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A RESOURCE BASED APPROACH TO GENERALIZATION IN THE CONTEXT OF GIS

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ABSTRACT

A reactive planning system for decision support in the context of GIS will be a complex system. The information flow is often great but of varying quality. Resources should be used as knowledge structures to organize the data involved in such systems and generalizations to reduce the data volume and create overviews.

This paper discusses what is meant by resources in the context of GIS and planning and how generalizations can be used in a wider perspective than only for cartographic simplification.

The project, which is in an early state, has the goal to design the data structures for a decision support system for crisis and emergency management.

1 INTRODUCTION

This paper presents some ideas from a project of designing knowledge structures for decision support systems in the context of GIS. The project is a collaboration between the Department of Computer and Information Science at Linkoping University and the Swedish National Defence Research Establishment. The primary application for the knowledge structures is a system for crisis and emergency management.

In a management system for different crisis and emergency situations a tool for decision support can be very useful. One reason for the need is that such situations appear seldom, which implies that it is hard to get experience for them. It is also so that when they appear everything seems to happen at the same time, but in different places, which makes it hard to get an overview.

A geographical information system is a tool that could be of great value in these situations. If the information system is object oriented it might be possible to retrieve data about the map-objects, for example type, size or landowner, depend-

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ing on the application. If the system has a good capability for handling topologies and networks it can for example provide us with data about shortest paths, visibility or relations between different objects. Unfortunately most GISs are not able to handle all the dimensions we are interested in. A project at the National Defence Research Establishment was therefore initialized for creating meta structures for information systems such as decision support systems. There are working systems for these kinds of activities where an existing two or three dimensional GIS is included as a part in a the support system, but our approach is that the all of the system components should be designed together.

Typical other applications for this kind of system are command control systems for military control and intelligence, logistic planning, and activity scheduling. A system like this should have capabilities both for live situations, and for training and simulation (Cohen et al. 1989).

2 DECISION SUPPORT SYSTEMS

As mentioned in the introduction the goal for this project are frameworks for a decision support system for e.g. command control, crisis and emergency management or logistic planning. An important activity in such a system is the planning or scheduling of allocating resources of different types.

2.1 Planning

To carry out plans different resources are needed. For example to transport some goods between point A and B we might need a truck, a driver and the goods. We do also need some way between A and B and of course we need some time for the activities.

If the way is long it might be necessary with additional fuel for the truck and food for the driver etc. We call all these important things resources.

2.2 Manual Planning

Given the conditions above we can sketch a plan for solving this problem. This can be done in a traditional way using a paper map and knowledge about the capabilities of the resources. However, when the number of plans to solve increases or the tasks get more complex it would be useful with some tool to help us. This is were the computers and GIS come in.

2.3 Autonomous Planning

Planning is an important topic in logic, artificial intelligence and robotic research. One of the goals is to solve plans autonomously. A simple but typical problem can be seen in the blocks world. Imagine a world of three blocks X, Y and Z and a hoisting crane H. If we want to come from the status of figure 1 a to the status of 1 b we have to go through some steps. By using the crane we first pick up block Z and put it on the floor. Now we can choose between three activities. We can either put Z back again, put Y on top of Z or put Y on the floor. We put Y on the floor. Several

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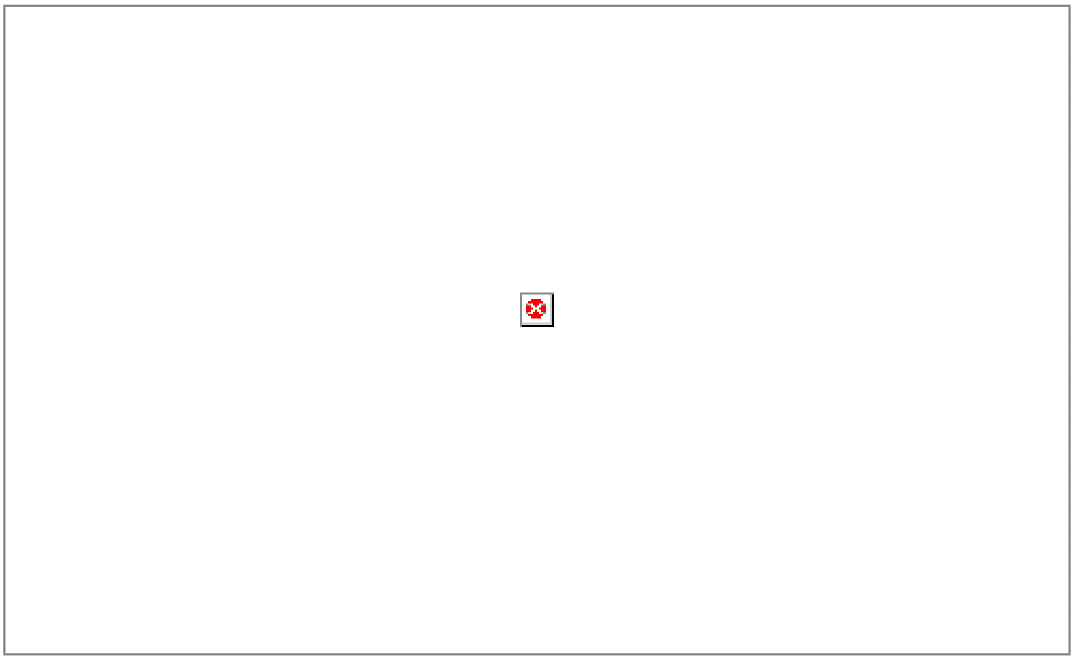
different activities are now possible and we prefer to put X on the top of Y and finally we put Z on X, at the top, and we are ready.



