FROM MANUAL TO AUTOMATIC STEREOPLOTTING : EVALUATION OF DIFFERENT ROAD NETWORK CAPTURE PROCESSES

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XVIII ISPRS Congress
Commission III

KEYWORDS : digital photogrammetry, object recognition, aerial image, road detection, user interface.

ABSTRACT :

Within the framework of the French topographic database capture, IGN is looking for solutions related to the photogrammetric data capture automation with the double goal to reduce the production costs and to reduce the data availability delay. Since digital stereoplotters have been introduced in the production lines, it is now possible to integrate automatic or semi-automatic tools in the traditional data capture process. One of the most advanced project in the MATIS laboratory concerns the road network automatic extraction. We are working at the same time on very ambitious approaches, looking for a fully-automatic interpretation of the image and on semi-automatic approaches, looking for a short term efficiency. Corresponding to this second axis, this paper concerns the different semi-automatic solutions which can be built around a road following algorithm to increase the efficiency of such kind of approaches. It presents also what means will be used to evaluate the contribution of these different solutions in a production context.

RÉSUMÉ :

Dans le contexte de la saisie de la Base de données topographiques, l'IGN s'intéresse à des solutions concernant l'automatisation de la saisie photogrammétrique avec le double but de reduire à la fois les coûts de production et le délai de disponibilité des données sur tout le territoire. Dans la mesure où des appareils de restitution numériques ont été introduits dans les chaînes de production, il est désormais possible d'intégrer des outils automatiques ou semi-automatiques dans les processus traditionnels de saisie. L'un des projet les plus avancés du laboratoire MATIS concerne l'extraction automatique du réseau routier. Nous travaillons parallèlement sur des approches très ambitieuses, visant une interprétation complètement automatique de l'image, et sur des approches semi-automatiques, visant une opérationnalité à court terme. Correspondant à ce deuxième axe, ce papier présente différentes solutions semi-automatiques qui peuvent être construites autour d'un algorithme de suivi de routes pour tenter d'augmenter l'efficacité de ce type d'approches. Il présente également quels moyens seront mis en oeuvre pour évaluer l'apport de ces solutions dans un contexte opérationnel.

1. INTRODUCTION

Within the framework of the French Topographic DataBase[1] production, IGN[2] is looking for solutions related to the photogrammetric data capture automation with the double goal to reduce both data acquisition costs and data availability delay. Since digital stereoplotters have been introduced in the production lines, it is possible to integrate automatic or semi-automatic tools in the traditional data capture process.

1.1. The French Topographic Database

In 1990, IGN began the production of the topographic database which is going to replace the traditional topographic 1:25000 maps as topographic reference on the whole French territory. The semantic content of this database is very close to the one of traditional maps with a better geometric accuracy (in the range of one meter r.m.s.) and 3-D coordinates for all the objects. Data acquisition consists of a photogrammetric data capture from aerial photographs at the scale of 1:30000. The need to reduce the data availability delay incited IGN to invest in digital techniques (Jamet, 1995a) : a research program was started up in image analysis to provide semi-automatic helps to the plotting and softcopy stereoplotters have been acquired in the production lines. The digital photogrammetric platform which has been chosen is named SAPHIR[3] Géo and is developed by SYSECA. SAPHIR Géo is a solution for high-accuracy softcopy image exploitation system which integrates a comprehensive photogrammetric and image processing package with an object-oriented GIS able to manage on-line geo-referenced objects.

1.2. The semi-automatic approach

The MATIS[4] laboratory is the research laboratory of IGN which works on the questions related to the topographic database data capture automation. One of the most advanced project in our laboratory concerns the road network automatic extraction. We are working at the same time on very ambitious approaches, looking for a fully-automatic interpretation of the image and on semi-automatic approaches, looking for a short term efficiency. Fully-automatic systems have often been presented in the literature for the extraction of man-made objects from aerial images but no system has been shown to work both accurately and completely with a variety of images and objects (Hsieh, 1995). In front of the difficult problem of the automatic

[1] BDTopo®.
[2] Institut Géographique National (FRANCE).

