<3h	<100k	50-100k	4-6	HIGH	Box-T	AVG
15	<100k	<4h	<100k	50-100k	7-10	HIGH	Box-T	AVG
16	<100k	>4h	>100k	>100k	4-6	PREM	Semi-T	LARGE
17	>100k	<3h	<50k	<50k	4-6	MID	Box-T	AVG
18	>100k	<4h	<100k	50-100k	7-10	HIGH	Box-T	AVG
19	>100k	>4h	<100k	50-100k	4-6	HIGH	Semi-T	LARGE
20	>100k	>4h	>100k	>100k	4-6	PREM	Semi-T	LARGE

III. RESULTS AND DISCUSSION

The parameters of the FIS are: implication method - min, aggregation - max, type of defuzzification - LoM (last of maxima). In the simulation study of the operation of FIS, results are obtained that confirm the correct combination of the input linguistic variables to obtain the necessary data at the output of the system. One example is on fig.10 – fuzzy input values and fig.11 – fuzzy output values.

Fig. 10. FIS simulation – fuzzy input values.

The results may be more accurate if the number of rules in the set is increased. The different types of input and output variables can be modified depending on the specific task. The explanation of the simulation data is described on Fig. 12.

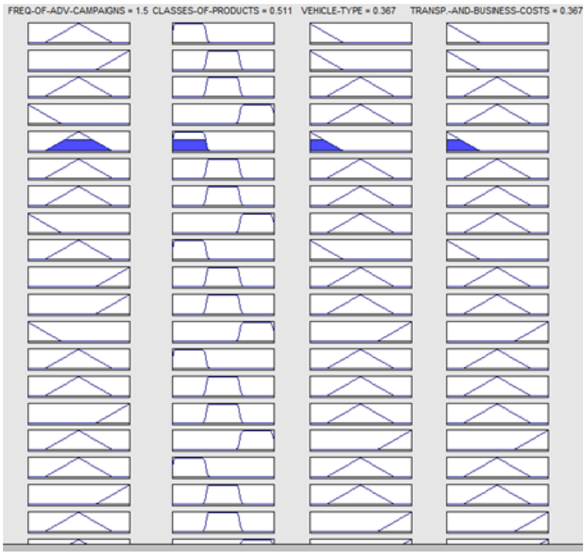

Fig. 11. FIS simulation – fuzzy input values.

CITY-POP-x10^4-people = 2.127 (21 270 citizens) &
DISTANCE-TO-HUB-x10^2-km = 0.8686 (less than 2 hours) &
SALES-x10k-USD = 3.397 (33 970 USD) &
AVG-INCOME = 0.4231 (less than 50k USD)
==>
FREQ-OF-ADV-CAMPAIGNS = 1.5 (4-6 times per year);
CLASSES-OF-PRODUCTS = 0.511 (middle class);
VEHICLE-TYPE = 0.367 (utility van);
TRANSP.-AND-BUSINESS-COSTS = 0.367 (small costs)

Fig. 12. Simulation with input and output fuzzy values (summary).

IV. Conclusions

This approach is applicable only to dedicated GIS projects for logistic management, enterprise resource planning systems (ERP), and for research of the market situation purpose. For any other implementation of similar geodata usage approaches in other areas of human activity with artificial intellect, a specific database would be needed.

The described working structure of an expert GIS system and a company's management decision system can be adapted or used in various fields of human activity in which action planning on the ground or in space is required, such as for tracking purposes in military sciences [8], application of UAVs for surveillance [9] or defensive approaches against UAVs [10], in analysing the spatial position of users [11], as well as in combination with other applications of artificial intelligence in defence and security [12].

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References

[1] H. Aghajani and A. Alizadeh-Zoeram, "Identifying urban neighborhoods with higher potential for social investment using GIS-FIS approach", May 2020, Applied Geomatics 13(7), https://doi.org/10.1007/s12518-020-00317-4

[2] A. I. Loureiro, A. Bressane, V.F. Nascimento and R. G. Negri, "Enhancing Landfill Monitoring and Assessment: A Proposal Combining GIS-Based Analytic Hierarchy Processes and Fuzzy Artificial Intelligence", October 2023, Knowledge 3(4):610-625, https://doi.org/10.3390/knowledge3040038

[3] A. Wismadi, M. Brussel, H. Sutomo and M.F.A.M. Van Maarseveen, "GIS infrastructure interdependency modelling with fuzzy inference systems (FIS) for predicting the distribution of economic opportunities", Conference: Ecocity World Summit 2009 : the 8th International Ecocity Conference : Urban Ecological Foundations for Climate Solutions, December 2009

[4] L.A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning—I", Information Sciences 8, 1975, pp. 199-249.

[5] L.A. Zadeh, "Outline of a new approach to the analysis of complex systems and decision processes", IEEE Transactions on Systems, Man, and Cybernetics, Vol. 3, No. 1, Jan. 1973, pp. 28-44.

[6] E.H. Mamdani, S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller", International Journal of Man-Machine Studies, Vol. 7, No. 1, 1975, pp. 1-13. https://doi.org/10.1016/S0020-7373(75)80002-2

[7] Mathworks Support - Functions https://www.mathworks.com/help/fuzzy/referencelist.html [Accessed Jan 19, 2024]

[8] D. Dimitrov and D. Atanasov, "Implementation of the hough transform in detection of target trajectory", International Scientific Conference, Shumen, 2017, pp. 400-408,

https://www.aadcf.nvu.bg/scientific_events/papers/NS_2017.pdf [Accessed Jan 13, 2024]

[9] M. Iliev and M. Bedzheva, "An Aproach for Application of UAVs for Observation of Processes in Agriculture", 7th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE), 2020, https://doi.org/10.1109/EEAE49144.2020.9279028

[10] V. M. Genoff, L. E. Manov, Y. V. Yosifov, „Experimental evaluation of the applicability of low-budget non-professional lasers for blinding drones at ranges over 3 km", Proceedings of International Scientific Conference ―Defense Technologies, 2023, ISSN 2815-4282, pp. 439-443, https://dtf.aadcf.nvu.bg/wp-content/uploads/2024/01/DTF-2023.pdf [Accessed Jan 19, 2024]

[11] M. Nedelchev, R. Dimov, S. Parvanov, "Algorithm for application of information for management of users spatial disposition in the process of automated software-defined radio communication network implemented by orthogonal frequency division and multiplexing", Proceedings of the conference "Scientific research and education in the air force – AFASES 2023",pp. 39-46, https://doi.org/10.19062/2247-3173.2023.24.5

[12] A. Borisova, L. Nikolov, "Systems with artificial intelligence for defense and security", Proceedings of the conference "Scientific research and education in the air force – AFASES 2023", pp. 53-58 https://doi.org/10.19062/2247-3173.2023.24.7