This kind of problem can be solved automatically in several different ways. The more blocks the more complex solutions become, however. Since we have defined that this is what our world looks like, nothing more, nothing less, there are no other consequences that we do not know about.

2.4 Reactive planning

In a decision system it is not acceptable with completely autonomous decisions that may affect the humans involved. At least not if all the consequences are not known. In systems for command control and crisis management there should always be a competent person who takes the hardest decisions and gives the most important orders. (Compare with a medical advice systems for a doctor.) A decision support system can nevertheless be used as an aid for this person.

A reactive planning system as we conceive it works quite autonomously. It considers all interesting data available and then it presents some suggestions. If more information is needed then the user is asked. When the system is finished it is up to the decision maker to use the results. He can also refuse the suggestions or add more data to the systems to perhaps get a better solution.

It is also very important to present the suggested plans in a user-friendly way. If, which we assume here, a GIS is used the plans should be clearly visualized. For such purposes there exist some visual languages. Swedish defence forces use a language, consisting of symbols, lines, arrows etc., for displaying the status on the maps (Chefen for armen 1979). This symbol language is quite similar to the one used in other countries. It also seems to work well on paper maps. Raddningsverket (the Swedish National Rescue Service Board) has tried to construct a visual language more suited for civilian emergency situations (Berg & Sjodell 1991). When constructing a user interface for a reactive planning system it is important to look

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at these language and see what they can offer and then improve them for computer use.

One important feature in a reactive decision support system is that there must be an ability to treat and present incomplete and fuzzy data. If the system does not have enough data for creating solutions it should still work as far as possible. Then in the result it should be clearly specified what is missing. It should also be possible to present plans where some steps are missing.

3 RESOURCE BASED GENERALIZATION

To be able to handle all the information in a complex decision support system some overall strategy has to be taken at the design level. One goal is to keep the system as object oriented as possible. That is, everything should be regarded as objects. Since the term object in an object oriented system covers a lot more than we are interested in here we prefer to call the objects that are visible to the user *resources*. This name also fits better with how they are used.

One way of getting rid of great quantities of data is to simplify them. This can be done in several different ways but the gathering name for it in this field is *generalization*.

Both generalization and resources are described below.

3.1 Resources

As mentioned above an object oriented system is to be desired. In such a system different phenomena can be treated in a similar way and it becomes easier to explain properties and behavior of the objects.

One advantage of object orientation is inheritance (e.g. a specified kind of road can inherit properties from more general roads). This simplifies the creation of new classes of objects a lot. Another feature of object orientation is that each object keeps its own properties and behavior and it is therefore easy to organize the data since these data always are included in the objects (i.e. a road knows how wide it is, its name, how to draw it self etc.). A third benefit is that several different objects can be aggregated into one new object (e.g. several roads can be joined to road networks and houses, blocks, roads etc. can together form villages).

Unfortunately there are also phenomena in a system for reactive planning that do not behave like objects. One example of this is time. Therefore the term resources is used instead. All the things needed to solve a plan are resources. Obstacles are also handled as resources, or rather anti-resources, since they are very important for the final plan. Some examples of resources follows below. In the end of each example follows a list possible properties for the resource type (not complete).

3.1.1 Personnel

Personnel is a typical resource in an emergency situation. To carry out a plan, e.g. putting out a fire, a lot of different persons are needed. Therefore they are a resource.