[3] System for the Automation of Photo-Interpretation and Remote sensing data analysis.
[4] Méthodes d'Analyse et de Traitement d'Images pour la Stéréo-restitution.

interpretation of aerial images, many authors present the semi-automatic approaches as the only ones able to bring a significant contribution in a production context in the years to come (Heipke, 1994 ; Gruen, 1995).
We proposed (Airault, 1994a ; Airault, 1994b). and evaluated (Airault, 1995) a semi-automatic solution in former publications. The evaluations we performed have shown that it seems to be possible to save time with our semi-automatic solution if the road following algorithm is used in a good way : only when the road in the image corresponds well to the road model used in the algorithm. The efficiency of the semi-automatic technique will much more depend on its reliability (predictable behavior, low sensitivity to small changes in the parameters, preference to no result than to a wrong one,...) than on its exhaustiveness (Jamet, 1995b). Nevertheless, even if the results of our evaluations were very optimistic according to the automatic extraction geometric quality, these results were rather modest according to the efficiency in terms of productivity enhancement (from 10% to 40% of saved time according to the landscape characteristics). Independently of the robustness and of the efficiency of the detection algorithm itself, a semi-automatic work session takes time from the user, at least the time taken by all the moves into the image and the time taken by the user's decisions.

1.3. How to increase the automation level ?

To enhance significantly the productivity, we have to increase the automation level.
One solution consists in keeping a semi-automatic approach but which would be initialized by a pre-computed incomplete road network graph (Figure 1) :

- fully-automatic extraction of a little part of the network.
- interactive completion using a road following algorithm.

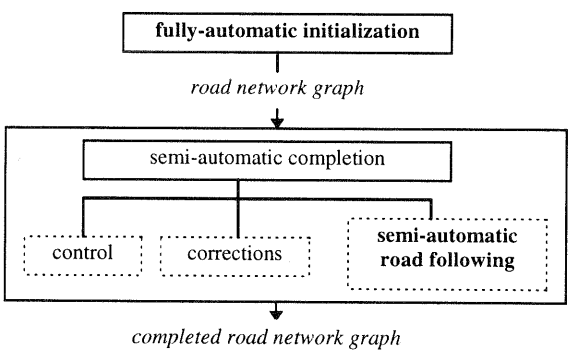

Figure 1 : semi-automatic completion of a pre-computed graph.

If fully-automatic systems are not ready to extract the whole road network with a good reliability, it seems to be possible from now to extract automatically the "easiest" ones with a very low error rate, applying very hard constraints. A so extracted part of the road network can then be presented to the user for a visual control and a semi-automatic completion.

2. THE SEMI-AUTOMATIC SOLUTION

The semi-automatic approach we propose relies on several algorithms used sequentially on the same platform.
The main originality of the approach is to separate the detection step and the geometric adjustment step (Airault, 1994a). The complete processing can be divided in five distinct (and successive) steps (Figure 2) :

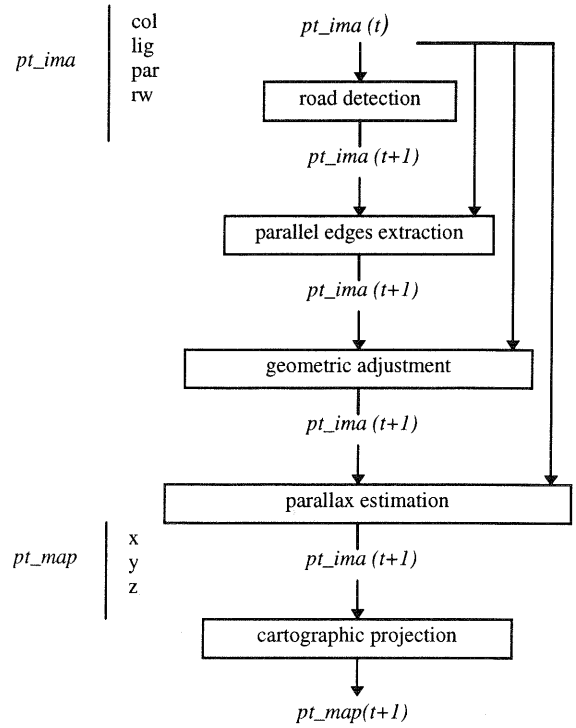

Figure 2 : Modular decomposition of the semi-automatic road following algorithm.

