Toward a taken into account of the “background themes” in a multi-agent generalisation process

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Introduction

Most of the works in automatic cartographic generalisation concern the conception of measures, generalisation algorithms and the triggering processes of these algorithms. The important majority of the obtained results concerns the road and building themes. The automatic generalisation of some other themes such as the relief and the land use has been treated [Weibel 1992; Monier 1997; Peter 2001; Galanda 2003] but not jointly to other themes. Usually, except the case of the road and building themes, the developed methods have not been put into practice for a jointly generalisation of the themes. The obtained results often imply imperfections, even sometimes incoherences between the themes.

This paper aims to present the issue of a PhD beginning at the COGIT laboratory. The object is to find a solution to take into account the relief and the land use themes in a global generalisation process based on the models AGENT of [Ruas 1999] and CartACom of [Duchêne 2004]. In contrast to the road and building themes, these themes are present everywhere, in each point of the space. They are a continuous coverage of the geographic space. They compose the “background themes” on which the others objects seem to be put.

First and foremost, we will see with obtained outcomes from the AGENT and CartACom prototypes why the generalisation of building, road, land use, relief and hydrographic themes should be proceeded jointly, or at least why some object modifications must take into account the background themes.

Then, we will see in a second part some complex phenomena for which relief, road, building, hydrography and land use are involved. Some possible pertinent and meaningful relationships between the objects of these themes will be presented. These relationships will be the ones to preserve or to exaggerate during the generalisation process.

Eventually, we will see some propositions to explicit some constraints in order to preserve the patterns and relationships of objects between themes. We will present why the addition of these constraints to the AGENT and CartACom models is not straightforward, and finally, we will propose a new way to consider the map background themes.

1/ Outcomes from AGENT and CartACom

In this part, some application cases of the AGENT and CartACom prototypes will be presented. We will show some situations transformed without taking care of the background themes.

1.A Outcome of the AGENT prototype

The AGENT prototype arises from the AGENT project presented in [Barrault et al. 2001]. The principles of the AGENT model are exposed in [Ruas 1999]. Some aspects are presented in section 3.

The following examples are extracted from a prototype map resulting from the AGENT model for the 1/100k. This is the result of the “Carto2001 project” presented in [Lemarié 2003]. This project aimed to specialise the AGENT prototype for the production of 1/100k maps from the CartoDB database of the IGN (10m resolution).

Some of the themes of this map are the relief (as contour lines), the land use (as forest areas), the hydrographic and road networks, and urbanised areas. In the generalisation process, the relief is not generalised. Nevertheless, the hydrographic network is modified: when a river and a road are too close to each other, the river is systematically displaced. The road network is considered as having priority over the hydrographic network. In some cases where the road and the river symbols are really too close to each other, the symbol of the road overlaps the river one.

The cartographic quality of the results has been judged good enough to start a broad-based production of 1/100k maps. Nevertheless, some light incoherences between the hydrographic network and the relief exist. The rivers are displaced to let space for the roads symbols without modification of the relief. For this reason, we can find some situations where a river does not flow anymore precisely in its thalweg (figure 1).