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Personnel are often needed to manage other kinds of resources, for example vehicles. People can be grouped into units. Well known are the military ones, e.g. squads, platoons, companies. Attributes: name, age, weight,...

> Status: healthy, resting, coordinates,...
> Carries: helmet, first aid kit,...
> Subtypes: fireman, woman, captain, truck driver,...
> Activities: move, sleep, eat, rest,...

3.1.2 Vehicles

Cars, boats, trains, planes etc. are all useful resources. But to be valuable they need to have personnel. A fire-engine needs a driver and some firemen to be a complete equipage.

Attributes: registration number, colour, weight,...
Status: moving, coordinates,...
Carries: driver, water,...
Consists of: 6 wheels, engine, water tank,...
Subtypes: fire-engine, helicopter, truck,...
Activities: move, stand, wait,...

3.1.3 Supplies

Supplies are needed to make other resources work. Examples are food, fuel, water and cloths. Different supplies are used by different other resources. A typical property for some kinds of supply is that they are incidental materials, that is, they have to refilled.

Attributes: age, label,...
Status: quantity left, quality, coordinates,...
Subtypes: food, tinned goods, water, drinking-water, diesel oil,...

3.1.4 Time

That time is an important resource in most planning is very obvious. But time is also an obstacle, but that is a more philosophical question. Tune can be divided in two waysi a static one, dates and times, and a dynamic one, seconds, hours, days etc..

Status: current time
Consists of: seconds, hours,...
Subtypes: date, time, seconds, hours,...
Activities: always running

3.1.5 Activities

Activities as resources coincide with the activities properties. Examples of activities covers all from a great military operation to refuelling a car. Other typical activities are moving, building and resting. An activity often consists of other sub-activities and is often performed by somebody.

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Attributes: name, goal,...
Status: in progress, terminated, coordinates,...
Consists of: vehicles, personnel, supply, sub-activities,...
Subtypes: moving, resting, refilling,...

3.1.6 Plans

Plans are, of course, a very important concept in a reactive planning system. They are also a kind of resource. To carry out a plan other sub-plans are often useful and each plan does usually also consist of several other resources like time, personnel, vehicles etc..

Attributes: responsible person,...
Status: in progress, coordinates,...
Consists of: other plans, supply, vehicles, personnel,...

3.1.7 The surroundings

The surroundings or, as one also might call it, the map, is of course an important resource. Each object in the map is also considered as a resource, some of them very useful for working out plans and some of them are indifferent to the plan while some can even be obstacles.

When constructing a knowledge structure of the map data two different matters appear, topography and topology. It is not so that some objects are topographical and topological, but they have properties of both kinds.

Topography is typically a description of the terrain, where things a placed, elevations, areas etc. It can be seen as a number of pictures in layers with different map objects.

Topology describes how things in the map are related to each other. Typical descriptions are how road networks are connected to graphs or how different regions and places border upon each other. The topologies give rise to well defined knowledge structures (Corbett 1979, Laurini & Thompson 1992).

The properties are the typical ones for map objects:

Attributes: name, area, length, direction,...
Status: coordinates, availability,...
Consists of: other map objects,...
Subtypes: roads, fields, houses etc. of specified types,...

3.1.8 Obstacles

Obstacles are not a specified type of resource. They can be of any kind. An obstacle can be e.g. a plan or activity of an enemy, a fire, a marsh or some people with a vehicle.

The reason for considering obstacles as resources is that they have to be remembered when doing the planning. They are many in cases the most important resources when carrying out plans since they set the limits. It is also the case that without obstacles or "enemies" there would be very little use for this kind of decision support systems.

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3.2 Generalization

Generalization (Buttenfield 1991) for cartographers is often just a simplification or an adaption of the map to an other scale or a more readable format. But generalization can be much more powerful if used in an intelligent way. By using invisible generalizations, that is the generalizations are not made for displaying but for internal representation, it is possible to achieve overviews for the reactive planning mechanism.

These overviews might be similar to the ones used when doing manual reasoning but they can also be different and only interesting for the computer system.

Generalized structures can be accused of not being true and this might be a correct statement. Each time generalizations are made information is lost. But this is the meaning of generalization, to reduce the quantity of data. Still it is desirable to keep the quality of data as good as possible. Therefore the generalizations have to be done very carefully. In many cases it is possible to do great generalizations without losing too much information.

For example, 3 600 seconds can be generalized to one hour and still no information at all is lost. If, on the other and, 3 275 seconds is generalized to one hour this might still be a valid generalization, but we have an information loss, uncertainty, of about nine percent.

