Generalisation process for Top100: research in generalisation brought to fruition

Cécile Lemarié
Institut Géographique National
Service de la Recherche
Projet Carto2001
2 à 4, avenue Pasteur
94165 Saint-Mandé Cedex
FRANCE
Cecile.Lemarie@ign.fr

Abstract

IGN (the French National Mapping Agency) is working on a new production line to derive from a reference database a new 1:100.000 scaled map. The generalisation process designed has taken advantages from the last research in generalisation available with the multi-agent systems and elastic beams displacement algorithms. This paper reports on choices made by the Carto2001 project to design a production line using automated cartographic generalisation.

Keywords: multi-agent system, elastic beams, independent generalisation, contextual generalisation, inter-theme

1 Introduction

In 1999, the French National Mapping Agency (IGN) launched a new project in cartography called: "Carto2001: Space Cartographic Odyssey". This project is in charge, among other tasks, of the design and industrialisation of a new production line to derive a new 1:100.000 scaled map from the BDCarto® database (a 1:50.000 database with a 10-meter resolution produced by the IGN and covering the whole French territory). This paper will focus on the generalisation part of the derivation process (which otherwise includes label placement methods).

In the first section, the paper will present first the research and industrial context in the generalisation domain and then Carto2001's aims and constraints. The next part of this article will detail the choices which have led to our fully defined generalisation process. It will be shown that the project had to face several obstacles : the actual state of research work obviously, but also production constraints such as data volume, processing time, robustness, ergonomy. These two points have occasionally deferred us from adopting the best research tool available. Then the two parts of the generalisation process will be described : the automatic part but also the interactive one.

Eventually, the last part will present some concrete cartographic results but also future developments for bringing these generalisation tools into the updating life-cycle of the map but also for using generalisation tools for other map series.

2 Context and objectives

2.1 Research Context in Generalisation

The Carto2001 project was launched in June 1999 in a research context which expected a very fast improvement of generalisation tools in the next few months.

Indeed, in 1997, after ten years of research in automated cartographic generalisation, IGN started **European Project AGENT** then due to end in December 2000. This project was gathering five partners : the COGIT –

one of IGN's research laboratory -, LaserScan Ltd (LAMPS2 editor), the INPG Leibniz laboratory, the Geography Departments of Zurich and Edinburgh Universities.

The AGENT purpose was both to design a prototype for cartographic generalisation based on multi-agent concepts and to implement a commercial GIS software [Lamy et al. 1999] [Barrault et al. 2001]. Moreover, the prototype had to integrate generalisation algorithms developed in three research laboratories (COGIT, Zurich and Edinburgh).

The main foundations of the AGENT project are explained in the PhD research work of Anne Ruas [Ruas, 1999]. They rely on the use of "agents" which are intelligent objects. These agents have to reach a goal which is defined by satisfying a set of constraints. The AGENT principle is then to model cartographic objects as agents and to define a set of constraints: symbols must not overlap each other, roads must not be coalesced… Note that, constraints can involve either one or several agents : cartographic groups of agents are modelled as meso-agent (a building block for instance). Agents have autonomy to analyse their state (some measures are available), to trigger algorithms and to assess wether cartographic conflicts are solved.

These principles have been implemented in the LAMPS2 GIS to generalise roads and buildings. This approach is one of main axes of the Carto2001 generalisation process.

2.2 Carto2001 Project: the challenge

To define a digital production line for the 1:100.000 scale map series (called Top100) by deriving the maps from the BDCarto® database is not a new idea in IGN. A previous project had been started in 1994 but the production cost was too expensive to launch the new production line of the Top100. The generalisation process was then estimated to 1000 hours of operator work per map.

