Role of urban patterns for building generalisation: An application of AGENT

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Introduction

Urban areas are places of extensive human activities and therefore their cartography is complex. In such areas the information density of geographic data bases is high. Thus the generalisation of buildings is an important field in automatic cartography; it requires many processings.

The AGENT prototype results from the european project AGENT ended in 2000. It is a significant progress in automatic building generalisation in urban areas, as shown in [BAR 01] and [DUC 01]. At IGN, the french mapping agency, some recent developments such as the AGENT prototype are more and more ported to map production lines: it shows the interest of production for new tools and creates new needs of development improvements. That is why some recent works in COGIT deal with urban analysis to improve contextual generalisation for 1:50000 scaled maps. This paper presents how this results have been gathered together and adapted to be integrated with the AGENT prototype.

First and foremost, we will see how the geographic data have been enriched and characterized for 1:50000 generalisation. In a second part, we will remind the principles of the AGENT prototype and present how the recent works can be used to improve its results for building generalisation.

1 Enrichment and characterization for generalisation

Most of the data present in geographic data bases usually don't fulfil the requirements of all applications, especially for generalisation process. To generalise geographic data bases, some data resulting from analysis are needed as shown in [BRA 88] and [SHE 89]. This part present some analysis of the urban areas for building generalisation.

1.1 Model enrichment for buildings analysis

[BOF 00], [CHR 02] and [RUA 03] propose a way to analyse urban areas for generalisation. They build some urban patterns usefull for a more efficient choice of parametrisation of generalisation algorithms.
This urban patterns are (see figure 1.1):

- Town
- Urban district
- Urban block
- Empty space in block
- Buildings group in block
- Buildings alignment

Let us give the definition and the construction process of this patterns.

Towns are defined as closed set of dense building zones. They are built from buffers of buildings as described in [BOF 00]. **Urban**