The data structure *pt_ima* corresponds to the points characteristics in the image. It contains, in addition to the location in the image, the disparity (or parallax) value and the measured road width. The data structure *pt_map* corresponds to the cartographic coordinates of the road points.

2.1. The detection step

The detection step corresponds to the identification of the image area as a road object. This step is based on the local optimization. of a cost function The used cost function takes mainly into account the local homogeneity and the anisotropic aspect of the homogeneity of roads. It takes as input one point and one direction which can be given by the user (as an initialization) or which can be the previous result of this iterative processing. It gives as output the new possible location on the road and several indicators which allow to decide if the plotting is still on the road.

2.2. The geometric adjustment step

The geometric adjustment step is based on a local detection of parallel edges along the road. The whole step is designed to compute a precise location of the road axis, using both the detected edges and an *a priori* geometric model of roads (as cubic splines). The road edges are extracted as often as possible (they do not always clearly appear in the image) and the road model is used to interpolate the road position between these well positioned points.

2.3. Computation of the 3-D geometry

The previous steps are using only one image to detect the road. The goal of the next ones is to compute the 3-D coordinates of the road, trying to match the detected road with the corresponding object in the other image of the stereo pair and

then computing the final coordinates in the appropriate cartographic projection.
The method we use to match roads from both images is based on a local correlation which takes into account some contextual knowledge about the detected road : the last measured disparity, the road orientation and the road width are used to predict the image area which has to be correlated :

- road orientation is used to compute the correlation coefficient on elongated rectangular areas.
- road width is used to give more important weight to the road edges.
- last measured disparity is used to limit the search area through a maximal slope threshold.

The coordinates transformation from the image to the cartographic projection is not a problem since we know the image absolute orientation.

2.4. Implementation in SAPHIR Géo

This semi-automatic road extraction method has been implemented in SAPHIR Géo by SYSECA. The interactive part of the capture process needs a well adapted environment to be efficient :

- user-friendly human-machine interface, using a large range of input devices (mouse, handwheel, tracker ball) and multiple windows.
- 3-D display of the result to have a good mean of control, using the DPW® software of Helava.
- optimized hardware and software to respect the real-time constraint : real-time display of large volumes of information in both raster and vector form, real-time management of vector data in a GIS environment.

This interactive part of the data capture process is the only one which requires such an environment. If we decide to use as input of this step an automatically pre-computed graph of the road network, this graph may have been computed on any other environment, with no particular specifications.

3. THE AUTOMATIC INITIALIZATION

3.1. Using the image only

The first solution we propose to compute a reliable incomplete graph of the road network is based on the traditional steps described in the literature (Aviad, 1988 ; Gruen, 1995) :

- road finding.
- road tracking.
- road linking.

The first step is supposed to extract the most visible road portions using local properties. The second step propagates the road presence hypothesis from the previously detected road seeds. The last step introduces higher level constraints to re-construct the road network as a topological graph with a few interruptions.
Our approach may be divided into five steps (Figure 3). Each of these steps uses very hard thresholds since we are looking for a reliable result, even if this result is largely incomplete.

