GEOGRAPHIC INFORMATION AND EXPERT SYSTEMS INTEGRATION: SITUATION, REQUIREMENTS AND EXAMPLES

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Abstract
In this paper, the problem of integrating Geographic Information Systems with different corporate software applications, specially Expert Systems is described. First, a summary of the existing integration problem between GIS and corporate applications is introduced. Second, a brief description of Expert System characteristics and their advantages is shown. Third, a presentation of the specific integration problem between both technologies is described, introducing the existing requirements and possible alternative solutions. Fourth, a description is made about the possible applications of expert systems in relation with GIS, constituting what we have called Geographic Decision Support Systems. Fifth, some examples are introduced showing possible applications of both technologies. Finally, the overall paper conclusions are provided.

The existing integration problem

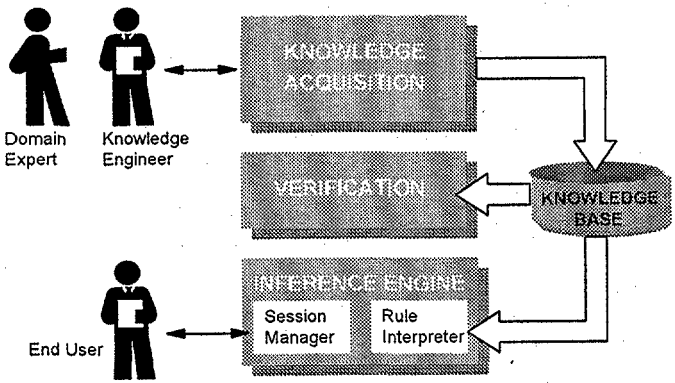
Geographic Information Systems have already been in use for quite a long time in different sectors of activity (utilities, environment, construction firms, bank, etc.). There are numerous examples of applications developed using this technology. Still, on each new implementation, two problems arise with almost complete security, the question of data acquisition to implement the system, and the necessity of integrating the new development with the existing legacy applications.

Traditionally, this problem has been solved by the capability provided by almost all GIS product vendors to access external databases where the corporation information is introduced. That implies that new software modules must usually be developed to provide data to such databases. They usually do not need to be developed from scratch, as they sometimes only take care of accessing to the data existing in the corporate databases, which has been provided by the already existing applications. With the recent improvements on different systems connectivity and middleware, it is everyday becoming easier to avoid the development of such application, having the different GIS products the possibility of accessing the data on its actual location.

This framework serves in a reasonable manner the purpose of accessing corporate data and presenting it graphically related to its geographic situation, feature that may very useful and enough for many GIS implementations. However, it does not provide the needed capabilities to facilitate the use of the existing applications fully integrated with the GIS. Neither does it allows the development of general-purpose applications which make use of the Geographic information included in the GIS specific databases. This feature becomes a necessity when speaking about the integration of expert systems technologies and GIS. New approaches are needed to overcome this problem, as we will see in the next sections.

Expert Systems

Expert systems have also been in use for a long time already. Although, unfortunately, that does not mean that many people really understand what this term refers to. Next figure shows a classical block diagram of an expert system. Two main blocks stand out as the principal ones:



- Knowledge Base:

The place where all knowledge about the referenced subject is stored. Ideally, this knowledge is introduced in the application in a declarative manner, that means that neither solving algorithms nor special codifications or procedures are needed. Just in the opposite way, only a declaration of the problem characteristics and its relationships is needed.

- Inference Engine

The generic procedural methods which make use of the knowledge base and, as a function of the information included, provides a solution to the stated problem. To change the performance of the system, a modification of the information included in the knowledge base is only needed. There is no need to introduce code modifications in the inference engine, it is designed to work with the existing knowledge, whatever it is.

The idea behind expert or knowledge-based systems technology is therefore very simple: Divide the problem in its two most important parts, the knowledge or, in a wide sense, existing conceptual information about the description of the domain, and the procedures to make use of such knowledge. Success comes when this separation is developed in a way that new changes in the application need only to refer to the knowledge, and the procedures remain unchanged.

This development strategy, sometimes called declarative programming, has unfortunately not been well understood in the past, most of the times being confused the term expert system with the concept of a rule-based system. This has caused the development of many general-purpose applications based in the rules paradigm or making use of Expert System tools, only with the objective of calling them expert systems when they where on fashion, and the avoidance of calling any development in that way now that they are not. Fortunately, other programming paradigms, like object oriented programming, very closed in the beginning to the concept of data oriented programming and expert systems, are increasing its implantation in the sector, although again, there is some doubt about if its main concepts and objectives are really being understood by the developers.

GIS & Expert Systems integration problem: Geographic Decision Support Systems

Once stated the main desired features of an expert or knowledge-based system, there is no doubt Geographic Information Systems include very interesting characteristics over which many expert systems may be developed. After all, as it has also been described before, one of the main problems of a GIS implementation, is the data acquisition and verification problem. Once this data has been included in the system, a task where expert systems may also play an important role, there is an impressive amount of related geographic and alphanumeric information which may be used by the corresponding expert systems applications to obtain many conclusions. Till certain point, the stored information may function as a underlying knowledge base. Methods (an inference engine) must be developed to treat such information, which, together with specific end-application knowledge may constitute what we have called Geographic Decision Support Systems (GDSS).