Figure 1: the river gets out from its thalweg

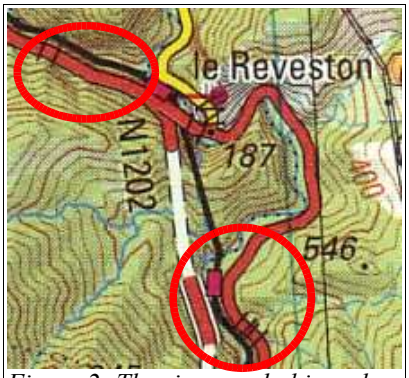


Figure 2: The river symbol is under the road symbol

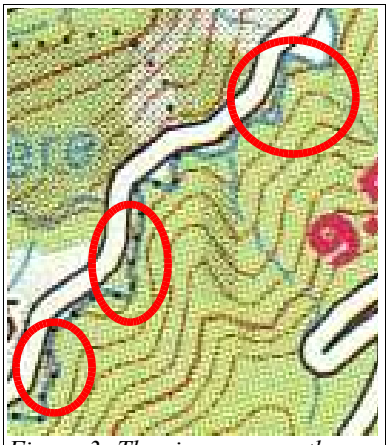


Figure 3: The river crosses the contour line

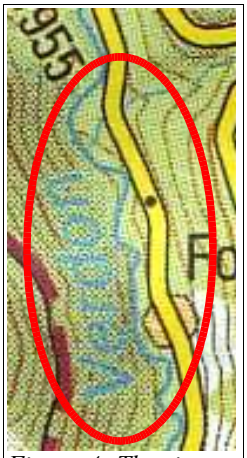


Figure 4: The river crosses the contour line

In some other cases, the river symbol can cross a contour line (figures 3 and 4) and give the impression to climb back the relief. A solution to avoid this problem would be to widen the thalweg. In many situations, a road goes through a narrow valley by following the river of this valley. The lack of room is then very strong when the valley is cramped. In the example figure 2, a road, a river and a rail track are located in a cramped valley. The lack of space is so high that the symbol of the river disappears under the two other symbols.

1.B Outcome of the CartACom prototype

The CartACom ("Cartographie avec des Agents COMmuniquants" or Cartography with communicating agents) model arises from [Duchêne 2004]. This generalisation model is based on transverse interactions between geographic agents with communication capabilities. In comparison with the AGENT model, there is no hierarchy between the geographic agents. This model has been specialised for the generalisation of buildings and roads in rural areas and could be specialised for other situations without any evident hierarchy.

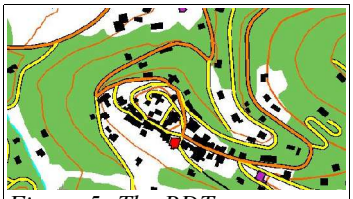


Figure 5: The BDTopo database

The situation shown here is a small village perched on a peak (figure 5). The peak can be seen with the contour lines on figure 6. The fact that this small village is "perched on a peak" is an important information of this situation. It is therefore necessary to preserve it: this information is still present on the manually generalised maps (figures 7, 8 and 9).

Figure 6: contour lines

The result for the scale 1/50k is shown on figure 10. In the CartACom process, each geographic agents (road or building) acts according to its environment composed of the other agents (roads and buildings), without taking care of the relief. As we can see, a lot of peripheral buildings of the village have been displaced from their road. It seems that they have "climbed down" the peak because of their displacement (figure 11). These transformations have broken the "perched" aspect of the small village.

Figure 7: 1/25k


Figure 8: 1/50k


Figure 9: 1/100k

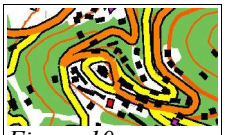


Figure 10: CartACom for 1/50k

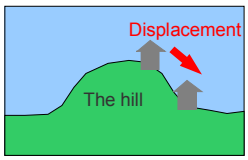


Figure 11: a house climbing down a hill

1.C Geographic database incoherences

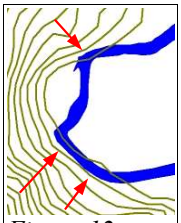


Figure 12

The incoherences shown previously are consequences of the generalisation process. But this kind of incoherences can be present in the initial data when these data have not been gathered jointly. The unconnected treatment of the different themes often causes incoherences between these themes.

For example, on figure 12, a wide river overlaps a slope. This slope and the river bed are linked: the modification of the direction of the river corresponds to a contact with the slope. It would be necessary therefore to avoid that the river climbs back up the slope, and also to keep the contact with this slope to show the existing link between these two phenomena.

On figure 13, a river flows in a thalweg. The thalweg is easily visible with the sharp angles of the successive contour lines. The river does not flow precisely in its thalweg. The sharp angles of the contour lines should be on the trace of the river.

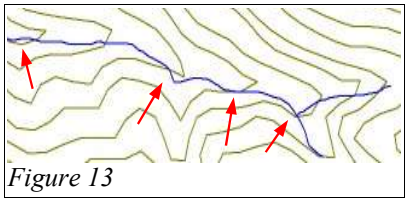


Figure 13

Such anomalies between the relief and hydrographic themes break a physical law « the water flows down ». This is all the more important to respect such a rule because physical laws are often stricter than geographic ones.

2/ Patterns and relationships

In the section 1, we have seen some geographic relationships existing between objects of the road, building, land use, relief and hydrographic themes. The destruction of some of these relationships caused by the generalisation process can be harmful according to the map specifications.

We present some other pertinent and meaningful possible relationships between these objects. The shown maps are extracts from 1/25k, 1/50k and 1/100k maps of IGN. These have been generalised manually. The different scales allow to see how the patterns and relationships between objects are sometimes enhanced, sometimes preserved and sometimes lost across scale changes.