Then, in 1999, it appeared that research in generalisation had progressed enough to think that now it could be possible to take up the challenge. But Carto2001 project had to take into account also other technical challenges simultaneously. The objectives of the Carto2001 project are :

- to define a generalisation process to draw the first version of the Top100 maps from BDCarto®
- to implement a label placement software for the automation of names and symbols placement on the map
- to define an updating process to introduce the BDCarto® updates in the Top100 database with a high degree of automation [Lemarié and Badard 2001]

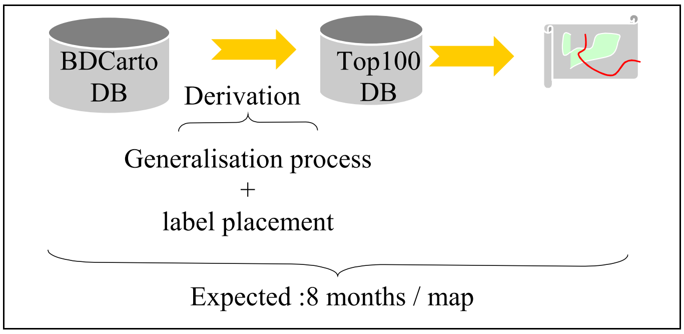

Figure 1: Derivation process

Notwithstanding they are separately presented, a high degree of interaction exists between these 3 processes, since to automate the updating some specific precautions have to be taken with the two other processes.

As the project was launched to take advantage of the AGENT solution, the generalisation and updating processes have been implemented in the LAMPS2 GIS.

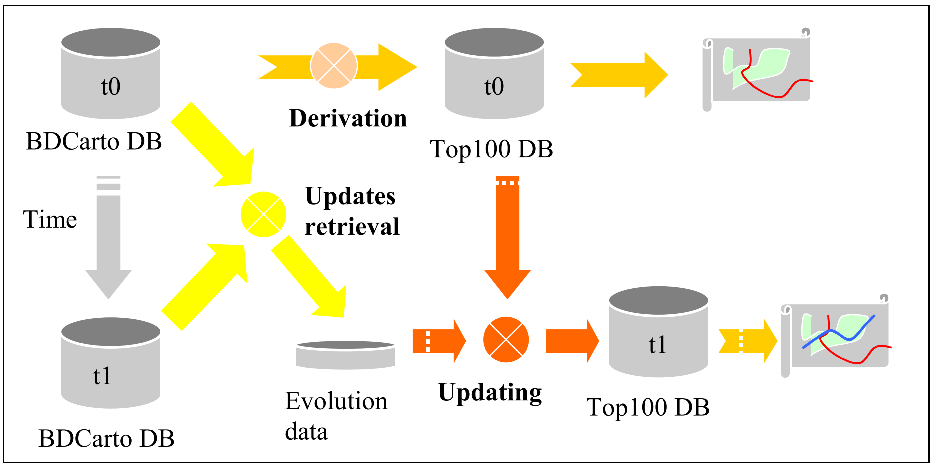

Figure 2 : Top100 DB life cycle

In addition to the project goals, some technical challenges appeared from the beginning of the project in order to reduce generalisation and updating costs. The most ambitious objective was to design a cartographic Top100 Database which would cover all the French territory.

In this article, only the generalisation process will be described. At the beginning of the project, it was thought the AGENT tool would solve all the generalisation problem and that the project work would only consist in testing and setting up the AGENT prototype to design the Top100 particular generalisation process. This point of view changed quite early, as soon as the first commercial version of AGENT was tested in June 2001.

2.3 The LaserScan-IGN Cooperation

The first commercial version of AGENT demonstrated that generalisation would not be a “push-one-button” operation. The tests we performed and the specific need we had, showed us that some things were really good in AGENT but that others had to be robustified or even thought differently.

The discussion between IGN and LaserScan proved that the two companies could benefit from working together to improve AGENT prototype and to share their specific knowledge : IGN brought its cartographic knowledge and capability to test the AGENT measures and algorithms, LaserScan brought its knowledge of LAMPS2 and its capability to develop and optimise the software.

In about a year and a half, AGENT has been both robustified and debugged but also enriched to deal with specific problems which had not been approached during the European project. Some of these elements will be detailed in the next part.