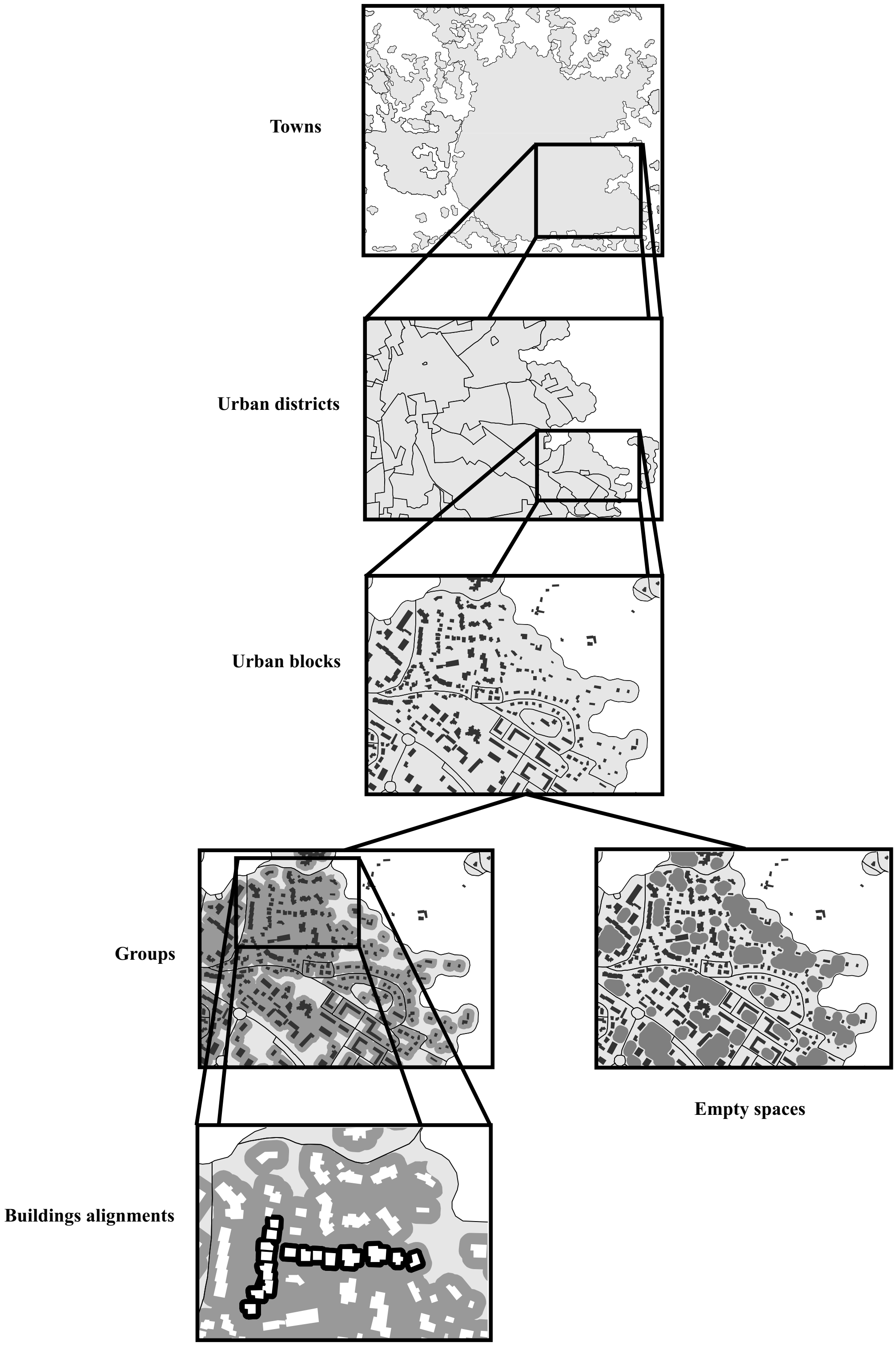


Figure 1: Urban patterns

blocks result from a partition of towns. This partition can be made through networks such as road networks, railway networks, hydrographic networks, administrative boundaries... These networks can be specified depending on the needs. **Urban districts** are built from an aggregation of similar adjacent blocks as described in [BOF 01a].

Then, we will identify **buildings groups** in blocks proposed in [BAR 04]. These groups are built from buffered buildings included in each block: these patterns enable to gather close buildings in blocks together. Their role is to add a new analysis level in urban blocks to improve some processes.

Empty spaces are then defined as blank parts in a block. They have a visual impact and therefore must be kept during the generalisation process. They are built in blocks from buffers of buildings.

Finally, a **building alignment** is defined as an urban pattern composed of buildings positionned as a queue. In such a pattern, an order between buildings has to be defined.

The first step of our work consisted in building a model integrating this set of urban patterns (see figure 2) using the UML formalism of [BOO 99]. The urban patterns classes are linked to the user's Data Landscape Model through an heritage link with the *building* class. Each building is linked to the urban pattern it belongs to. We emphasize that *urban pattern* and *building* are abstract classes. They both allow an efficient heritage of many characterization methods.

This model has been implemented in the GIS Lamps2. Automatic construction and characterization methods of the objects are available in a new COGIT prototype developed in Lamps2 (see figure 3).

Let us present now how these objects are characterized. We will see first a standard characterisation of this objects and secondly a characterization for 1:50000 scaled maps generalisation.

1.2 Standard characterization

To be characterized, the classes of the model have many attributes:

- Building: Area, coordinates of the center, concavity, elongation, orientation.
- Urban pattern: Area, coordinates of the center, number of buildings, density of buildings, elongation, orientation, concavity, type of the buildings areas, buildings functional type, average, standard deviation, minimum and maximum of buildings areas, average and standard deviation of buildings elongations, average and standard deviation of buildings concavities, average and standard deviation of buildings orientations.
- Town: Average of the urban blocks densities.
- Urban district: Size in its town.
- Urban block: Buildings density type, buildings areas standard deviation type, size of its empty spaces.
- Empty space in block: Size in its block.
- Group in block: Size in its block.
- Buildings alignment: Parameters ρ and θ of the line equation $\rho = x\cos\theta + y\sin\theta$, buildings centers isobarycentre coordinates, list of the minimum distances between two consecutive buildings, list of the distances between buildings centers, list of the links between buildings centers orientations, list of the distances from buildings centers to the regression line, average and standard deviation of these lists, many quality marks from [RUA 03].

Most of these characterization data are not specific to a generalisation purpose (even if it is the main subject in this paper). They could be used for other applications in urban studies.

