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GEOMETA – Geographical Minimal Elements for Environmental and Territorial Analysis

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Abstract:

The GEOMETA project applies spatial analysis concepts in local planning and environmental quality evaluation through the definition of geographical minimal elements (GME). A geographical minimal element is a conceptual systemic entity congregating different types of geographical information considered as fundamental for planning and environmental spatial analysis tasks.

The creation of GME is based in geoprocessing operations, especially overlay and grid modeling, defining a minimal spatial unit of homogeneous characteristics. The resulting elements are integrated in a unique type of information set or theme, fully maintaining its analytical potential and providing a new operational type of information with an enormous range of applications.

The GME are being created for a study area in Portugal, and several application software modules are being developed and implemented to test the capabilities of GME for environmental quality evaluation and spatial analysis operations in planning decision making.

GEOMETA project is expected to provide a major contribution to the definition and creation of a new type of geographical information. It also intends to create new methodological approaches to geographical analysis applied in the fields of environmental evaluation and local planning based in GIS (Neves, N., 2000).

This project is being developed based on geographical information produced by central and local administrative institutions, with normalized attributes and characteristics. This contributes for an application range that doesn't depend on the study area, and so is a basis for general development of new methodologies in the field of spatial analysis and land use management.

INTRODUCTION

The use of geographical information in physical planning and environmental evaluation is widely known, as well as the advantages of using spatial analysis tools supported by a GIS environment. However, the information created and its use has not been followed by methodological improvements in what concerns the description of the relationship between geographical elements or its evaluation in specific contexts of land use planning.

Considering that today's technological support largely overcomes the needs for a major part of the existing GIS applications, there is a need to focus the research effort in developing new structures for geographical information. The central idea is to create geographical information structures that improve the spatial analysis potential or, on a more ambitious path, to integrate geographical data into a composite data set with a wide range of applications (Goodchild, M. F., 1998).

The new era for spatial analysis should also consider the possibilities of using artificial intelligence systems for a better simulation of real systems. This should be an interactive process that can be, undoubtedly, a very rich *milieu* for the appearance of new methods and processes of spatial analysis and knowledge representation.

In systems theory approach it is considered the existence of a minimum element as a key part for complex systems of relationships, actions and flows. Once understood the minimum element structure, it is possible to produce analytical models based on the replication or identification of similar objects or phenomena. Within this global context of systems theory it is natural that the GIS implementation methodologies replaces the relational structures by object-oriented approaches.

Concerning GIS data models, the recent development points towards the creation of specific highly specialized structures considering the main application objective. Some of these data models have more advantages for specific case studies (e.g. network analysis), but being so specific they frequently exclude the composite dimension of reality. So, they can not be used to create analytical models for a more complex scenario of relationships that can only be understood in a context of vertical integration of a large number of data for a single location.

The challenge on the creation of minimum elements for environmental evaluation and planning is to identify the themes that can integrate, within a GIS environment, a set of composite information. This set of information is supposed to be built according to systems theory framework and to provide an interpretative support and warehouse for a system of geographical relationships (Neves, N., 2000).

Geographical minimum elements creation process

The first step to create Geographical Minimum Elements (GME) is the identification of GIS spatial analysis functions that are used to support environmental evaluation and planning activities. That is how it was possible to create a database model containing all types of geographical information, as well as the description on how they should be used.

The creation of GME is based on geoprocessing operations of overlaying different information coverage's or themes. The primitive information elements are integrated into a single geographical information theme, maintaining their individual characteristics of shape, position and class identifiers.