3 A new generalisation process for the Top100 production line

3.1 BDCarto® data and Carto2001 needs in generalisation

The Top100 cartographic database is derived from the BDCarto® database - a 10-meter resolution database originally designed for the 1:50000 scale-. The BDCarto contains all the topographic themes : roads, rivers, railways, administrative limits, landcover, orographic details but also touristic information and labels, which will all be used in the Top100 map.

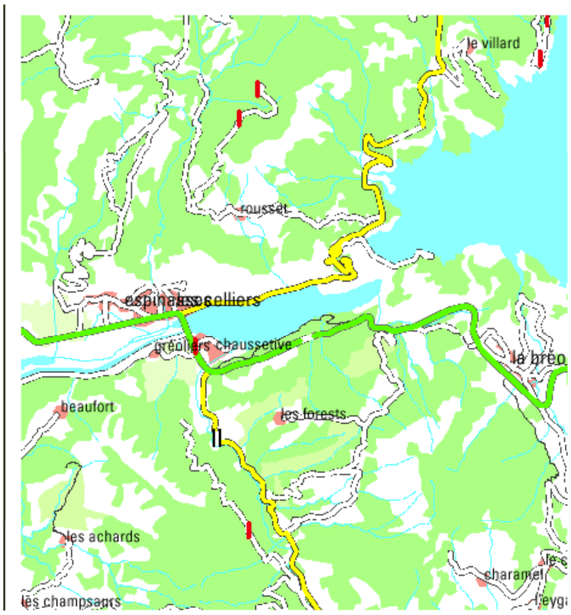

Figure 3 : BDCarto overview

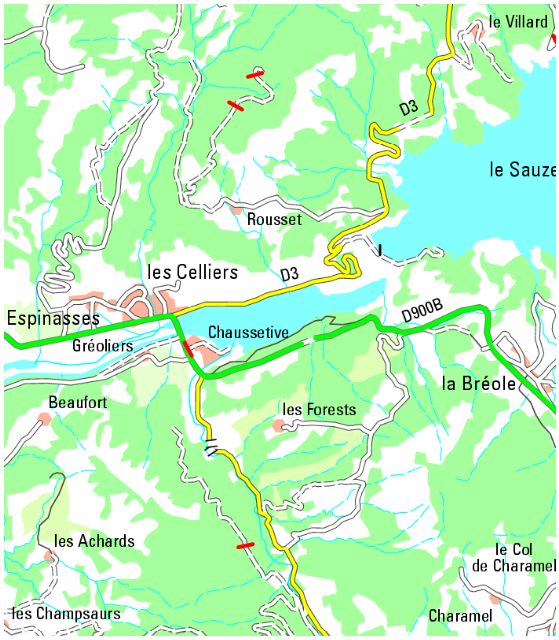

Figure 4 : Top100 overview

Buildings as elementary objects are not present in the BDCarto®.

In the generalisation process we will consider two distinct issues :

- **independent generalisation** which consists in solving the conflicts due to coalescence and noise at the object itself. This will have to be used for mountain roads for example.
- **contextual generalisation** : the object is considered in its environment and then due to symbol widths and density, it is sometimes necessary to displace objects to preserve a minimal distance between them or to enforce the readability of a junction for example. Contextual generalisation will be used to displace rivers which are in the road symbols but also to process the network made with roads and railway.

Concerning the Top100 map, our constraint for the generalisation process is to obtain a good road symbolisation. Independent but also contextual generalisation solution will have to be used but maintaining **consistency with other themes** is also required:

- topological relations must be preserved
- geometry shared between objects must be preserved : roads and administrative boundaries can share the same geometry
- relative positions of objects have to be preserved: displacement of roads must preserve the relative position of punctual objects (museum, hospitals…), road equipments along roads must remain along the roads…
- displacement of objects can be limited by other objects : roads cannot be displaced into the sea or lakes

So, we had to answer the question: what happens to related objects (connected, neighbours…) when a road is displaced ?

Such "diffusion" rule and displacement constraints are not specific to the Top100 needs but AGENT prototype did not allow to express them easily. Even if the AGENT prototype was for the Carto2001 project a major asset in the automation of the generalisation process, the difficulty to preserve the consistency between roads and other themes was another problem which had to be tackled and solved. Our cooperation with LaserScan has led to enrich AGENT with diffusion functions making possible to maintain the database consistency.

