

AvEMC tools for decision making

M. J. Torres & E. C. Amorós
*Laboratorio de Geoprocesamiento,
Centro de Investigación en Computación,
Instituto Politécnico Nacional, México*

Abstract

In order to improve the Multicriteria Decision Making, a Multicriteria Evaluation Module has been designed. It can be integrated as an extension (AvEMC) into Arc View software. This module counts with several tools in order to classify and discover new mine deposits based on Cluster Analysis, Similitude Gower Coefficient and Heuristic Methods. This extension is able to work with *qualitative, dichotomical* and *quantitative* attributes and incomplete information, developing a Decision Support System into Geographical Information System.

1 Introduction

Nowadays, Geographical Information Systems (GIS) are powerful and useful tools as means of information, visualization and research or making decisions tools (Torres [1]). One of the benefits that the society has obtained, developing these systems (Carver [2]) is that those applications can be used in order to assist in the decisions making. This kind of assisting could be either in visual or in automatic ways. It has developed new research lines for integrating Decision Support Systems (DSS) and Geographical Information Systems. Therefore they end up being of great impact for the society (Sreedhar [3]). The capacity of the Geographical Information Systems to generate a set of alternatives for decisions making, is based on spatial relationships like the connectivity, proximity, adjacency and overlay (Romero [4]).

The main problem for using GIS in this way is presented around the decisions that is how to incorporate the preferences of people that make them in this process. That is because GIS has very limited capacities in order to integrate these preferences (Batty [5]).

The decisions making are defined to either include any option or select the alternatives in action. Therefore it is very important in several fields such as Natural and Social Sciences, including the Geographical Information Sciences (Geocomputation). The problems on the decision model generally involve a great set of alternatives with multiple subjective conflicts and criteria of evaluation. These alternatives are generally evaluated by a reduced group of people, who establish their preferences with respect to the relative importance of their criteria. It would imply to become subjective solutions. Due to this, GIS is always tried to be integrated based on Multicriteria Decision Making (Amorós [6]).

2 Interaction between GIS and DSS

A GIS can be designed for many purposes and different scales in order to represent the spatial data. It depends on its general functional schema, the duties of subsystem analysis, its implementation, the types of analysis to be considered and the accuracy of computation and results (Romero [4]).

The decision making is a process that involves a sequence of activities that starts with a decision in a recognition problem and finishes with recommendations. The present work is tried to provide an alternative how to use GIS as classified tools in order to make a decision in a mining exploration (Sreedhar [3]).

A system proposed in this work is a special tool that can be used in order to plan and administrate natural and social resources in a regional level or in finest scales. The system has the capacity of answering specific questions based on the combination of two fundamental elements (Tkach [7]):

- A database that claims different georeferenced layers (inside GIS).
- One or more simulation models that integrate different information layers, making computation and providing results based on the user's needs. These models can change their complexity in attribute's number, but they permit to approach the database and to relate the existing information.

3 AvEMC Architecture

In order to develop a prototype of DSS, a special Module of Multicriteria Evaluation can be programmed and integrated into commercial GIS. This module contains algorithms to work with attribute tables that are associated to thematic layers, especially for *qualitative attributes*. Because in the majority of the cases the information that is available in the GIS databases is incomplete, and they show the characteristics of the object that describe and sometimes contain much more subjective information about the observations. Figure 1 shows the general schema on Spatial Decision Multicriteria Support System (SDMSS). The prototype consists of GIS that interacts with an external module. The GIS provides a sophisticated interface for the spatial data and permits to make operations on the geographic elements (Jankowski [8], McKinney [9]).

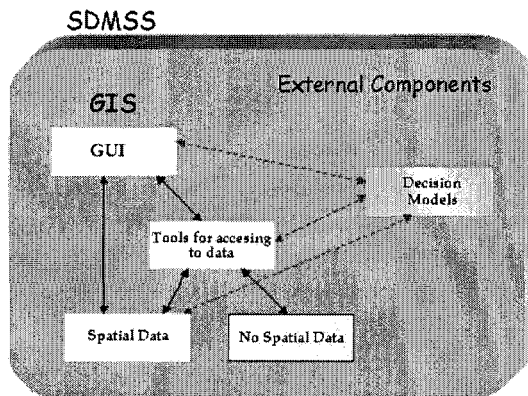


Figure 1: General diagram of spatial Decision Multicriteria Support System.