1.3 Characterization for the generalisation

Let us now see how we compute the urban patterns characterization to improve the generalisation process for 1:50000 scaled map from a geographic data base. For this scale, the objects to be characterized are the towns,

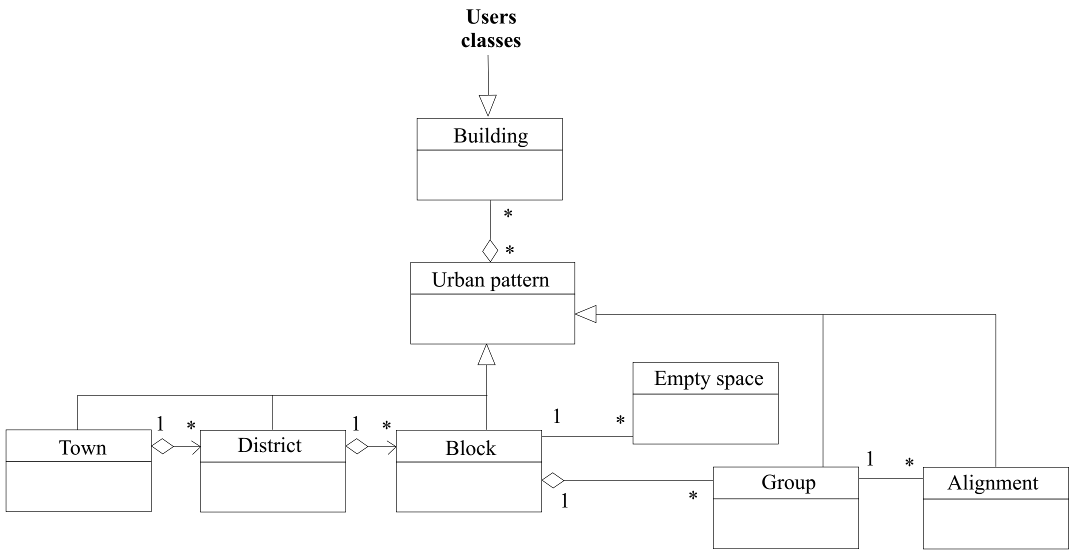


Figure 2: UML model of urban patterns

the blocks and groups in blocks (see figure 3). This characterization is done thanks to a new field *generalisation type*. The possible values and the way to compute them are described below:

Towns: *Hamlet, village, big town.*
The type of a town depends on its area. The type of the towns for which the area is less than 0.5 km^2 is *hamlet*. If this area is more than 1 km^2, this type is *big town*. The type of the others is *village*.

Blocks: *Urban, suburban, farm, unitary, empty.*
Blocks without building are declared as *empty.* Then, the characterization of the others blocks is done depending on the town type of each block. For the hamlets, a block including only one building is declared as *unitary*. Otherwise, his type is *farm*. In villages and big towns, blocks at the townborder are *suburban*, the others *urban*.

groups in blocks: *town center, housing estate, urban, suburban, activity area, unitary.*
Groups are not built in hamlets. In villages and big towns, *town center* groups are first characterized: These groups belong to high density blocks. Certain groups close to those first detected are declared as *town center* too. Then, among the remaining groups, the ones containing only one building are declared as *unitary*; the ones for which the buildings areas average is less than 300m^2 and the standard deviation less than 70m^2 are *housing estate*. The remaining groups are characterized depending on the fonctional type of their buildings: if the density and number of industrial or commercial buildings is high, their type can be declared as *activity area*. Finally, the remaining groups have the same type as their block (*suburban* or *urban*).

These patterns and their characterization have been made espacially for 1:50000 generalisation. It's important to emphasize that the pertinent patterns of a map depand on its scale. That's why this characterization method is certainly not adapted for generalisation to others scales (1:100000 for example).

Let us present now how this patterns and their characterization can be used for generalisation with the AGENT prototype.

