SPATIAL KNOWLEDGE BASE FOR NATURAL HAZARD PROTECTION : THE ARSEN PROJECT

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Abstract

The development of a decision support system dedicated to a specific natural hazard requires a good representation of spatial knowledge : geometrical objects and spatial processes have to be taken into account for the construction of such a system. Several systems have been developed in France recently for different natural hazards : snow avalanches, slopes stability, forest fires, snowdrifts, torrential floods... For each of these applications, the representation of space has been studied and implemented separately in a different manner.

The aim of ARSEN project is to take advantages of this experience to build a kernel of spatial objects and methods which could be used as a generic tool. It will be integrated in future systems to organize and manipulate spatial knowledge in order to get a simulation of natural hazards and face real-time crises.

In a first part, this paper gives a few samples of objects and processing methods used in the already existing systems. We lay emphasis on the analogy between these different applications. After this analysis of the spatial representation requirements, we suggest a definition of the kernel of ARSEN. In a third part, we describe the way in which ARSEN is implemented. Finally, we present an application where the kernel of ARSEN is used to take into account rock falls and snow avalanches.

1. Introduction

Protecting human beings and their equipments against natural hazards has always been a great preoccupation in people's mind. The first thing people do is to study the phenomenon, and try to understand the way it functions.

Then, the experts often try to simulate the comportment of that natural hazard by employing models, in order to protect dangerous zones from disasters. These simulations, using the help of computers, need a spatial representation of the studied terrain. This paper presents a generic tool aimed at helping designers in obtaining that representation, and its possible applications.

2. Spatial representation in existing systems

The development of an expert system dealing with a natural hazard needs a good spatial representation. The aim of that representation is to apply numerical models or expert methods. Here are some examples of such developments.

ELSA [Buisson 93]

This system is dedicated to avalanche path analysis. It specially studies the starting zone of avalanches. To apply a reasonning of expert, ELSA needs a tesselation of that zone in elementary areas called "small panels". These small panels are considered homogenous for parameters such as slope, type of vegetation...

According to the designers of ELSA, programming that spatial representation was a very long and hard part of the development. And now, as these designers want to improve ELSA by adding new models, others representations are required, so another period of tiresome programming is supposed to begin.

ETCBC [Jover 93]

This knowledge based system studies the phenomenon of torrential floods. The aim of the spatial representation is to apply the ETC model, that works with spatial entities such as watersheds and reachs. These spatial entities are obtained by entering some polylines (boundaries of slope basins, thalwegs...) and extracting from this information the polygons and polylines used by ETC model.

With a rainfall simulation, the program gives the rate of flow in each reach, so the user can predict floods and act to avoid them.

XPENT [Faure 92]

The aim of this expert system is to study slope stability, in order to suggest technical solutions. The requirements in spatial knowledge consist in getting soil sections to apply expert reasonning on the differents layers.

The input spatial data of a slope stability study are often ponctual informations given by drillings. Other informations are obtained from a terrain expert who enters some specific objects such as springs, torrents, rifts...

The program must organise this spatial knowledge to be able to give the right soil sections.

πR3D [Tartivel 93]

This program was developped to simulate rock falls. To apply a simple numerical model based on bouncing onto triangle surfaces, πR3D needs a spatial representation based on a regular grid with an elevation at each intersection.

To apply πR3D to a real rock fall path, the easiest way is to buy a digital elevation model (DEM). But in many cases those DEM are not available, so the user has to create his own DEM with, for example, a digitized map on which he notes some points with their elevation. After a triangulation of those points, altitude can be calculated everywhere with a linear interpolation.

For each of these developments, the creation of the right spatial representation is a tedious programming task. The designers often waste their time in building that representation. Moreover, a lot of common tasks have to be developped separately : getting some objects (points, lines, areas) on screen, triangulations, interpolations...

There are lots of tools dedicated to help designers, such as automatic tesselators and geographic information systems (GIS). But the general drawback of these tools is a real problem of integration. For example, creating a spatial representation may be done through a series of file transfers, because that creation needs a GIS on a Unix work-station and a tesselator on a PC machine. If the aim of the study is to consider two or three examples a year, this is an acceptable drawback. But in an engineering context, facing real time crises or a lot of problems, the rapidity is very important, and those manipulations are unacceptable.

So there are some well determined needs in spatial representation, especially in integration of classic methods and objects with numerical or empirical models.

3. The ARSEN project

This project gives a solution to the requirements of the first part. ARSEN is a kernel of spatial objects and methods, constructed to be used as a generic tool. It is designed in order to help designers to get easily the spatial representation they need.