A GIS has its own Database Management System (DBMS) that permits to link the interface and the database to offer to the users to make spatial queries. Although GIS has certain limitations, it can work as Decision Support System, using external components. We can add the models that permit to generate the decision center with the evaluation criteria so that it can develop alternative series that shows a solution (Enache [10]).

The external component, called AvEMC, was added as an extension to ArcView. It can operate as decision making tool, especially for the *qualitative* and *dichotomical* attributes. The functionality of GIS can be subdivided into four subsystems: **Input**, **Administration-Storage**, **Analysis-Management** and **Data Output**. Each one of these elements has particular functions that permit the operation of GIS. Moreover, they provide the capacity to obtain data for decisions making. The Analysis-Data Management Subsystem counts with the capacity for integrating the spatial data analysis and attributes. We can add new external modules incrementing the analysis that a GIS can make. These modules supply the limitations that GIS has in the decision analysis, and also these

modules are used to improve the decision models (McKinney [9]). So that the data in GIS can be analyzed and managed into the each subsystem. The modules that have the basic functions and the spatial analysis tools, must interact together in order to manage and analyze the spatial data and attributes. By means of new functions, we can work with data that are storage in the database, adding mathematical models for decisions making with AvEMC extension. In Figure 2, the Architecture of GIS with Multicriteria Evaluation Model is shown (Torres [1], Amorós [6]).

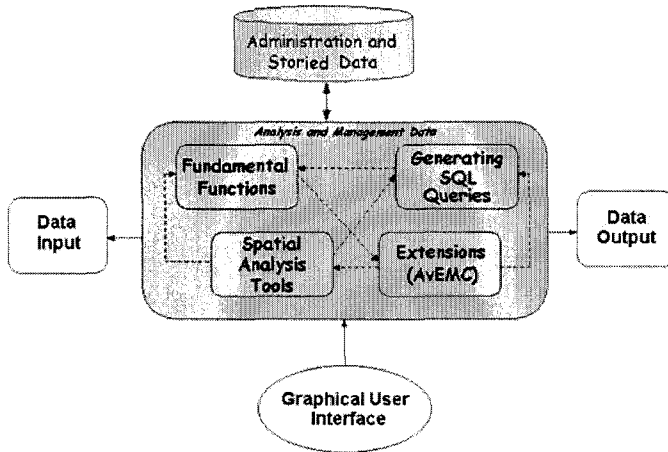


Figure 2: Architecture of GIS with Multicriteria Evaluation Model.

As we have seen, this tool permits to generate digital decision maps by means of the combination of several decision models that involve Heuristic Classification Methods of any attributes, especially the *qualitative* ones. This technique is not commonly used for these tools. Due to system's characteristics, this can be considered as a Decision Multicriteria Support System (DMSS) (Batty [5]).

4 Multicriteria methods in AvEMC extension

The tools implemented inside AvEMC extension work with any attributes: *qualitative*, *dichotomical* and *quantitative*. This extension is available to work with *incomplete information* too. The algorithms designed and developed were TOPSIS and Ranks. The algorithms implemented in AvEMC extension were Cluster Analysis and Similitude Gower Coefficient (Sreedhar [3]).

The TOPSIS and Ranks tools permit to assign the weights depending on the importance of the attributes, locating the weights inside a rank. In the other words, each criterion is categorized by the preference of decision center (priorities). Once these ranks have been established, we need to select three methods to classify them, based on their importance:

Ranges Sum. Weights are calculated by eqn (1):

$$w_i = \frac{n - r_j + 1}{\sum_{k=1}^N (n - r_k + 1)} \quad (1)$$

w_i Normalized weight for j-th criteria
 n Number of criteria to consider ($k=1, 2, \dots, N$)
 r_j Position of range inside the criteria

Reciprocal Ranges. Weights are derived from normalization of the reciprocal values of criteria. eqn (2) is used to calculate these weights:

$$w_i = \frac{1/r_j}{\sum_{k=1}^N (1/r_k)} \quad (2)$$

Exponential Ranges. Weight values that are inside the range [0, 1] are calculated by eqn (3):

$$w_i = \frac{(n - r_j + 1)^P}{\sum_{k=1}^N (n - r_k + 1)^P} \quad (3)$$

The last method has a drawback because it is necessary to add a weight variable for the attributes (Romero [4]).