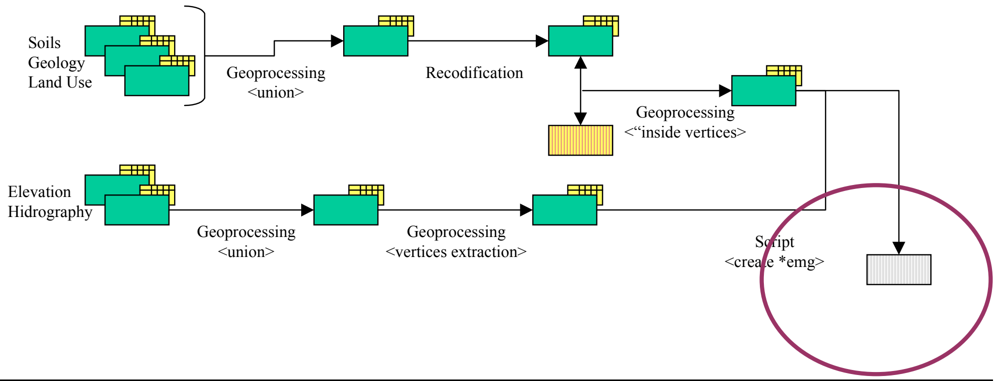

Fig. 1 – Creation of geographical minimal elements

When a GME is represented as a polygon shape, then it assumes the characteristics of a homogeneous area for a set of descriptors. The GME's storing structure enables the *on the fly* definition of its descriptors. This flexibility characteristic enables the user to build functional systemic elements with the appropriate detail and adequate structure according to the analysis needs, and is a key factor for GME's application range. Whenever it is considered necessary, the GME created by this approach are submitted to a restructuring process based on the reconfiguration of their topological relations, on their shape and on their final relative positioning.

In order to create an integrated information basis, GME are transformed into a table of coordinated points (Fig. 1). This table is codified as a text file with the extension *.emg and integrates the vertices of all the features considered in the creation of the composite basis.

For lines and point data features, vertices define the exact location of initial shape and integrate all the information required for the re-creation of initial features. They also integrate in a codified way information that is necessary for specific analytical purposes (e.g. data models for network analysis, etc.).

Considering that polygon features used in biophysical characterization (e.g. soils, geology, land use, etc.) are an imprecise abstraction of reality, the vertices extraction considers an "inside polygon" defined at a fixed distance of initial borders (Fig. 2 and Fig. 3)

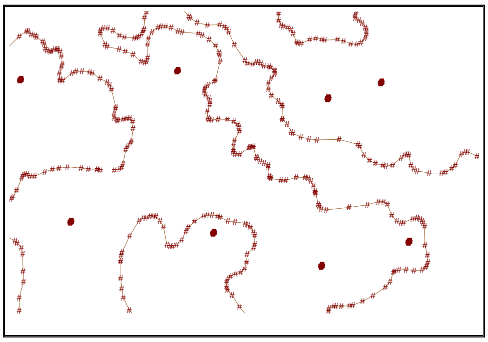

Fig. 2 – Vertices extraction from lines and points shapes

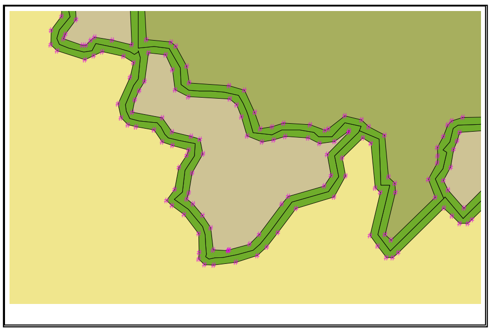

Fig. 3 – Vertices extraction from polygon shapes

The GME’s creation process flexibility involves, however, a long development of the underlying application support. There can be considered the following major tasks in creating GME:

- Base information deconstructing processes and creation of a simplified data format. This process ends with the creation of the *.emg file which can be read by the specific GME application;
- Creation of restructuring models embedded in the application source code. These models can, if one wishes, rebuild the base information keeping its original characteristics untouched;
- Creation of composite structuring models. These models are able to create any possible combination of GME’s descriptors, according to the purpose of spatial analysis process.
- Creation of GME’s evaluation models. These models explain, in a detailed way, the environmental evaluation perspectives established accordingly to the primary attributes of each type of selected information and the vertical integration combinations.

Application example:

One of the most important information basis for planning in Portugal is the National Ecological Reserve (REN), firstly established in 1983. REN is an attempt to protect and manage ecologically sensitive areas providing guidance for an adequate biophysical support for human activities.

REN is typically a cartographic modeling generated information, as it delimitates areas easily defined through spatial analysis or geoprocessing operations. It includes a set of elements or areas such as ridges, erosion sensitive areas, flood risk areas or protection areas to waterlines, (Neves, N., et all, 2001).