In this paper, the word **designer** is used to represent the person who uses ARSEN, and the word **user** mentions a person who uses the application developped thanks to ARSEN. The following figure explains the position of the user and the designer.

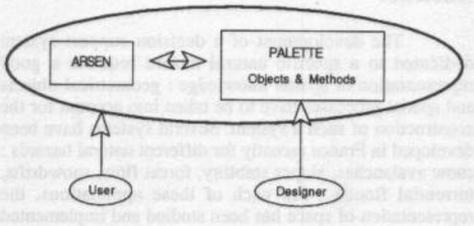

Figure 1 : General Architecture of ARSEN

The "palette" is the structure defined by the designer, in which the specifications of the application are included. For example, in an application concerning snowdrift, this palette should contain specified objects such as ridges and snow fences, and methods such as a simulation of snow falls. Then, when the development of the application is finished, the user can load the palette defined by the designer , in order to use it to obtain the spatial representation of the terrain he studies.

To be useful, ARSEN needs a good organisation of spatial knowledge to cope with the requirements of models. These data are organised in three layers, in order to get a complete description of the terrain :

- a geometric layer, including parameters such as x,y coordinates, length of segments, area of triangles.
- a vectorial topological layer, following the GIS model, to include knowledge such as neighborhood of faces.
- a user layer, corresponding to the requirements of natural hazard studies. The spatial knowledge is organised in point, line and area objects, with the possibility of mixing some of those simple objects in a complex object (like a coverage).

The following figure 2 explains that organisation. The user layer is the only one visible by the user. The other layers are transparent to him. But the designer may act on each layer, which gives him the ability of implementing his own procedures (for instance a special triangulation) on the objects he wants. This specificity distinguishes ARSEN from a classic GIS, where dealing with the geometric layer is often impossible.

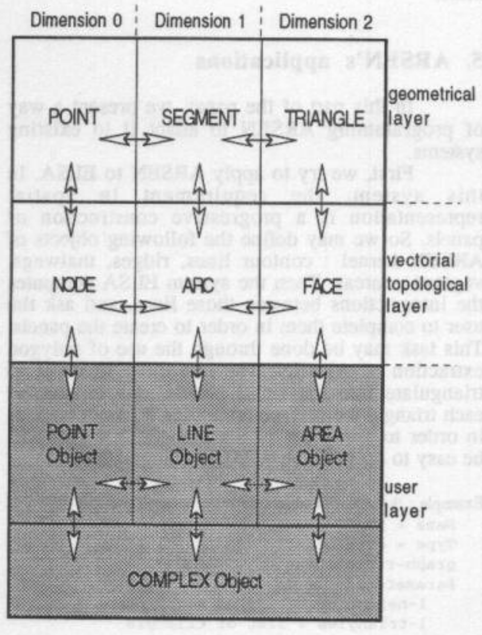

Figure 2: The Spatial Knowledge Organisation
The multiple arrows are representing the dynamic relations between the elements of the layers. For example, if we consider an arc, it has a beginning and an end node, a list of segments composing it, a right and a left face, and a linear object in which it is included.

When the user data are defined, different methods have to be employed to fill the layers. At the beginning, we suppose we have a domain of study (a polygon), and some point, line and area objects given by the user. At this step the user layer is complete.

The first thing ARSEN has to do is to fill the vectorial topological layer. One of the constraint of that layer is that two arcs can't intersect. So if two line objects are intersecting, a node has to be created to respect GIS rules. A decomposition in faces is also required, so that operation is called "polygon extraction". The figure 3 explains that operation.

The next operation consists in filling the geometrical layer. To have a complete description, we need a decomposition in triangles of each face. So this second general operation is a triangulation, also shown in figure 3.

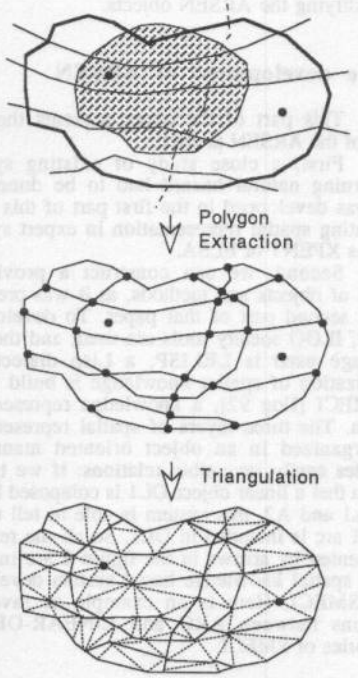

Figure 3 : Filling the layers
The domain of study is within the thick line, there are five line objects, two point objects and one area object. The polygon extraction calculates the intersections between the user lines, and erases the part of objects outside of the domain. Then the triangulation constructs the segments and triangles to complete the data structure.