The classification of spatial objects is very important, because it reduces the number of spaces, forming groups with special and common characteristics. In this way we can establish a required typology that links common patterns of all spatial objects. Moreover the defined objects are similar and present either spatial contiguity or spatial adjacency. We refer this as a "*Regionalization*" or a set of elements in areas with spatial adjacency. The model for qualitative data combines two techniques: *Cluster Analysis* and *Similitude Gower Coefficient*. These classify the attributes in groups with the same characteristics. Using this model, we can make a classification and generate the *Voronoi Diagrams* in order to show the *Regionalization*.

Figure 3 shows the model of *Regionalization* generated by AvEMC. It is important to mention that AvEMC is able to use the *Thiessen Polygons* or *Voronoi Diagrams*.

We need that the elements present a special topological structure. In this case the point objects and the use of overlaid maps are taken as criteria to be considered (Carver [2]).

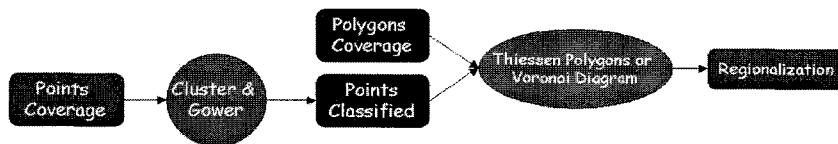


Figure 3: Modeling of process in order to generate the Regionalization of points.

After defining the *qualitative variables* for the process, we need to define the observation matrix, where the distance between the objects is calculated. A metric for calculation of the proportion of distance between two objects i, j is defined by eqn (4):

$$D(i, j) = [2(1 - G(i, j))] \quad (4)$$

$D(i, j)$ is the value that characterizes the similitude between i and j by the Euclidean distance, called *Gower Distance*. Then i and j have a strong similitude, while the distance is small.

This methodology has been experimented in the classification of lands depending on natural conditions to develop social and economical activities (Carver [2]). Figure 4 shows this classification by means of Cluster Analysis using Gower Distance.

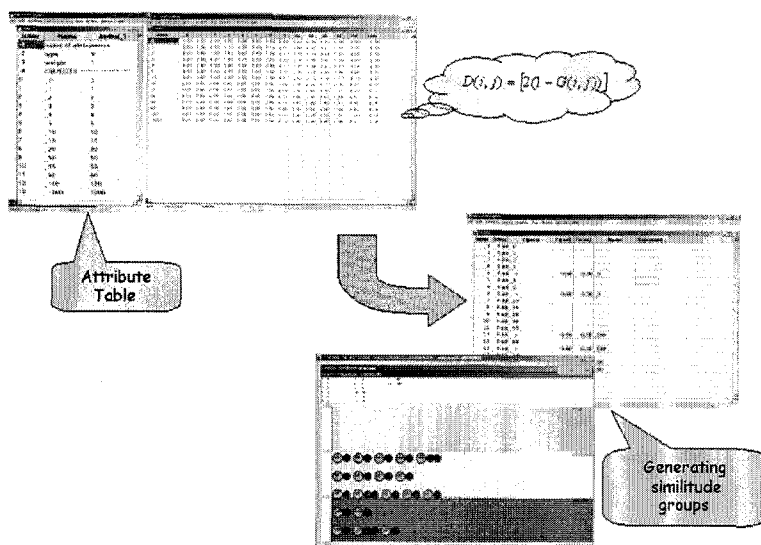


Figure 4: Attributes classified by Cluster Analysis using Gower Distance.

5 Results

Using presented methods, we can develop or generate digital maps with *qualitative* attributes, according to the weights that were added to the criteria. Moreover, it is necessary to use a combination of TOPSIS method for generating the Ranks. In the other case, the *qualitative* and *dichotomical* attributes are elaborated with Cluster Analysis using Gower Distance. Interpolating the point objects we can produce a digital decision map that shows the areas of interest of mine deposits with the same characteristics (minerals). In Figure 5, the analysis made by the AvEMC Extension is shown (Amorós [6]). At that, Figure 5a shows the Ranks Method that consists of TOPSIS + Weight Assignment and Figure 5b displays the Digital Decision Map that is composed by Cluster Analysis, Similitude Gower Coefficient and Thiessen Polygons (Voronoi Diagrams).

