CONTRIBUTION OF EXTERNAL DATA TO AERIAL IMAGE ANALYSIS

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ABSTRACT :

To face the difficulties of a fully automatic aerial image analysis, we study the potential contribution of external data. Different methods to integrate external data in image analysis are presented. Two examples of image analysis which use external data are described more precisely. Both of them are taken in the domain of cartography and concern the road network extraction in aerial imagery. The external data are provided by a cartographic database in the first case and by a scanned map in the second one.

RÉSUMÉ :

Pour surmonter les obstacles rencontrés lors de l'élaboration d'un système entièrement automatique d'analyse d'images aériennes, une solution souvent adoptée consiste à utiliser des données externes. Différentes méthodes d'utilisation de ces données sont présentées. Deux exemples précis d'utilisation de données externes pour l'analyse d'image sont décrits. Ces deux exemples, issus du domaine de la cartographie, concernent plus particulièrement l'extraction de routes dans les images aériennes. Les données externes qu'ils utilisent sont fournies par une base de données cartographiques dans le premier exemple et par une carte scannée dans le second.

1. INTRODUCTION

The French IGN (National Institute of Geography) intends to automate the acquisition of the BD Topo®, a topographic database which content fits with 1:25 000 scale maps, with a metric accuracy for the three coordinates X, Y and Z. Its acquisition is based on stereoplotting of 1:30 000 aerial images. In this context of automation, one of the solutions to reach an automatic and reliable aerial image analysis is to use external data. That is to say *a priori* data about the scene which has to be analyzed.

In parts 2 and 3 we describe the advantages and shortcomings of using external data for image analysis. In part 4, the different methods to integrate external data in image analysis processes are presented. Finally, in part 5 and 6, two examples of the external data contribution to road extraction in aerial images are described. In the first case, the external data source is a cartographic database, in the second one it is a scanned map.

2. MAIN DIFFICULTIES OF IMAGE ANALYSIS

Automatic interpretation of aerial images is known as a difficult task which has to face important obstacles. The complexity of the geographical reality is coupled with the diversity of the contexts to handle (rural or urban areas, coastal or mountainous landscape,...). The global consistency between the objects has also to be taken into account to explain the structure, the positionning and the shape of these objects. As all understanding system is a processing sequence of operators, each step produces errors that are difficult to be handled for the next step. Thus, the control of the global system is a very complex task, requiring the most higher level of mechanisms. Finally, all the information necessary to understand the underlying structure of the scene is not a visual one (for example, the administrative boundaries). For all these reasons, existing algorithms often fail to analyze aerial images with reliable results. An attractive solution to reach an exhaustive analysis is to use symbolic external data that include a part of the information missing to perform the image understanding.

3. THE USE OF EXTERNAL DATA FOR IMAGE ANALYSIS

Such data are available in several fields of image analysis. They may be anatomical sketches in the field of medical imagery, plans in the field of robotics. In our domain of aerial images analysis applied to cartography, external data may be maps, plans or geographic databases.

Cartographic external data provide a description of the scene, that is :

- an inventory of the cartographic objects which are in the scene (roads, buildings, forests...)
- a description of each of these objects : their shape, their inner features...
- a description of the links between the objects that constitute their geographic context.

These external cartographic data may be very useful to guide the image analysis. On one hand, they allow to focus the research on some objects and on some areas in the image. This first contribution is essential since it reduces drastically the processing time. On the other hand, the specific knowledge about the inner features of the objects and about their context allows to regulate the parameters of the low level algorithms or better still to select the most adapted algorithm. This contribution is also promising insofar as most detection algorithms are efficient in a precise context. Lastly, the external data may be used to validate the objects detected in the imagery. Thus, the number of false detections can be reduced.

Through these three contributions, it appears that using external data is really a good way to improve the efficiency and the reliability of aerial image analysis.

4. DIFFERENT TYPES OF EXTERNAL DATA AND DIFFERENT METHODS TO USE THEM.

In the field of aerial image analysis, the external data may be provided by various cartographic sources such as scanned maps, cartographic databases... The diversity of data sources leads to different methods to use the data in image analysis processes. These methods are closely linked to the following four characteristics of the data source :

- its semantic content,
- its scale,
- its geometric accuracy,
- its representation mode : raster or vector.