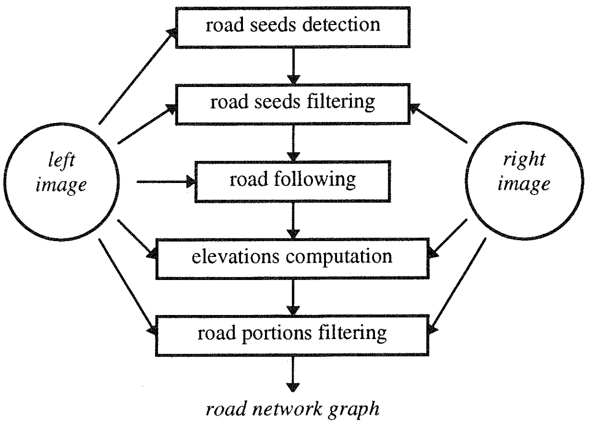

Figure 3 : the automatic processing using the image only.

a) road seeds detection : the road seeds detection is based on the shape analysis of the regions coming from a region-based segmentation (Ruskoné, 1994).

b) road seeds filtering : the shape criterion used before is too local and we have to apply other criteria to eliminate many false detections. The criteria we use as a confirmation of the road presence are :

- the contours around a road are geometrically organized : the entropy of the gradient directions around the road seeds has to be rather low.
- a road seed can not be a local maximum of elevation : using both images, we compute locally the elevations and filter the road seeds using a top-hat function.

c) road following : this step is based on the road following algorithm described in the previous part (road detection, parallel edges extraction, interpolation using splines).

d) elevations computation : the 3-D coordinates of the detected roads can be computed using the same criteria as in the semi-automatic approach (correlation using the road orientation and the road width). As we work in this case with large road portions, it is possible to optimize these criteria along the whole object, using an additive constraint of regularity of the road slopes. The model we use looks like the active contours model with the opposition between internal constraints (minimizing altimetric curvature) and external constraints (maximizing the correlation between both images).

e) road portions filtering : this step has to mix the different measurements which have been made along the whole processing to take the final decision. A supervised learning has been made for different kinds of objects (not only roads) in different kinds of contexts and it is possible to classify (Ruskoné, 1995) each road hypothesis and to compute a probability to belong to the road class. Only very high probabilities are kept.

3.2. Using external data

The other solution we propose to automatically generate a reliable incomplete road network graph is to use external data as input. In our case, these external data would be provided by a cartographic database, which is already available and have a geometric accuracy in the range of 10 meters. The external data could also be provided by the automatic digitization of paper maps.

The problem is, in this case, to refine the road geometry using the approximate location of roads and the topological links of the network.
We propose a two steps approach (Figure 4) :

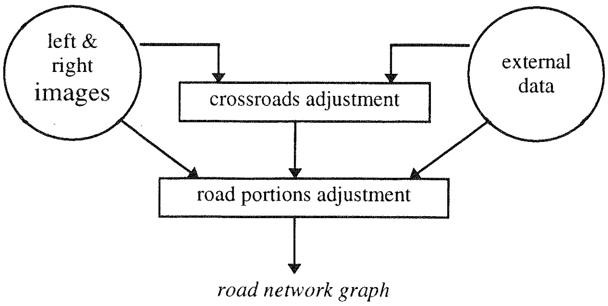

Figure 4 : the automatic processing using external data.

a) <u>crossroads adjustment</u> : we begin with the crossroads processing to give a precise location to all crossroads. This step is based on an profile analysis around each of the crossroads branches.

b) <u>road portions adjustment</u> : when the crossroads have been adjusted and knowing the network topology, the road extraction problem can be formulated as an optimization problem : we have to find the best road hypothesis between two crossroads. The computation may be performed using, here also, the active contours model, to take into account the measurements in both images and an *a priori* geometric model of the road.

This step can be followed by the road filtering step described before.

4. EVALUATION METHODOLOGY

It is now important to evaluate what is the contribution of the automatic extraction as an initialization of the semi-automatic processing. The definition of the evaluation methodology consists in defining which indicators have to be measured according to our production goals and in defining which parameters we want to evaluate with these indicators.

4.1. The indicators

About the indicators, we are interested in knowing if the geometric quality of the results is correct according to our database specifications and to know how much time can be saved with such approaches.