3.2 *A Powerful automated generalisation tool*

3.2.1 Evaluation of the AGENT prototype

As mentioned above, only network generalisation from what AGENT could offer was useful for the Carto2001 project, so tests and evaluation of AGENT prototype were made only for networks (roads, railway, rivers).

Two main goals had to be reached :

- to perform independent generalisation of the road network : road by road processing of bends and noises
- to perform contextual generalisation to solve overlapping of symbols between network objects (roads, rivers and railways)

AGENT was tested on these two issues and the conclusion was that :

- AGENT could solve most of the coalescence conflicts very efficiently
- Overlapping conflicts were not solved as efficiently as expected and, moreover, displacements were sometimes too large and not acceptable
- Eventually, AGENT could not process a lot of objects and time processing due to displacement was very long

So, the first conclusion was that AGENT was the solution to use for independant generalisation but displacements should be made using another technique.

3.2.2 Independent generalisation

The derivation of BDCarto data into map objects a the 1:100.000 scale requires :

- to remove tiny details which could be detected by the eye as noise
- to stretch some bends
- to remove some bends in bend series

In AGENT, thanks to agent technique, each road is considered as an agent. If coalescence constraint is not satisfied then the road will be cut into several parts, each one of a homogeneous coalescence value, considered in its turn as an agent on which specific algorithms will be tested: the one which gives the best result is chosen. So, at the end, the resulting road is the best which can be found with the available measures and algorithms.

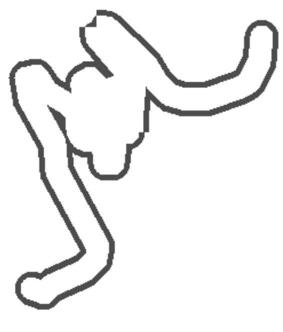

Figure 5: BDCarto data

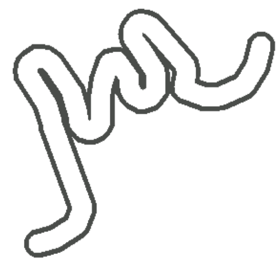

Figure 6: Result of the AGENT process

AGENT is thus used for independent generalisation on each object separately.

Such a use of AGENT takes advantage of the capability that AGENT has to find the best solution to solve internal conflicts, and ignores the problem of time processing due to launching AGENT on numerous sets of objects. The level of generalisation we are looking after doesn't suffer from such a choice but for a higher degree of generalisation, where independent generalisation could create more conflicts with surrounding objects, such a choice could be discussed.

3.2.3 Contextual generalisation

3.2.3.1 The "elastic beams" technique

The first tests on AGENT showed that agent technique was not usable since the cartographic result was not always good and too few conflicts were solved. Moreover, processing time was not acceptable, even on a few objects (each time an object is displaced, the others one re-evaluate themselves to check wether displacement is acceptable). The problem came not from the agent technology but from the displacement algorithms launched by AGENT.

At the same time, Matthias Bader [Bader 2001], from the University of Zurich, was working on "*elastic beams*" - another type of displacement algorithm, using an optimisation approach different from the sequential techniques used in AGENT.

Beams consists in defining internal and external forces on each of the objects' points, and in finding the minimum of energy for this system. Objects will reply to this force more or less easily, depending on their ability to be distorted, compressed or extended. This technique which seemed to bring a noticeable improvement for road displacement was finally developed by LaserScan and the "moveability" of objects was setup by the Carto2001 project.

Very satisfying results came out, even in very crowded areas and in very specific configurations as interchanges. The advantage of beams on agent is that beams try to find the best compromise between all the repulsion forces, so it tries to solve a bit each conflict, which in most cases is cartographically acceptable.