The description of the scene provided by the external data is more or less complete according to these 4 parameters. The more this description is accurate, the more the image analysis can rely on it.
Depending also on the image characteristics (resolution, landscape typology, ...), different ways to integrate the external data in the image analysis process have been developped in previous works.

4.1 Data fusion processes

These processes are based on data fusion methods in which external data and images are used without distinction. This kind of method may be used when the accuracy of the external data is compatible with the image accuracy. In (Roux, 1995) satellite images are classified by merging the images and external data such as DTM and several distance maps. In each document, the possibility for a pixel to belong to the different classes is computed. These different possibilities are merged and provide the final classification. This method is very useful to take advantage of different data sources (including symbolic data) which are complementary.

4.2 Matching and readjustment processes

These processes are used when the external data are enough accurate and when the image itself may provide a good description of the objects to be detected. The image processing is computed independently of the external data, then the external data are matched with the objects detected in the image. This matching allows to validate the objects detected and eventually to readjust the external data on these objects. In (Servigne, 1993), this method is used to update a cadastral database. Firstly, an edge detection is processed on the whole image then the segments detected are matched with the objects of the database. It allows to detect changes and thus to update the database.

4.3 Algorithms guiding processes

In these processes, external data are used to guide the detection, that is to say to choose the proper algorithm to process on the image and to adapt its parameters. The external data have a direct effect on the image processing.
In (Strat, 1995), the external data are used as contextual data. A general architecture for contextual interpretation is introduced. The principle is to process an algorithm only when the conditions (the context) in which it is known to be efficient are verified. The external data provide contextual information on each object to be detected in the image. The other contribution of these processes is the regulation of the parameters. In (Yu, 1994), the objects of a map are projected on the image, they define learning areas for the parameters of the classification. This kind of processes are suitable for external data with a rich semantic content.

However, even when the data source is as accurate as a topographic map the external data cannot be considered as an absolute reference. In any cartographic document, there are constraints which induce geometric distortions of the objects compared to the ground reality and to the image one.
Thus, before using external data, the data source must be studied :

- the information which is significant in the image must be selected.
- the geometric and semantic accuracy of the data must be evaluated in order to know what can be expected from them.

This preliminary study is essential and leads to an adapted analysis method.

Parts 5 and 6 present two examples of external data contribution to road extraction in aerial images. In the first case, the external data are provided by a cartographic database ; in the second one, they are provided by a scanned topographic map.

5. ROAD EXTRACTION GUIDED BY A CARTOGRAPHIC DATABASE

In this research, the source of external information is the IGN Cartographic DataBase (CDB) which contains the major road network, other networks such as railways and land cover areas. This database has been acquired by digitizing 1:50 000 maps and is devoted to the drawing of 1:100 000 maps. Its geometric accuracy is about 20 m. The road network, like the other objects of the database, has semantic attributes which characterize the road aspect (number of lanes, administrative class...). In this work, we limit ourselves to the problem of road extraction in high resolution aerial images.

Given the CDB characteristics and the aerial image resolution the process which has been chosen is an algorithm guiding one.

In the preliminary study about the CDB road network quality (Bordes, 1995), it appears that some objects of the database are very reliable geometrically, and others are far less reliable. In a first approximation, this reliability only depends on the road type and on the road context. The road network distortions cannot be modelized, therefore it is impossible to define an overall detection method using the CDB everywhere at the same level. This remark leads us to define an interpretation strategy so called "easiest at first", that is to say that we will look in the image for the road sections corresponding to the database ones beginning by the well-situated and easy-to-see sections. This hierarchic interpretation requires knowledge about the road sections reliability and legibility in the image. The results of the preliminary study allow us to predict the reliability of each road section location knowing its semantic attributes. To complete this prediction, we compute image tokens which confirm or not the location of the road section in the image. These image tokens and the a priori reliability of road sections are used to classify the sections by reliability order (cf Figure 1). The road extraction begins by the most reliable road sections and leans on these extracted sections to extract less reliable ones.