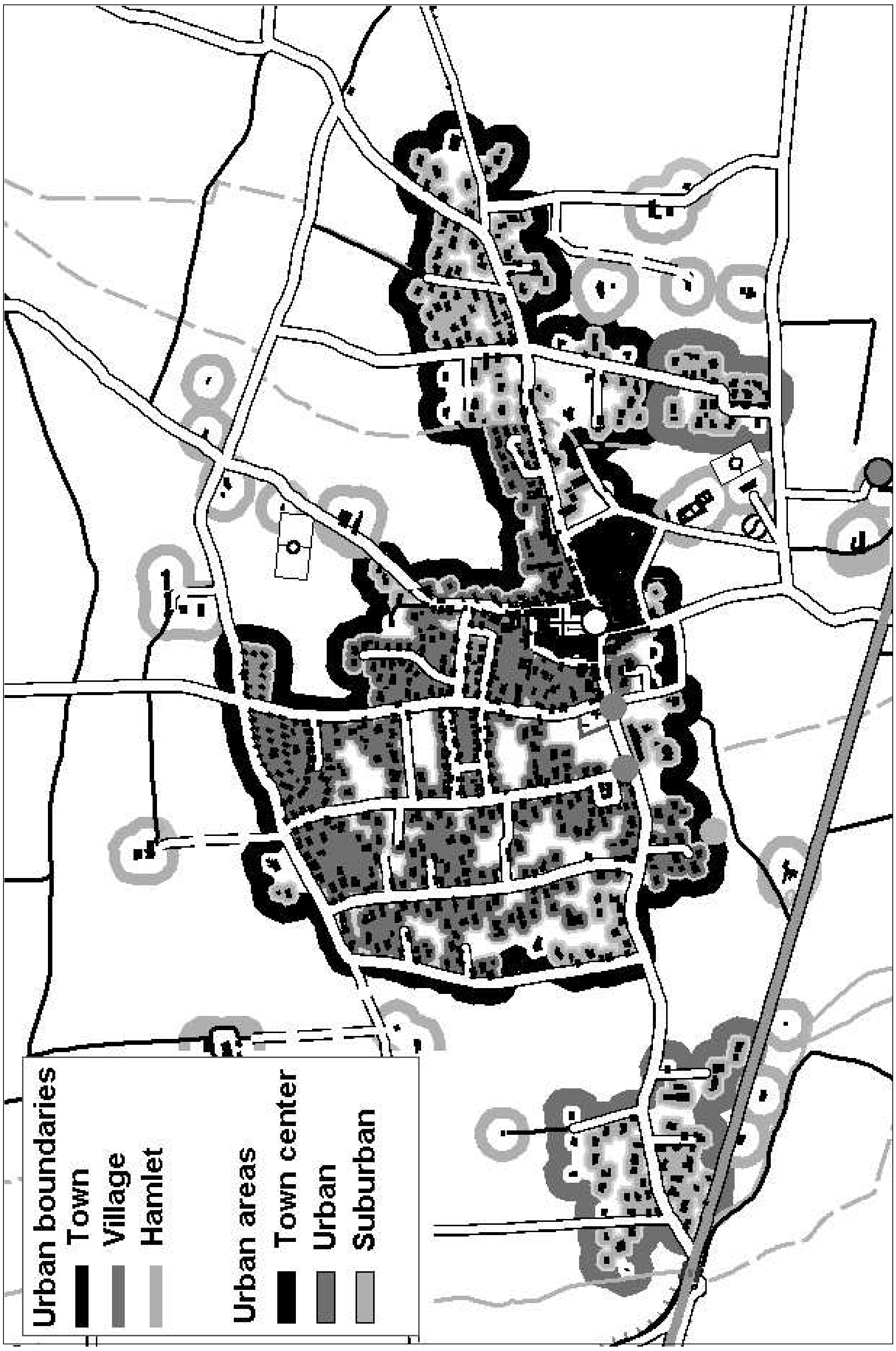


Figure 3: Characterization for generalisation (automatic result)

2 Using urban patterns to generalise buildings with AGENT at 1:50000

In order to generalise these buildings, we use the AGENT prototype (see [BAR 01], [DUC 02] and [AGE 04]). The generalisation process with AGENT will be improved by taking into account the characterization of the urban patterns (see figure 3). All the given examples focus on the mapping of a 1:50000 scaled map from the 1 meter resolution database of the IGN, the BDTopo ®.

2.1 The AGENT prototype: overview

The concept of "agent" comes from the world of Artificial Intelligence ([WEI 99] and [FER 95]). An agent is an object with an end to achieve (its goal). It has its own autonomy to fulfil this goal. In the AGENT model [RUA 99], each geographic object is considered as an agent. To do its own generalisation, this agent must attempt to satisfy a set of generalisation constraints (i.e. its goals to achieve). It first characterizes itself with a set of measures at its disposal. This characterization tells it whether its own constraints are fulfilled or not. If not, the agent then acts in order to improve them. The result of the generalisation process is the state where a maximum of constraints are satisfied.