A GDSS therefore involves several elements:

- Alphanumeric Corporate Databases (where information coming from different applications is stored and read, might be of different DBMS, etc.)
- Specific Alphanumeric Data (The included data which is used by the GDSS to solve the related problem)
- Geographic Elements (GIS related specific data instantiated with their specific characteristics, links to the alphanumeric data, etc.)
- Geographic Elements Relationships (Existing geographic related relationship between the different elements (proximity, connectivity, etc.)
- Integrated Decision Support Systems (Expert and Knowledge-based Systems, Declarative Decision Trees, Declarative Statistical models, etc.). They make use of the existing geographic and alphanumeric data to transform it into useful elaborated information and conclusions to help the user in their decision process. They will probably need to access and execute other existing general-purpose corporate applications in order to take their decisions.
- User Interfaces (Use of the existing GIS supported interface, although possible integration with multimedia information).

Which must be fully integrated in the same application.

A GDSS it is therefore a complete application, integrated in a GIS environment which uses of all the GIS related data to take its conclusions and make its decisions. It is not an autonomous application which is called through the GIS interface, make its calculations independently of the GIS data, and present its results again via the GIS interface. Even if its developed based in the rules paradigm, that application is not a GDSS.

Therefore, to develop a GDSS application, it is very important that the overall system architecture allows for a flexible access to all system-related data (a consistent data model) and that the existing developed procedural functions and methods both from the GIS and expert system side may be called respectively in a simple and easy-to-use manner.

However, those requirements are not always easy to find in GIS commercial products. In fact, with regards to this point, two main kind of GIS products exist in the market, those mainly driven by the Geographic Information, and those driven by the Integration objective and production Databases. They present the following main characteristics:

- GIS driven by the Geographic Information:
  - Focus on the geographic information itself

- Connection to Corporate Databases through complex & occasional links
- Complex access to geographic data from external programs
- Difficult access to existing geographic related procedures from external applications
- Very good graphics and useful for exclusively GIS applications, bad for integration and decision-support.

- GIS driven by the Integration objective and production Database
  - Focus in the existing applications (databases, organization, communications, etc.)
  - Fully connected to Corporate Databases
  - Easy access to all kind of geographic data from external applications
  - Full integration with external application with simple use of existing geographic procedures
  - Fair graphics and correct for exclusively GIS applications, very good for integrated applications and decision support.

Obviously, in order to implement operative GDSS the second alternative is much more interesting. Unfortunately, most existing GIS products belong to the first category of systems. That usually difficulties the implementation of GDSS applications and their subsequent utilization by the system users.

GDSS possible fields of development

There are numerous examples in the literature of expert and knowledge-based applications which make use of Geographic information in various degrees. Their integration capabilities also differ as a function of the application and chosen GIS product. Nevertheless, they serve as good examples of possible fields of applications of this technology. Some of the current existing fields of development are:

Utilities sector (electric, gas, water):
- Navigation systems
- Dynamic reconfiguration support
- Operation support
- Network development
- Network design

Construction Engineering firms:
- Navigation systems
- Road state evaluation (traffic flows, etc.)
- Road planning and development
- Road design

Transport and distribution firms:
- Navigation systems
- Best path finding
- Static/Dynamic distribution planning
- Support for subcontractors negotiation
- Location of distribution centers

Service, Sales & Marketing companies:
- Selection of new selling installations
- Configuration of the new installations facilities
- Full analysis of an area
- Detection of unexpected situations

Environment:
- Classification of the territory in relation with the environment
- Selection of best-location sites for industries, installations, etc.
- Urban development
- Evacuation plans in the case of emergencies
- Fire fighting planning and operation
- etc.

Some GDSS examples

The former section has introduced some of the different fields where GDSS applications could be developed. In this section, a more detailed description is made about some of the applications developed by Software AG España:

IDEA: A Geographic Decision Support System for logistic planning

IDEA GDSS is a software system for aiding business organizations whose objectives are directly or indirectly involved with logistic (distribution) planning.

IDEA supports organizations with different distribution problems (p.e. delivery of products by road) on the daily work of planning, monitoring and re-allocating the corresponding resources, expenses and decisions, allowing maximum integration with other corporate applications and the external world.

In order to do so, it integrates the following technologies:

1 Geographical reference system (including Network Representation; Utilities; Positioning and Monitoring).
2 Dynamic Planning modules (including specific vehicle conditions, surrounding restrictions, flexible optimization objectives).
3 Alternatives evaluation and Decision Support (including schedule and cost analysis of a solution, user explanations, analysis of possible plan modifications).
4 Integration (including Resource Management; Communications; Environment; Corporate Applications and Databases Integration).

SILCI: A Geographic Decision Support System for Marketing and Corporate Planning

SILCI is a software system for aiding business organizations which include disperse selling and distribution locations and must decide their best business strategies.

SILCI support organizations to decide the best location for its installations, the definition of its characteristics and to quantify the expected results and total sales they will provide. In order to do so, SILCI analyzes the area characteristics, possible existing market, competitors location and positioning, the influence of the new installation over the market, etc., always with the objective of supporting the organization responsible people by giving them quantified estimations of the benefits provided by the installation in a cost-effective basis.

It integrates the following technologies:

1 Geographical reference system (including installation location; area qualifications, etc.)
2 Best location selection and market effect evaluation.
3 Interactive tactics modification, as individuals and in reference with the possible competitors.
4 Integration (including Resource Management; Communications; Environment; Corporate Applications and Databases Integration).

Conclusions

Geographic Information Systems need to be fully integrated with existing legacy and new software applications. This is specially true for Expert Systems, giving their integration to a special new kind of applications called Geographic Decision Support Systems. In these applications, it is fundamental that all geographic and GIS-related information may be accessed from the developed application and vice-versa, a functionality unfortunately not facilitated by many GIS products. Many GDSS fields of application exist and have been shown. An important effort is needed from the GIS product developers community to provide next generation systems which includes these features