- geometric quality evaluation : we have to show that both automatic and semi-automatic extraction algorithms verify the geometric accuracy specifications of the manual capture.
- succes rate evaluation : we have to evaluate the succes rate of the initial automatic extraction by counting both the number of roads which have been succesfully extracted and the number of detected objects which are not roads.
- capture time evaluation : the capture time is the most important indicator, in the sense that our final goal is to save time with the automatic processings (increasing the succes rate of our methods is just a mean to reach this goal).
- user's remark : it is essential to take into account the user's remarks about the human-machine interface. A semi-automatic solution will be operational only if it is well accepted and well understood by people who are going to use it (McKeown, 1996).

4.2. The parameters

The other part of the evaluation methodology definition concerns the parameters we are going to study in order to be sure that our results will be successfully extrapolated to the whole database acquisition :

- choice of the test areas according to the French landscapes diversity (urban areas sub-urban areas, mountainous areas, forest areas,...).
- choice of the number of human operators necessary to evaluate the reliability of our measurements (influence of the operator training).
- choice of the most efficient human-machine interface for the control, the corrections and the completion of the automatically extracted network.
- choice of the optimal set of parameters for the initial automatic extraction to find the best ratio between exhaustivness and reliability, according to the control and correction step.

4.3. The reference data

The reference data we have to use, as well for the geometric accuracy evaluation as for the data capture time evaluation, are provided by the traditional manual data capture process (to get an "absolute" evaluation). But, according to the different approaches presented in this paper, we have to compare the different results, in order to evaluate the contribution of the fully automatic initialization of the semi-automatic process.

5. CONCLUSION

We proposed two different solutions to increase the automation level of a basic semi-automatic road extraction process. We presented also the evaluation methodology supposed to be applied to appreciate the contribution of the proposed approaches. It was too early to give complete results about this evaluation. These results will be presented in a forthcoming paper.

6. REFERENCES

Airault, S., Jamet, O., 1994a. Détection et restitution automatiques du réseau routier à partir d'images aériennes, Congrès RFIA, Paris, France.

Airault, S., Jamet, O., 1994b. Road detection from aerial images: a cooperation between local and global methods. In : Image and signal processing for remote sensing, SPIE, Rome, Italy.

Airault, S., Jamet, O., 1995. Evaluation of the operationality of a semi-automatic road network capture process. In : Digital photogrammetry & Remote Sensing '95, SPIE, St-Petersburg, Russia.

Aviad, Z., Carnine, P. D., 1988. Road finding for road-network extraction. In : proceedings of computer vision and pattern recognition, Ann Arbor, USA.

Gruen, A., LI, H., 1995. Road extraction from aerial and satellite images by dynamic programming. In : ISPRS journal for Photogrammetry and Remote Sensing, Volume 50, number 4, 1995.

Heipke, C., Englisch, A., Speer, T., Stier, S., Kutka, R., 1994. Semi-automatic extraction of roads from aerial images. In : ISPRS commission III Symposium, Working group III/2, Munich, Germany.

Hsieh, Y., 1995. Design and evaluation of a semi-automated site modeling system. Report CMU-CS-95-195, Digital Mapping Laboratory, Carnegie Mellon University.

Jamet, O., Le Men, H., 1995a. Digital photogrammetry at the French National Geographic Institute : presentation of the research policy of a national mapping agency. In : Integrating photogrammetric techniques with scene analysis and machine vision II, SPIE, Volume 2486, Orlando, USA.

Jamet, O., Dissard, O., Airault, S., 1995b. Building extraction from stereo pairs of aerial images : accuracy and productivity constraint of a topographic production line. In : Automatic extraction of man-made objects from aerial and space images, edited by A. Gruen, O. Kübler & P. Agouris, Birkhaüser, Basel.

McKeown, D., 1996. Top ten lessons learned in automated cartography. Report CMS-CS-96-110, Digital Mapping Laboratory, Carnage Melon University.

Ruskoné, R., Airault, S., Jamet, O., 1994. Road network interpretation : a topological hypothesis driven system. In : ISPRS commission III Symposium, Munich, Germany.

Ruskoné, R., Airault, S., Jamet, O., 1995. Road network extraction by local context interpretation. In : Image and signal processing for remote sensing, SPIE, Paris, France.