Individual generalisation and *micro-agent* In the AGENT prototype, the individual generalisation is triggered by a so-called *micro-agent*. A surfacic building, for instance, is a *micro-agent* triggering its shape generalisation. It has to check whether it is big enough to be readable at the scale of symbolisation (size constraint), whether the tiny details of its outline are readable enough (granularity constraint), whether its angles are squared enough (squareness constraint) and so on. The building *micro-agent* then tries several actions, each one corresponding to different algorithms and parameters. At the end, it selects the best state to satisfy its constraints. In figure 4, you can see an example of buildings *micro* generalisation for a 1:50000 scaled map.

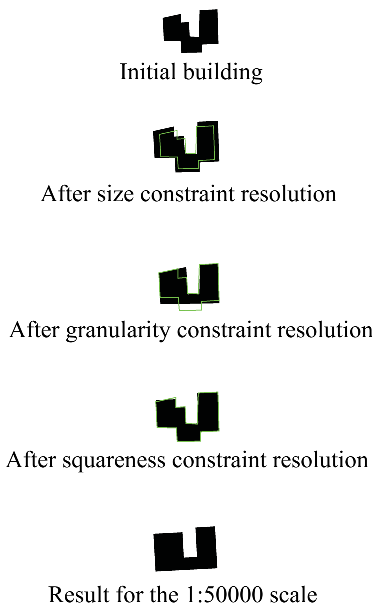


Figure 4: Building *micro* generalisation for a 1:50000 scaled map

Contextual generalisation and *meso-agent* The contextual generalisation uses the same approach but is triggered by some so-called *meso-agents*: these *meso-agents* decide what the *micro-agents* have to do in order to solve their contextual conflicts. The generalisation of urban objects is therefore triggered by the urban patterns such as urban alignments, urban groups and urban blocks. These *meso-agents* are hierarchically organised: one urban block contains some groups containing themselves some alignments.

Let us see how these different kinds of *meso-agents* can interfere in the generalisation process.

Default generalisation process of urban patterns As a general rule, *meso-agents* such as urban patterns must check:

- they have enough room to place all their buildings. It's the **density constraint**. If necessary, *meso-agents* can decide to remove some unimportant buildings (taking into account their semantic, their size and their congestion) in order to ensure a good cartography of the so kept buildings.

- the shape of their surfacic buildings is correctly shaped generalised. It's the so-called **micro constraint**, which triggers the individual generalisation of each building (*micro* generalisation of the shape).

- their buildings don't overlap the communication network. It's the **network proximity constraint**. This constraint triggers a displacement of the overlapping buildings inside the *meso-agent* to remove the conflicts. It propagates the displacement computed on the conflicting buildings to the other buildings of the pattern, with fading.

- their buildings are not too close from one another. It's the **local proximity constraint**. This constraint triggers local displacements between conflicting buildings (without propagation). It can also do local removals if conflicts cannot be solved with displacement only. Removals can be strict or followed by local displacements of the closest buildings to fill up the gap made by the removed buildings: these displacements are also called "amalgamation".

Urban patterns try several scenarios to satisfy their constraints and finally keep the best state found. All these constraints are not necessarily used. Their taking part in the generalisation process depends on the scale of symbolisation and on the type of urban pattern involved.

2.2 Urban blocks generalisation

Urban blocks consist either of buildings (isolated buildings or farms) or of urban groups. Buildings in a group are not managed directly by the block containing the group, but by the group itself (see below). Urban blocks trigger either the generalisation of their individual buildings or the generalisation of their urban groups.

Isolated building : unitary blocks A unitary block is therefore a block consisting of one building. Because it's isolated, the generalisation process must preserve this building. The characterization of such a urban block will allow this preservation. The generalisation constraints of unitary blocks are:

- the micro constraint on the isolated building

- the network proximity constraint if the block is containing networks.

Farm blocks: The farm blocks are the urban blocks coming from hamlets and consisting of more than one building. In this kind of blocks, we will try as much as possible to preserve all the existing buildings. The density constraint won't be used in order to do only local removal with the local proximity constraint when no other alternative exists. In this case, the local removals are followed by an amalgamation. The generalisation constraints of farm blocks are:

- the micro constraint.

- the network proximity constraint if the block is containing networks.

- the local proximity constraint allowing local removals with amalgamation.

The figure 5 gives an example of farm blocks generalisation.

Urban and suburban blocks: The urban and suburban blocks consist of urban groups. When triggering their generalisation, they merely tell their groups to generalise. In this case, groups are the managers of the effective urban generalisation (see below urban groups, suburban groups and town centre).