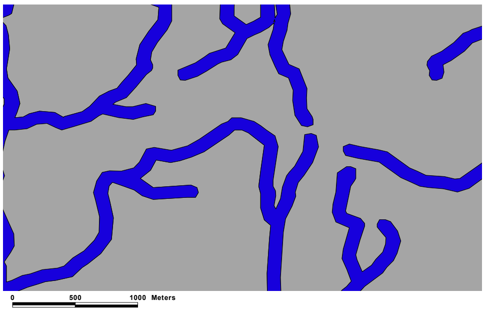

Fig. 4 - REN: Waterlines protection areas

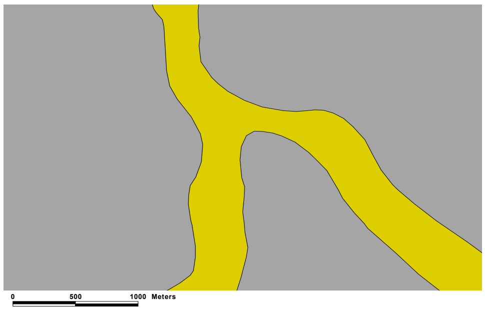

Fig. 5 - REN: Ridges

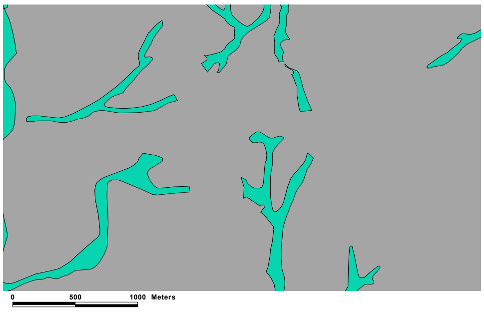

Fig. 6 - REN: Flood risk areas

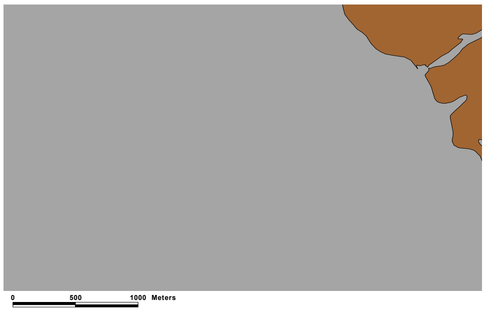

Fig. 7 - REN: Erosion risk areas

REN is an effective regulative figure in the planning process and the elaboration of any levels of municipal plans must observe REN regulations in a restrictive or "negative planning" perspective.

As the information elements or spatial analysis delimited areas are relatively consensual and they are commonly applied as result of a set of spatial analytical processes nowadays through GIS based methods, REN became increasingly better defined and functional in the Portuguese planning process.

However, the methodologically old conception of REN, firstly based in traditional cartography, generates a type of geographical information that is poor in terms of attributes as they are essentially binary (it is REN or not), and it's very difficult to manage the bureaucracy associated to any land use transformation process.

Fig. 8 shows the appearance of "Classical" REN in a digital polygon format. In opposition, Fig. 9 shows "Composite" REN with all the attributes and possible combinations.

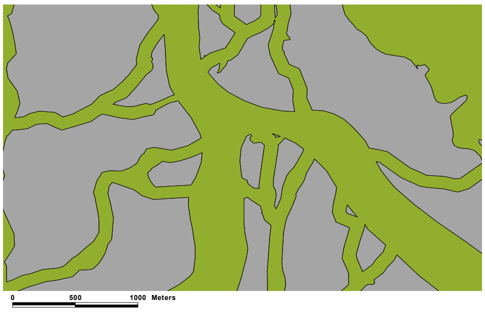

Fig. 8 – “Classical” REN

Fig. 9 – Composite REN

In order to facilitate the management process of the Portuguese National Ecological Reserve defined areas, a new information basis was created for REN, based on geographical minimal elements. This information basis relies on the insertion of REN criteria in a GME theme, maintaining all its information attributes and adding all the attributes of GME.

The information basis obtained is far richer in terms of an adequate biophysical characterization, providing a continuous scenario of biophysical evaluation and supporting planning decision in a more effective way.