The second stage in which the external knowledge is very useful is the choice of the proper road extractor and the control of its parameters. More precisely, for each road section, the CDB knowledge about the road characteristics and context are used to select the proper road extraction algorithm and to control its parameters. We use three road extraction methods : a road following based on homogeneity criterion, a road following based on profile analysis and a road detection based on the "top-hat" morphological operator. The most reliable road sections of the CDB are used as road seeds to initiate the road followings (cf Figure 3). Then, the extraction of other roads leans on these reliable road sections. The top-hat operator is used for unreliable sections in order to compute a coarse detection which allows to initiate the road followings. This hierarchic strategy appears to be efficient for the detection of most evident roads.

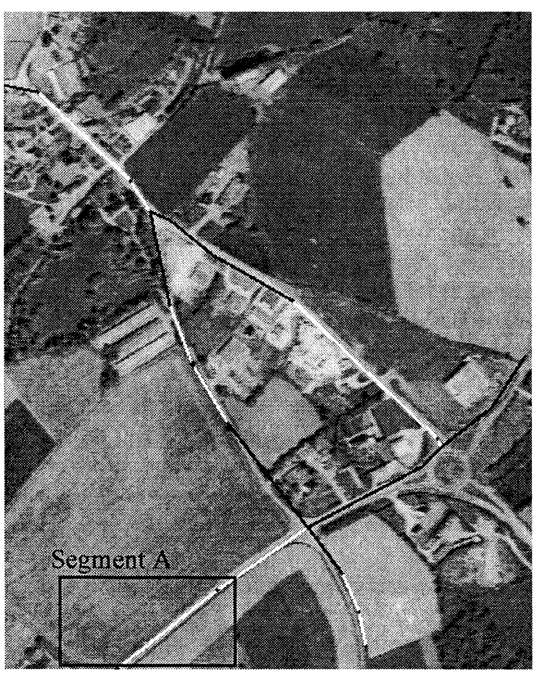
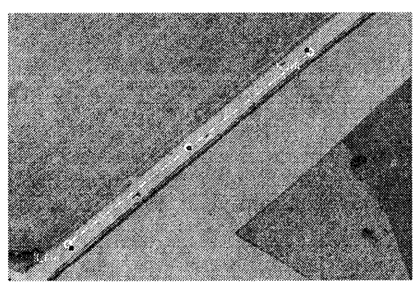


Figure 1: The CDB road network projected on the image.
in white : the most reliable road segments
in black : the unreliable road segments



Semantic attributes :
Administrative class : secondary road
Number of lanes : 2 lanes
Number of separated roadways : 1
Position of the road : level road
Land cover type : rural area

Figure 2 : The Segment A is selected
In white the CDB road segment, in black, the points after readjustment on the center of the road.

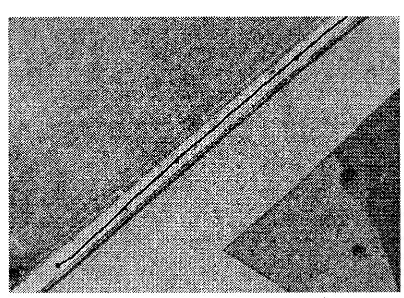


Figure 3 : The road following is processed (in black).
The CDB point (readjusted on the road center) is used as a road seed.