2.A Examples of relationships and patterns involving background themes

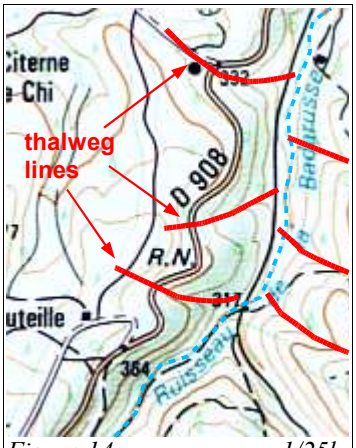


Figure 14 1/25k


1/50k


1/100k

On figure 14, a river flows in a thalweg along the irregular mountainside composed of secondary thalwegs. A road falls away along the thalweg. The road's slope seems almost constant. The bends of the road are corresponding to the irregularities of the relief. Indeed, the presence of bends on the road and the constancy of the slope are two linked phenomena: the constancy of the slope is the cause of the road's bends.

On the 1/100k map, the irregularities of the relief are not visible anymore, but little bends of the road that are the consequence still remain visible. These bends suggest the thalwegs.

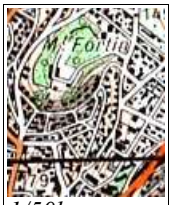
Figure 15 *1/25k*

1/50k

1/100k

On figure 15, a housing estate is located at the border of a cliff. This housing estate is surrounded with forests. A kind of deforested strip is around the housing estate and contains some buildings. On the 1/50k map, this strip is preserved but not on the 1/100k map.

Figure 16 *1/25k*



1/50k

1/100k

On figure 16, we see an urbanised area in a rugged relief. A fort stands on the peak of a wooded hill. Almost the whole space is urbanised, despite the strong constraint imposed by the relief. We can see that the relief constrains the road network a lot: The roads must keep a low slope. Most of the roads perpendicular to the contour lines are short.

The relief also seems to constrain the orientation of the buildings: the buildings are oriented rather towards the slope. This could be a direct consequence of the relief, or this could be a consequence of the fact that the buildings are oriented first with the road network that is itself oriented with the relief.

On the 1/100k map, the contour lines are not visible anymore but the road network still suggests the shape of the relief.

Figure 17 *1/25k*

1/50k

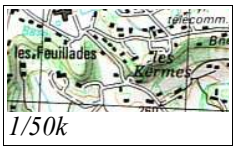
1/100k

Figure 18 *1/25k*

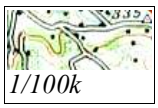
1/50k

1/100k

Figure 19 *1/25k*



1/50k



1/100k

Figures 17, 18 and 19 above show the kind of relationships we can find between other kinds of objects. A tunnel that goes through a little part of the relief (figure 17), a canal that goes along the contour lines of a mountainside with a constant altitude (figure 18), a steep part of the relief covered by forest (figure 19) : these relationships could be preserved by generalisation. The geometry modification of some of these objects must be done in conjunction with the others.

2.B Discussion

Among the previously presented relationships, it appears that the relief and hydrographic themes must be considered as interrelated themes. The link between these two themes is very strong: a river flows in a thalweg and the thalweg is ploughed by a river. Each modification on one of these themes should be made in conjunction with the other.

The question of the existence of a hierarchy between the themes could be asked. We could consider the natural themes (relief + hydrography, land use) as less important than the human ones (buildings and roads). In the situations shown in section 1 and 2A, it seems nevertheless that such a hierarchy is neither global (a natural phenomenon could be locally more important than a human one), neither absolute (depending on the map specifications, the relative importance of the themes changes). It is therefore necessary to consider the phenomena according to their contextual situation and not according to the theme they belong to.

These examples also show that it is important to model and make explicit the numerous patterns between objects of different themes. It is necessary to see the map as a "*palimpsest of patterns inherent among symbolised objects"* [Mackaness and Edwards 2002]. That is why it would be useful to enrich the initial data by building and characterize these patterns and relationships. Some constraints to preserve characters of these patterns and relationships could be then considered.

3/ Propositions

We have seen that many complex patterns may be generated by the interplay of elements with the background themes. In this part, we will mention tracks for a translation into constraints of some of these phenomena to preserve. We will then see why the addition of these constraints in the AGENT and CartACom models is not straightforward. Eventually, a new way to consider the background themes will be presented.

3.A Propositions for data enrichment and translation into constraints.