2.3 Urban groups generalisation:

Urban groups consist of buildings and urban alignments. Buildings in an alignment are not managed directly by the group containing the alignment, but by the alignment itself (see below).

Default urban groups: Urban groups trigger a default generalisation of their buildings using all the constraints explained above: density, micro, network and local proximities. The local proximity constraint will allow local

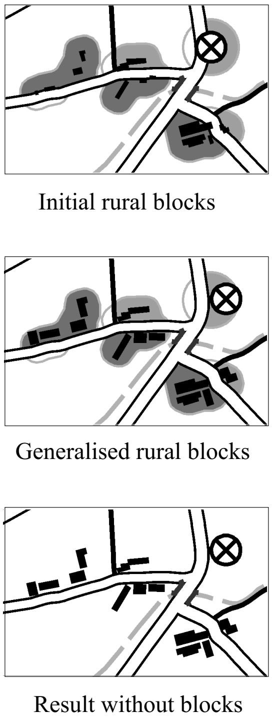


Figure 5: Using AGENT to generalise *unitary* and *farm* blocks

removals (without amalgamation). A urban group looks on its alignments as big buildings concerning all its constraints except the *micro* one. When it actually asks its buildings to generalise their shape (*micro* constraint), the alignments will be capable of triggering the *micro* generalisation on their own buildings (see below), and then computing their new hull. The figure 6 gives an example of urban groups generalisation.

Suburban groups: Suburban groups, or groups on the town border, follow the same generalisation process, except that the removal action done by the density constraint is no more based on a density goal value. Being near the town border means that there is room left towards the countryside. The removal is therefore based on a number of buildings to keep. The figure 7 gives an example of suburban groups generalisation.

Town centre: Town centre groups are special groups symbolised by a grey area: their generalisation doesn't need a process with