As the construction is complete, some methods are easily applicable. For example, if the value of a parameter is known for each point of the representation, it is possible to know the values of that parameter everywhere, with a linear interpolation in the triangles.

The general idea of the ARSEN project is to create a tool that designers can easily adapt to their own problems. They should be able to define their own objects (such as ridges, forest areas, drillings...), and to implement their own methods dealing with these objects. For the designers, the access to the data structure has to be quite easy, in order to help them in customizing the system. For instance, if the model they want to apply needs a triangulation where the circularity of triangles (ratio : perimeter^2 / area) is under 40, they can program that special triangulation using, creating or modifying the ARSEN objects.

4. The development of ARSEN

This part of the paper presents the main steps of the ARSEN project.

First, a close study of existing systems concerning natural hazard had to be done. This part was developped in the first part of this paper, presenting spatial representation in expert systems such as XPENT or ELSA.

Second, we can construct a provisional kernel of objects and methods, as it was presented in the second part of that paper. To develop that kernel, ILOG society tools are used, and the main language used is LELISP, a Lisp dialect. The organization of spatial knowledge is build thanks to SMECI [Ilog 92], a knowledge representation system. The three layers of spatial representation are organized in an object oriented manner. It provides easily inversible relations: if we tell the system that a linear object OL1 is composed by two arcs A1 and A2, this system is able to tell us that the A1 arc is included in OL1. So all the relations represented by arrows in the figure 2 are included in the spatial knowledge based system developped with SMECI. Here is an example of inversible relations between ARC and LINEAR-OBJECT categories of SMECI.

Details about the slot l-linear-objects of category ARC:

```
Name = l-linear-objects
Type = list of linear-objects
Inverse = l-arcs
```

Details about the slot l-arcs of category LINEAR-OBJECT:

```
Name = l-arcs
Type = list of arcs
Inverse = l-linear-objects
```

There is also a need in graphic tools to develop an user friendly and rapid interface for ARSEN. That part of the project is developped with MASAI-2D [Ilog 93], an interesting tool which can deal with a lot of graphic objects on screen, using a quadtree structure to store the geometric data. That second part of the development of ARSEN is currently engaged.

In a third part, there will be some tests on existing systems, such as those already studied in the first part of this paper. The aim of that part of the development is to improve ARSEN by applying it to existing systems.

After this phase of improvement, ARSEN will be distributed to others designers of environmental studies, in order to test it on a large scale.

5. ARSEN's applications

In this part of the paper, we present a way of programming ARSEN to adapt it to existing systems.

First, we try to apply ARSEN to ELSA. In this system, the requirement in spatial representation is a progressive construction of panels. So we may define the following objects of ARSEN kernel : contour lines, ridges, thalwegs, vegetation areas. Then the system ELSA computes the intersections between those lines, and ask the user to complete them in order to create the panels. This task may be done through the use of polygon extraction of ARSEN. The last thing to do is to triangulate into the small panels, and to give to each triangle the surface properties it has to possess in order to apply the ELSA model. That part will be easy to do with the ARSEN triangulation.

Example : the ARSEN object defining a small panel.

```
Name = small-panel
Type = area-object
graph-representation = bundle*
Parameters =
   l-neighbors = list of small-panel
   l-triangles = list of triangle
   nearest-ridge = ridge
   distance-to-ridge = real number
   slope = method
   surface = method
```

*** : a bundle is a structure of MASAI-2D that specifies the color, the type of line, the priority of display... of an object on screen.**

The second example we shall present is the πR3D system. The aim of the representation is to get the altitude on each intersection of a regular grid. The user's objects of ARSEN may be ridges, thalwegs, points where the altitude is given (reading a map or making a field measure). There is also a need in expressing the nature of the surface by including area objects in the ARSEN representation. By completing the other layers of the input data, we have a complete representation of the terrain that can be interpolated through the triangles in order to obtain the grid. This interpolation may be done with ARSEN (a linear one is to be implemented) or the designer of πR3D model can program his own one. The idea of

ARSEN is to provide an easy integration of such a specialized development for a special model.

These two examples, the implementation of which is not done yet, may help us in improving ARSEN.

6. Conclusion

At the current state of development of ARSEN, it is not possible to affirm that this kernel of objects and methods is a good solution to help designers yet, in order to obtain the right spatial representation they need to apply their models. But the ideas presented here are useful, and may help a lot of persons who develop natural hazard studying systems.

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