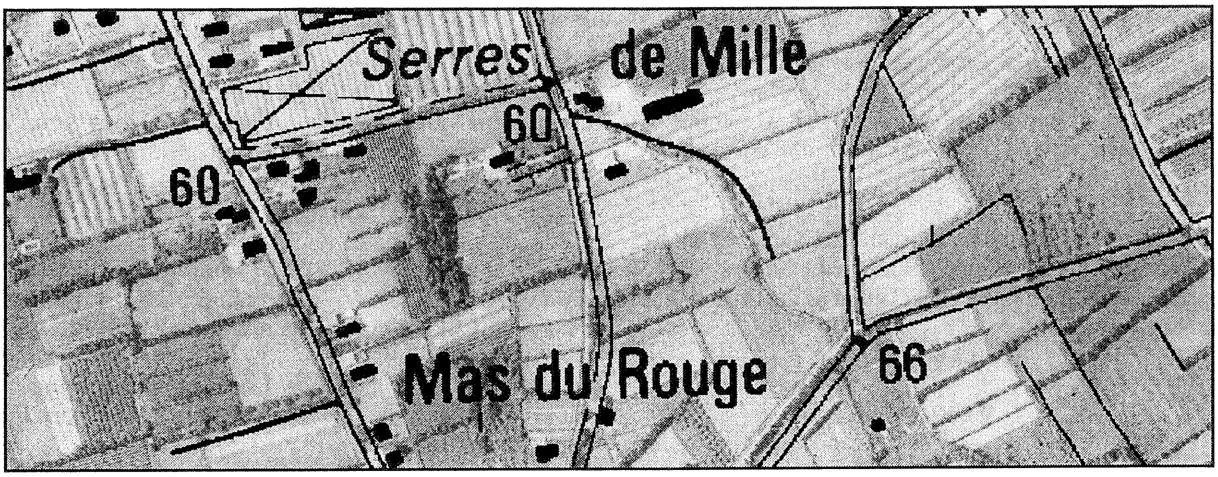


Figure 4 : The map, an image understanding tool

6. MAP AIDED INTERPRETATION

The topographical map which is used as external data source is a 1:25 000 scale scanned document which content is quite similar to the final result (BD Topo®) that is intended to be acquired. The symbolization of the geographical objects is directed by the legend and by the map drawing rules, enabling a real representation homogeneity. The implicit relations existing between the different objects are expressed by the visual variables : shape (geometric, figurative or symbolic), size, color, orientation, ... The characteristics of these variables (associativity, differentiation, order and quantity) and their arrangements define the cartographic language, the semiology. It provides a potential global comprehension of the scene (cf Figure 4), emphasizing the networks organization and the spatial relationships existing between the different objects layers.
In a first time, the scanned map is digitized : the road network and the other cartographic objects are identified and reconstructed to be available for the image understanding task (Guerin, 95a).
As all information issued from a treatment, the map is subject to unavoidable distortions with regard to the ground reality. These alterations have consequences at the geometrical, topological and semantic levels. The preliminary study of the map quality (Guerin, 95b) has outlined the main tendencies of the distortion model, especially for the road network :

- from a quantitative viewpoint : maximum values of distortion, general statistics on a test set.
- from a qualitative viewpoint : role and importance of the context on the distortions, local configuration and information density influence, topological inconsistencies detection and study.

The results lead to a prediction model of the road network aspect.
This study has shown that in these topographical maps the global topology and geometry of the road network is correct except near complex cross-roads and dense areas. The accuracy of the document allows to use a method of readjustment, implemented as follows : the road network extracted from the map is registered on the image and distorted in order to fit the roadways detected in their neighbourhood. By this way, the image analysis problem is restricted to a matching process.
Two operators are developped, one specialist for the detection and the restitution of the intersections, another for the roadways. Using the map knowledge, the crossroads defined as reliable by the prediction model are first positionned. They carry valuable information describing their local shape, the average radiometry of the surface, the position and orientation of the incoming roads. Then the roadways are sought, starting from the validated cross-roads. By this way, the detections are propagated all along the graph of the road network.

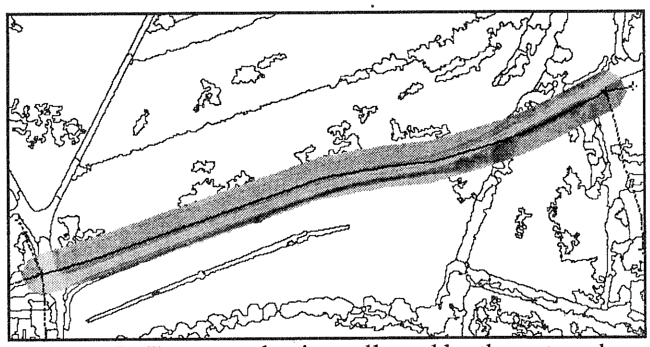


Figure 5 : Focus mechanism, allowed by the external data knowledge

7. CONCLUSION

The use of external data is a promising solution for image understanding. But through the two examples given in this article we can see that the way this external data can be used is closely linked to the content, the scale and the accuracy of the data source.
In part 5, the cartographic database is very rich semantically but the geometry and the topology of the road network are not reliable, thus the road extraction method is very local and have to be adjusted for each road section, according to its reliability and to its characteristics.

On the contrary, the topographic map road network which is used in part 6 is very reliable, so it can be used as a whole and is registered on the image. But it requires to be firstly digitized and the symbolic knowledge is not directly available.

As a conclusion, the external data are very useful for image analysis but they have to be used cautiously. The interpretation method has to be adapted to the data source characteristics.

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