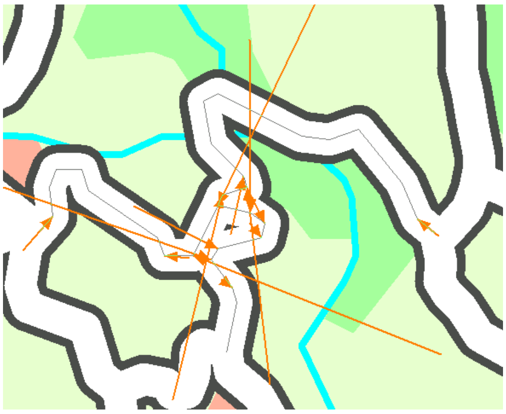

Figure 7: Beams forces

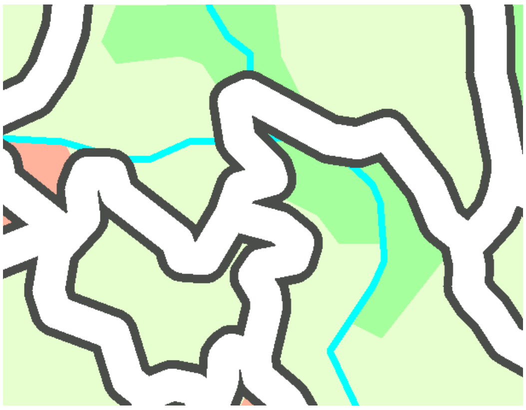

Figure 8: Beams result

3.2.3.2 The flexibility graphs

Once the cartographic quality of beams had been recognized, the next problem was an operational one: beams cannot process thousands of objects at the same time due to the fact that beams are based on matrix inversions. To process all map objects together was then not so easy at first see. Two solutions were tested:

- The first one was to simply partition data from the network of main roads. In this solution however conflicts which are often on the main roads were not processed in the same way in the two partitions. The effect would then be that the partition limits might be visible on the map because ther would then be a break instead of a nice continuous displacement.
- The second one was to detect all the conflicts, and for each one to define in function of the road bending characteristics the set of roads which could be displaced to solve the conflicts. This set of roads is called the **flexibility graph**. It represents the extent of the conflict in terms of displacements to solve it. Then, these graphs are aggregated and beams are launched on each graph. **Detection of conflicts is done with the available AGENT measures. This is the solution we chose**

The flexibility of a road is a measure which qualifies the sinuosity of the road, the more bends the road has, the more flexible it is. Concerning displacements, the more flexible a road will be, the faster the displacement will be cushioned. Our approach concerning the flexibility graph is to determine from an object in conflict (the source object) the set of objects which are supposed to be displaced. The flexibility path from a source object to another object is defined as described on the following figure :