The constraints to add in order to keep the patterns and relationships are not readability constraints but preservation constraints. As seen previously, there are numerous patterns and relationships to consider. We will see only a few of them presented figures 20 to 23.

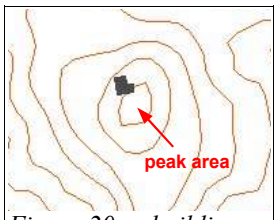


Figure 20: a building close to a peak.

Figure 21: a building in a non-wooded area.

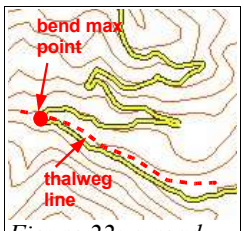


Figure 22: a road climbing a mountain side with a thalweg.

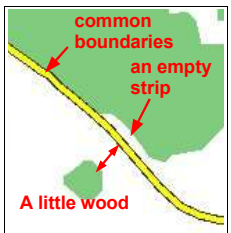
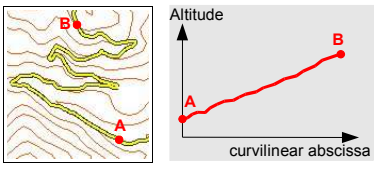


Figure 23: a road going along a wooded area

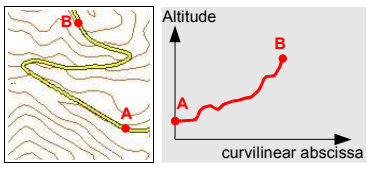
Figure 20 presents a building on a peak. The information to preserve would be the altitude of the building (quantitative information) and the type of relief area it is belonging to (qualitative information). The definition of the constraint to preserve the altitude is easy. To preserve the relief area belonging, we will need to explicit these relief areas. Some works as [Carvalho 1995; Jamet 1996; Wood 1996; Monier 1997] give methods to extract such partitions from a DTM. As shown on figure 20, the peak area has a fuzzy definition, and the building is almost at the top, but not exactly. [Fisher et al. 2004] gives a way to build a fuzzy partition of the relief into peaks, ridges, pass, planes, channels and pits. The belonging of the building to one of these relief areas can be measured using this patterns.

Figure 21 shows a building inside a non-wooded area. The belonging of the building to one of the area type can be measured even when the building overlap land use boundaries (by using for example the proportion of the building's area overlapping the different land use areas). The position of the building in his land use area should be preserved too by using a Delaunay triangulation for example like in [Hojholt 2000].

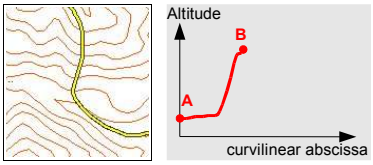
On figure 22, a road climbs a mountain side. One of the bends is going in a thalweg: the bend maximum point cross the thalweg line. The *profile* of the road seems to be an interesting structure to control the slope constancy of the road (figure 24a): this profile sums up the relationship between a linear object and the relief. The application of some algorithms can destroy this relationship (figure 24b, 24c). The information to preserve could be the altitude of characteristic points of the road section, and the shape of the profile. [Plazanet et Spagnuolo 1998] give a method to study the shape of a profil line.



a. the initial road and its profile



b. effect of the bend removal algorithm



c. effect of a Gaussian filter

Figures 24: effects of some algorithms on the profile of a road

On figure 23, the information to preserve would be the relationships of some parts of the road with some parts of the wooded and non-wooded areas. A part of the wood limit touches the road. It is a non-wooded strip between the road and the wooded area. A little wood stands close to the road. To define a preservation constraint of such relationships, it would be necessary to build measures of relative position of an area to a line. An adaptation of some of the measure proposed in [Peter 2001] for the categorical maps could be considered.

We will see now appearing problems when including these constraints to the AGENT and CartACom models.

3.B Integration to the AGENT model

The AGENT model [Ruas 1999] is used with data organised into a pyramid-shaped structure (figure 25): a "meso" agent triggers and controls the generalisation of its composing agents. Each agent applies transformations to itself. Its goal is to satisfy a set of constraints. This model has been specialised for the generalisation of the building theme in urban areas. A hierarchy used for this theme is presented in [Boffet 2001]. This hierarchy is a segmentation of the geographic space into cities, districts and blocks given by urban analysis. It has also been specialised for the generalisation of road sections by cutting each road section into homogeneous parts following [Plazanet 1996] and [Mustière 2001]. The principles of this model are used a lot nowadays as shown in section 1 with the "Carto 2001 project" at IGN France.