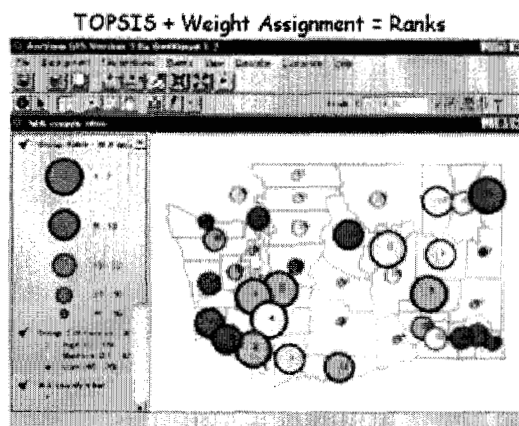


Figure 5a: Ranks method.

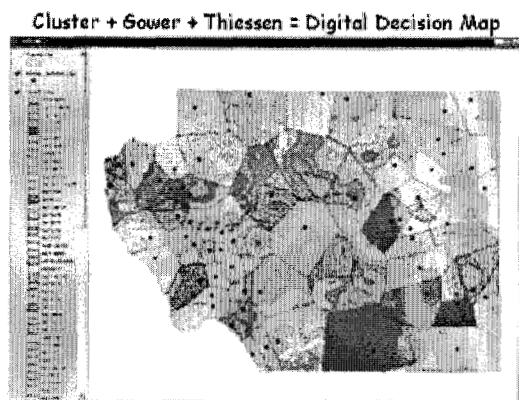


Figure 5b: Digital decision map.

Figure 5: Types of Analysis made by AvEMC Extension.

Our methodology can be applied for searching mine deposits using known criteria. The deposits and the environment around them, such as geology, drainage density and fracture density. These permit to find areas based on characteristics of deposits that have a higher probability of containing other minerals. Using Voronoi Diagrams, the mines that are represented by point symbols, permit to delimit areas. These areas are classified and they contain the same minerals. See Figure 6 (Amorós [6]).

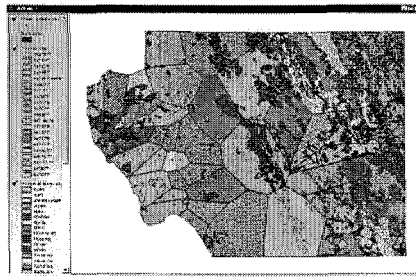


Figure 6: Creating areas throughout geology criteria-deposits.

In the figure 7, we show the classification of mine deposits considering the fracture density. Although the digital map is similar to Figure 6, it presents some differences, because when the Thiessen Polygons were constructed, these polygons cover a smallest area and present a different density fracture. The points that correspond to the mine deposits are in the same geologic part (Amorós [6]).

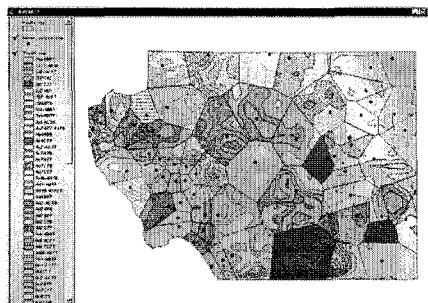


Figure 7: Creating areas throughout fracture density criteria-deposits.

Obtained spatial data by means of AvEMC extension have been compared with real spatial data provided by a mining company. We observe that there exists a high range of similitude with respect to generated groups with *qualitative characteristics* of the mine deposits, because the spatial data of resulting layer are overlaid to the provided by the mining company one. We saw that in the resulting layer there do not exist much discrepancies and the classified groups are presented high range similitude.

6 Conclusions

Described in this work the AvEMC extension has been designed and developed to work with *qualitative*, *dichotomical* and *quantitative* attributes. The developed algorithms are the TOPSIS and the Ranks. On the other hand, the methods of Similitude Gower Coefficient and the Cluster Analysis have been implemented into the AvEMC extension in order to make the classification and regionalization of the mentioned above attributes. Using these methods, the decision digital maps consisting of homogenous groups of mine deposits with high range of similitude can be elaborated.

All algorithms of the AvEMC extension have been programmed in Avenue of ArcView and the GUI has been customized, using the same programming language.

The research areas - GIS and Multicriteria Decision Making - take benefits from each other. GIS technology has an important role in the analysis of problems on multicriteria decision making, because it offers unique capacities for automatic managing and analysis of spatial data in the decision making. On the other hand, the multicriteria decision making achieves to improve the decision model, which can be incorporated into GIS (Amorós [6]). Both techniques are very important in the problem analysis, because the multicriteria decision offers capacities for the automation, administration and analysis of spatial data (Carver [2]).

The most important topic of the work is related to the implementation of several multicriteria evaluation methods into the AvEMC extension, which are ready to use in ArcView (Amorós [6]).

7 References

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