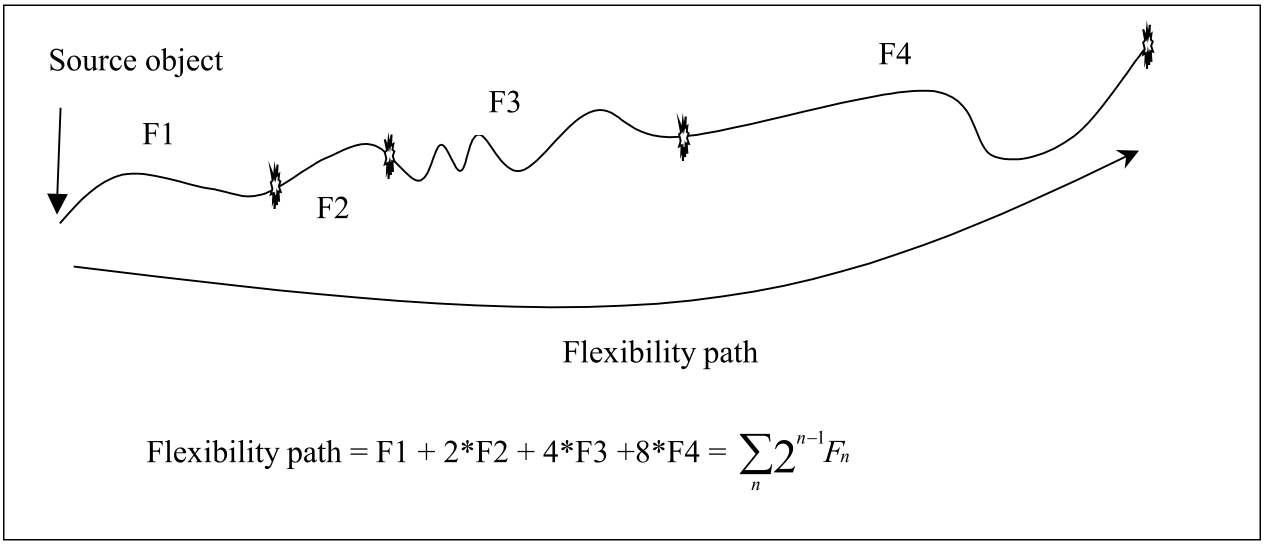

Figure 9: determination of the path flexibility

So, the more an object is far from the source object the more its flexibility is taken into account. The flexibility graph of a source object is then composed by all the objects relying on a flexibility path which has a total flexibility less than a given value (parameter depending on the type of conflict to solve).

Once the flexibility graph has been calculated for each object in conflict, these graphs are merged so that each object is only in one graph and beams are then launched on each merged graph.

Cartographic results are very satisfying and make us think that this, at the moment, is the best way to solve our problem.

Moreover, facilities have been added by LaserScan to freeze some objects, for example “water border”, to prevent displacement of roads upon seas or rivers.

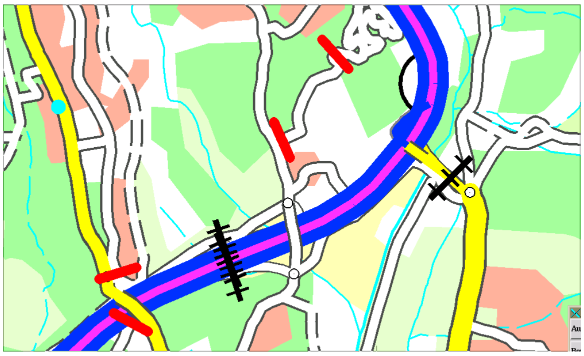

Figure 10: BDCarto® data

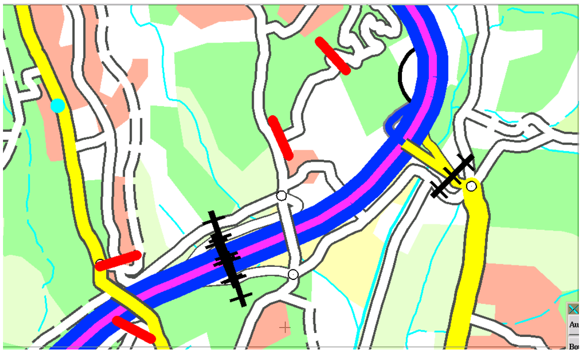

Figure 11: Beams result

3.2.4 Inter-theme consistency

To preserve the “geometry sharing” between objects, LaserScan has developed a “diffusion” function which makes possible to diffuse roads displacement on connected objects but also on objects which share the same geometry. This function has been interfaced with the AGENT and beams tools.

We have also used this tool to maintain consistency between the road network and isolated points by adding a fictive line object which links an isolated object to the road network.

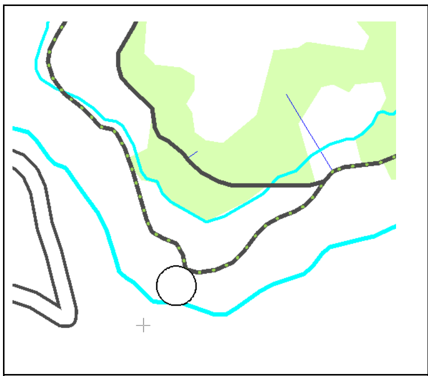

Figure 12: BDCarto® data

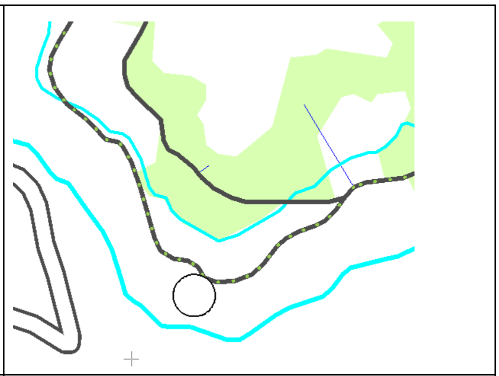

Figure 13 : Displacement of the road: the punctual object is moved and the administrative boundary also