Generalization should be seen as a *heuristic* for solving problems in the planning and information systems. The idea is to get a good solution quickly with small effort instead of a perfect one after long waiting and a great amount of work.

3.2.1 Top-Down reasoning

Generalization can often be seen as a bottom-up process. Start with the details and create an overall unit. Creating plans is often a top-down process, where one starts with the plans in the large and gradually or recursively refines them. In this way a plan is a generalization where the generalized data not yet are known. Some parts in such a plan might be known, but others have to be left out until more information is available. Still, should the plan in large, be refused only because some parts are missing? This is a natural way of reasoning. Compare to the following example:

> *This is my plan: I plan to go EGIS'94 in Paris. That will hopefully be possible, I think. I start by deciding to go there by air. Tuesday March 29 from Stockholm will be fine. Now I book an air ticket and get times for the departure and the arrival. I also book a room in some hopefully good hotel. That was the greatest part. My next problem is how to get to Stockholm from my home town Linkoping. I decide it will be by train. So I find a train that matches the departure of my flight and book the tickets. To go to the railway station I usually take the bus. It leaves about every 15th minute so therefore I do not have to bother more about that. The hopefully last problem is to find my hotel in Paris. For this I have not yet any real plan but there are at least two alternatives. There will probably be buses from the airport to the city of Paris and then I can take a taxi the last way just to be sure to and it or I can catch a taxi at the airport and go with it all the way. Any way there is no reason to plan that now. If I only come to Paris the rest will probably also be alright.*

In this example it is obvious that we can not have the entire plan ready from the beginning. Therefore it is important to be able to make refinements and add more

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information to a rough plan or solution.

By integrating generalization to planning the same mechanisms for computing and storing can be used. This also gives us a general way of describing and showing maps, units, plans and other facts.

3.2.2 Resource generalization

There are several models for digital generalization and the application has to be decisive for which ones should be used. This is also a algorithmic matter where time and memory set the limits.

In Shea & McMaster (1989) aspects of cartographic generalization is discussed, asking *why, when* and *how* it should be used. This can also mostly be applied to resource generalization.*Why* generalization should be used has already been mentioned in this paper. The *when* aspect has three parts; *conditions, measures* and *controls*. To transform the data, how, twelve different operators can be used. They are *simplification, smoothing, aggregation, amalgamation, merging, collapse, refinement, typification, exaggeration, enhancement, displayment* and *classification*. To these we put two additional namely *abstraction* and *induction*. Abstraction is similar to the typification and is used hierarchical object oriented structures. Induction is a rule based method primarily used for topologies. It is based on hypotheses which are empirically verified.

On the whole it is hard to find prior work on generalization methods for something else than map topographies. It seems that there has not been any need for generalization of topologies and other knowledge structures yet. At least not in the context of GIS. In Kilpelainen (1989) and Laurini et al. (1992) some ideas are suggested.

Some typical generalizations of resources are described below.

Soldiers are often grouped together in units like squads, platoons or companies. Even material and vehicles are often said to belong to these units. The units are typical generalizations since we do not know exactly what they contain but the name tells us the approximate size of it. It might also be the case that some persons or material is missing. They are still the same unit.

Time can also be generalized. A number of minutes can always be approximated with a suitable number of hours or days. For an exact point of time far from now the date is enough at this moment.

Map symbols can be generalized in the traditional way by smoothing, simplification, amalgamation etc.. The theories of topographical generalization will probably work fine. When working with the topologies there might be some problems. It is very important that the topological relations are preserved.

Several similar activities can be merged to one common. For example can movements of soldiers in a platoon be generalized to one movement of the unit.

Plans can, if they coincide, be merged into super-plans. Compare this to the topdown process of planning.

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4 CONCLUSIONS

Resources seems to be a powerful platform for decision support systems in the context of GIS. To be able to handle the great data flow in this kind of systems the data have to be organized in a perspicuous way. This is done by generalizations.

Since generalizations generate overviews in terms of for example scaling and abstraction it should easy to find alternative solutions to problems.

Nevertheless, there are disadvantages with generalizations too. The first comes by the definition of generalization, the lost of information. No real simplification can be done without losing information. There is a balancing between generalizing as far as possible and keeping the data consistent.

The second problem is that any generalization takes time. It might be possible to save time by first making a rough solution to a problem and then refine it, but it can also be the case that the generalization takes to much time from the problem solver. This is an other balancing.

Hence, it is very important that the generalizations are kept in mind when designing the resources and the other data structures.

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