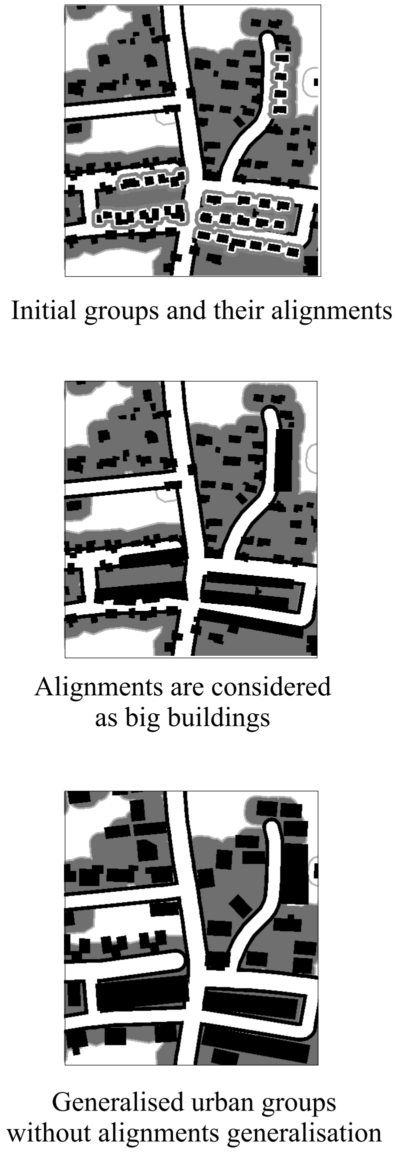


Figure 6: Using AGENT to generalise urban groups

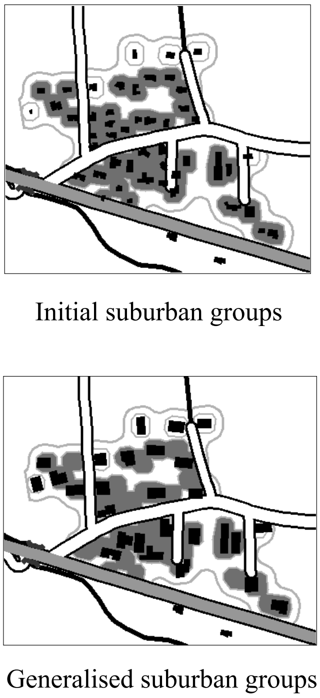


Figure 7: Using AGENT to generalise *suburban* groups

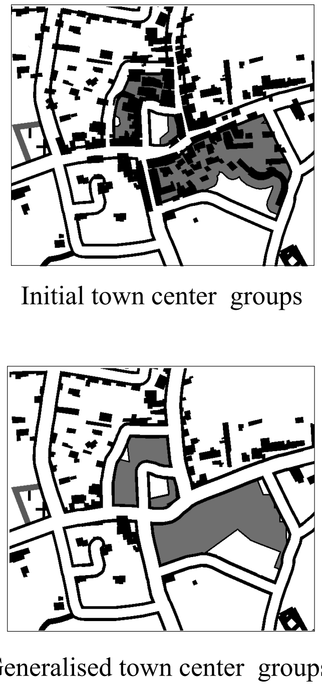


Figure 8: Symbolising *town center* groups

constraints. Once characterized, the town centre group computes its own hull for the symbolisation using a combination of squared buffers from its own buildings. Then, it symbolises itself in grey, and finally it removes all its buildings (see figure 8).

Other groups: Unitary groups, i.e. groups consisting of one building, trigger their generalisation in the same way as unitary blocks (see above).

We also intend to study the generalisation of other kinds of groups such as "activities areas": industrial estates, commercial estates. They generally consist of big buildings and in this case, aggregations of buildings could be more appropriate than local removals.

2.4 Urban alignments generalisation

Urban alignments consist only of buildings. Two constraints trigger the internal generalisation of an alignment:

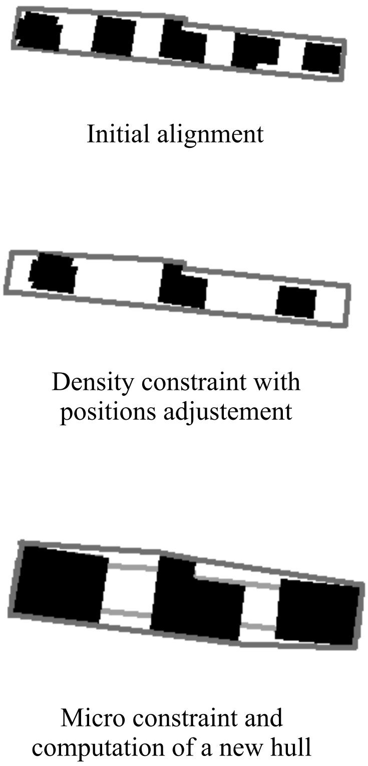


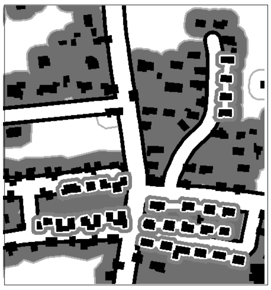
Figure 9: Using AGENT to generalise an alignment

- a special constraint of density which removes the least distinctive buildings of the alignment with an adjustment of the positions of the kept buildings in order to preserve the initial regularities.

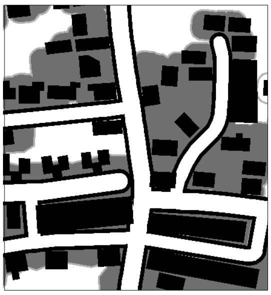
- the micro constraint.

Taking into account the new shape of the buildings after the generalisation, we eventually compute a new hull for the alignment. This hull is useful to the group managing the alignment. The figure 9 gives an example of urban alignment generalisation.

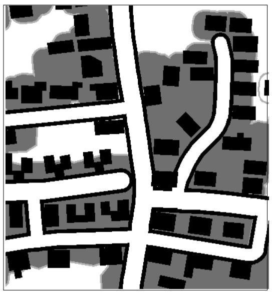
The figure 10 shows as an example the result of the alignments generalisation on the urban groups seen page 8 figure 6.



Initial groups and their alignments



Generalised urban groups
without alignments generalisation



Generalised alignments

Figure 10: Complete generalisation of urban groups

Conclusion

To sum up, we have proposed functionnalities to analyse and characterize urban areas for 1/50000 scaled map generalisation. We have seen that the ways of triggering the generalisation process can be different from one urban pattern to another. That is why the characterization of the urban patterns help us to improve the generalisation of buildings.

These automatic processes of construction and characterization are now available on Lamps2 on each independent level of analysis: blocks, groups and alignments. The coordination between these three levels is still in development from the AGENT prototype at the COGIT laboratory. We expect to have some operational results shortly.

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