3.3 Carto2001 generalisation process

3.3.1 A powerful automated process

The automated process uses all the tools described above, and runs in three main steps once the data have been symbolised and inter-theme relations have been identified :

1- **Hydrographic displacement :** beams are used first to offset rivers when they are lying in road symbols

2- **Independent generalisation :** agent is then used, road after road

3- **Contextual generalisation :** road and railway conflicts are then processed with beams

3.3.2 Interactive tool

Although, the automatic tools are powerful, they cannot solve all cases. The project has then tried to lighten the interactive correction.

Two ideas have emerged :

- In AGENT prototype a set of algorithms are used to evaluate objects and **to point where conflicts are**. These tools have been reused for interactive part, to visualize and mark the objects which have to be checked by the operator.

- In AGENT a set of algorithms have been designed to solve conflicts. Some of these algorithms can now be used by the operator to make conflict solving easier. For example, some displacement tools are available, the user select the object which has to be displaced and the object which is in conflict. The tool will calculate the appropriate displacement and will diffuse it on the connected objects.

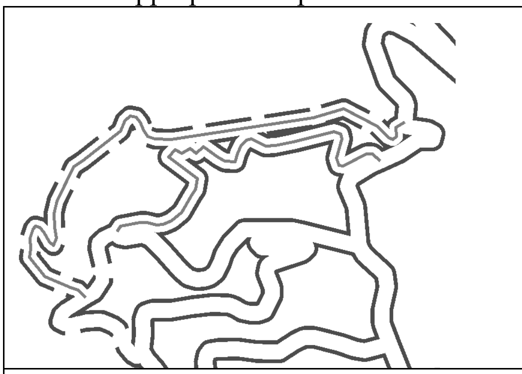

Figure 14: roads selected by the operator

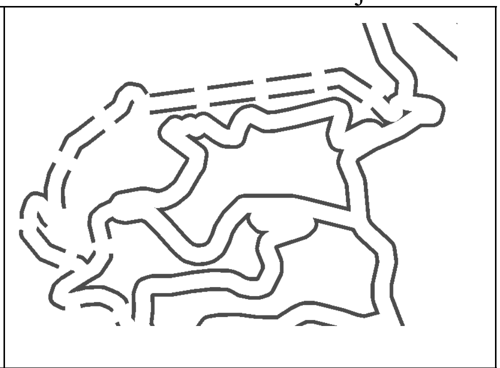

Figure 15: proposed displacement

Such tools makes a great improvement for the user, who can work easier and faster. Making them available was not a very complex task once they had been developed for automatic purposes.

4 Results and outlooks

The Carto2001 generalisation process seems now to be almost defined and will be tested on a real map. The automatic phase has been estimated to about 50 hours on a Pentium III computer. The interactive part should be of about 100 hours and limited to specific areas (interchanges and urban areas)

The future work now, will be to interface this process with the updating process. The Top100 will be updated by integrating in the Top100 DB only the objects which have been modified in the BDCarto®: so, it will not be necessary to generalise all the map, but only the objects which have been modified.

Other products in IGN, should soon take advantage of the knowledge and experience of the Carto2001 project. The departmental maps (1:125.000 and 1:140.000 scale) derived from the BDCarto® could use some of the generalisation tools. A new project concerning the production of 1:25.000 maps derived from the BDTopo® could also reuse some specific tools.

The Carto2001 results show that beams displacement algorithm is a very powerful tool, it would be possible to integrate in AGENT the beams displacement algorithm by defining suitable meso-agents on which such algorithm could be launched.

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