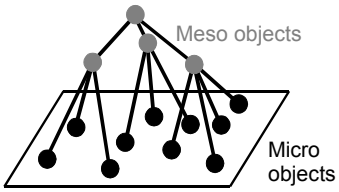


Figure 25: Pyramid-shaped structure of the AGENT model [Ruas 1999]

The spatial context of each object is made explicit using the meso objects. A micro object changes according to its internal constraints and to the meso object he belongs to: the constraints of the context are beared by the meso object. To include the constraints of the background themes, it would be necessary to explicit the patterns they form as meso objects, and make the micro objects involved in these patterns respect the constraints of these new meso objects. The problem would be that an object would depend on several other meso and have to respect their instructions which could be opposed. The management of such a situation has not been treated in the present model.

3.C Integration to the CartACom model

The CartACom model is based on transverse interactions between agents (figure 26). The agents communicate and apply algorithms to themselves according to internal and relational constraints they have to satisfy.

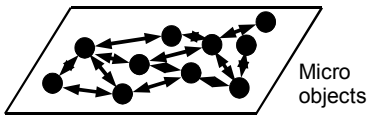


Figure 26: transversal interaction of the CartACom model. [Duchêne 2004]

This model has been applied to the road and building themes in [Duchêne 2004]: buildings and roads are communicating agents. They perceive their context through relations they have with other agents. They swap informations and act in concert with other surrounding agents.

To apply the CartACom model to the map background themes, the land use areas and relief areas could be seen as agents. The problem is that these objects are composing a partition of the space: it appears difficult to see them as isolated geographic agents. When they are displaced, they must be deformed according to the other objects of their theme. It seems that the relational constraints between two agents exposed in the CartACom model are not adapted to these case. Their display order is different too: this theme are always displayed under the building and road themes. Moreover, the effect of this background themes on the other objects is rather diffuse and continuous: they don't lead the generalisation process but must be taken into account.

3.D Proposition of improvement

To take into account map background themes, it would be necessary to allow the agents to act according to "environmental constraints" that are not taken into account for the moment in the AGENT and CartACom models. It would be necessary to spread the perception and analysis faculties of the agents to the map background themes. The agents will be constrained by the map background, and sometimes act on it.

The notion of "environment" is present in the field of the multi-agent systems [Ferber 1995], [Weiss 1989]. The environment in multi-agent systems is the set of objects which are not agents but which are perceptible by agents and influence them. This environment can be a continuous coverage or not. An adaptation to our issue should be considered. Figure 27 shows how the map background themes could be seen as the environment of the geographic agents: the geographic agents are put on the backdrop, are influenced by it and can deform it.

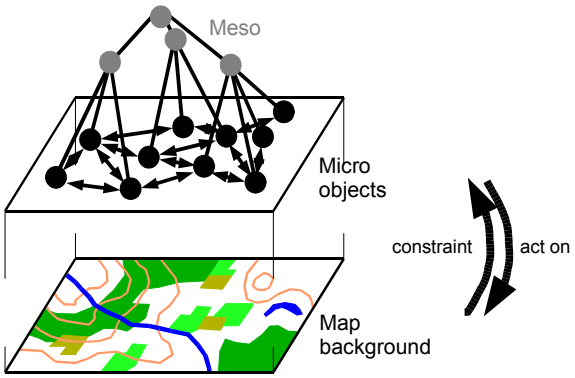


Figure 27: the geographic agents and the map background as environment

Conclusion

We have seen in sections 1 and 2 that the relationships existing between the road, building, relief, hydrography and land use themes are plentiful and complex. In section 1, we have seen that some of the automatic generalisation processes can damage such relationships and patterns. Indeed, the generalisation of these themes should be made jointly, or at least take into account these themes interplays.

Our purpose is to improve the existing models to keep the relationships and patterns between the background themes and the others (we don't aim to make a jointly generalisation of these themes). We have seen in section 3 some propositions to develop constraints to preserve some patterns and relationships between objects. The difficulty to add these constraints to the AGENT and CartACom models has been presented. We have finally proposed a new way to consider the map background theme, as a backdrop of the geographic agent.

This constraints have not been implemented for instance. This is a beginning work. Some deformation algorithms will certainly be needed too in order to allow the geographic agents to act on the background themes. Beside our work, some works in COGIT laboratory are still in progress to merge the AGENT and the CartACom models into a single one. Our work will be to introduce some principles to take into account the map background themes in a single multi-agent model.

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