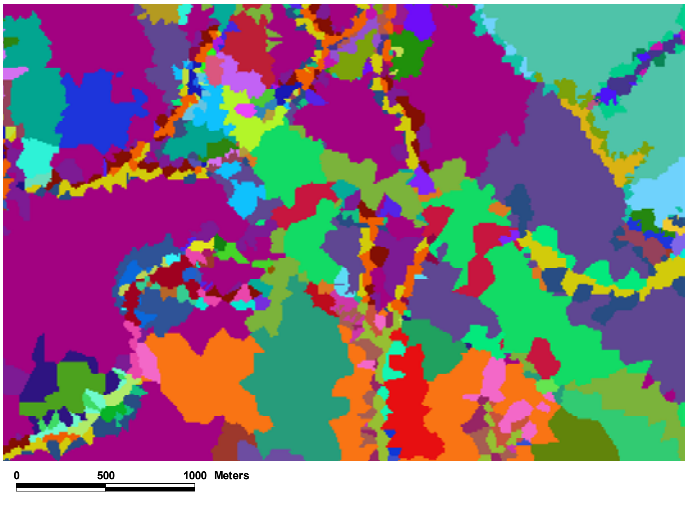

Fig. 10 – GME containing REN attributes code proximity areas

Fig. 10 illustrates a composite scenario of geographical information considering the GME code including types of soils, geological features, land use and REN delimited areas.

The general GIS model uses a new type of geographical information (*.emg) with expanded possibilities for spatial analysis processes. The ongoing research will also address to the issues of new geo-codification methods creation and specific spatial analysis operations for a better understanding of relationships among geographical elements. All the GME's implementation process was done using GIS macro-languages and standard programming languages.

Application models for environmental evaluation and planning

The application model for environmental evaluation is being developed with the purpose of establishing GIS simulation models that will produce scenarios of environmental associations. The GME's interaction scenario definition integrates several perspectives, according to the specific phenomena's knowledge level.

The actions for developing an environmental evaluation model of spatial analysis functions based on GME are the following ones:

- Identification and environmental characterization of GME as isolated entities and as components of a systemic association scenario;
- Likelihood function analysis definition and identification of dynamic and sensitivity scenarios for several phenomena or actions within environmental evaluation;
- Identification of parameters for computer algorithms development with the purpose of creation GIS simulation models;
- GIS model implementation.

The Fig. 11 shows the process of knowledge discovery and model generation based on EMG.

Phase 1 is related with knowledge parameters (values) acquisition based in a reference surface that commonly is a grid surface with values describing a different spatial occurrence of a given phenomenon. It also includes first proposals on the analytical function that might be similar with the phenomenon pattern.

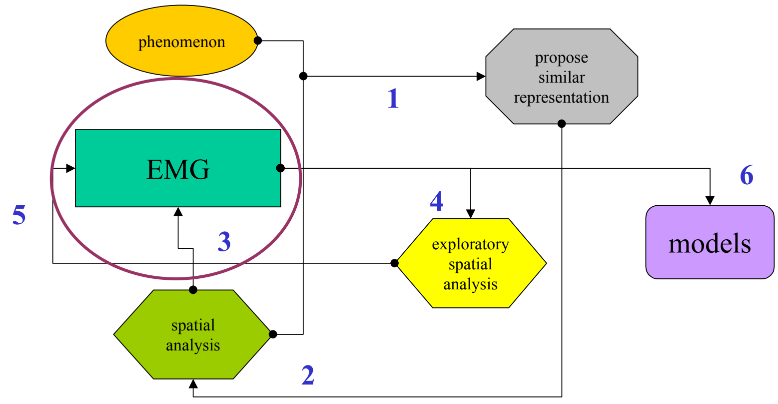

Fig. 11 – Knowledge discovery and model generation general structure

Phase 2 is related to the generation of analytical function results to be compared with the reference function. This phase involves naturally adequate knowledge on the analytical function generation process and the nature of the values generated. Phase 3 regards the "insertion" of analytically generated values in the information base of GME.

Phase 4 is perhaps the most relevant in terms of knowledge acquisition for model generation, as it integrates the different statistical analysis processes trying to establish the set of relation models to relevant for model definition. Different analytical steps are considered to define similarity relations between the similarity surface generated and the reference function: similarity relations between the different types of GME in order to retrieve indirect information that will allow model implementation in different locations with similar but different GME; generation of model equation through linear, multiple regression or non linear estimation and equation selection and implementation as reference model to each type of simulation desired.

The applicability of this system will be enlarged through the flexibility on altering the structure or the model parameters. So, it is possible to create an information base which analytical possibilities for planning processes should increasingly be improved by the addition of new knowledge about relations between geographical elements.

So far, the results reached show that GME can be immediately used as a support for biophysical characterization and evaluation in environmental assessment and planning. The GEOMETA research project is also going to focus its work on the development of new methodologies of environmental assessment and on the production of specific decision support tools for planning.

Acknowledgements:

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