KNOWLEDGE-BASED PROCESS MANAGEMENT TO POPULATE DATABASES WITH 3D MULTI-REPRESENTATION OF BUILDINGS

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ABSTRACT:

This paper presents our approach to improve the 3D-MRDB population techniques in the context of buildings (i.e. to define several geometric representations, different levels of details, of a geographical object). After having discussed our motivations, we present an overview of existing researches relating to the extraction of buildings' geometries. A description of the multi-scale pattern concept, developed in our working group to support the extraction of simplified geometries, is also provided. We present afterwards our system approach to improve the detailed geometry extraction automation (through parametric models) while facilitating the extraction of simplified geometries (through multi-scale pattern). Our system architecture, implementing the Instance Driven SASS (Instance Driven Selection of Algorithms Setting and Sources) concept based on a priori knowledge is then described as well as the associated concepts. This semi-automatic approach requests the operator to introduce a priori knowledge; the sources, the algorithms and the parameters are then automatically selected according to the context. Finally, our methodology, aiming at implementing and validating our system, and the progress report of the project are described in the last part of this paper.

1. INTRODUCTION

There exist various uses of geospatial data which involve different requirements regarding the geometric definition of objects, leading to multiple representations of a same semantic object and to different data structuring approaches.

For example, when tackling visual impact issues in urban planning projects, 3D realistic models of the site under study are decisive to better perceive the associations among the structures involved (e.g. occlusion, cast shadow) while their 2D ground-level footprint is generally enough for cadastral applications. From a data structure point of view, the geographic databases are offering better capacities than CAD (Computer Assisted Design) structures to perform tasks like data spatial analysis or data update. Likewise, multi-representations databases are more and more favoured to supplement "on the fly" map generalisation processes, which are required when dealing with advanced "maps on demand" applications or SOLAP (Spatial On-Line Analytical Processing) applications.

Thus, 3D-MRDB (3D Multi-Representation DataBases) seems more and more interesting to support a large range of applications. Besides, creating a unique 3D-MRDB to derive different cartographic products is an interesting avenue compared to the production of independent databases at different scales, especially to minimize the problems related to their consistent updates.

The 3D-MRDB population process involves several stages, including geometries extraction. In this paper, we consider only two groups to categorize the geometric levels of details: the first one represents the most detailed geometries in the 3D-MRDB and contains the Fine-grained Level Geometries (FLG; there is only one fine geometric definition for a same semantic object); the second group represents the coarser geometries, corresponding to the other abstraction levels in the 3D-MRDB, and contains the Coarser-grained Level Geometries (CLG; there are several coarse geometries for a same semantic object).
The FLG extraction and the CLG extraction constitute two major stages in the 3D-MRDB population process. Their production cost appears as a recurrent and driving problem in the field of data production techniques and has justified many researches. A significant share of these researches aimed at reducing the extent of human intervention in the workflow. Cost and feasibility reasons generally lead to FLG extraction process using photogrammetric approaches. Several researches have been done to automate these processes but the obtained automatic methods still need to be improved.
Extracting and integrating CLG with FLG can be achieved using three different approaches, either separately or in

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combination (Bernier and Bédard, 2005). These are (1) geometric and semantic matching of different sources at different scales; (2) map generalisation with linking of the result to FLG, (3) multi-representation data acquisition. While the first two approaches offer semi-automatic solutions, and highly automatics solutions in very specific cases, their efficiency remains to be improved. Over the last four years, our research group investigated the three approaches, focusing of the last one using the recent concept of multi-scale geometric pattern (Bernier, 2002; Cardenas, 2004).

The present paper introduces our approach to improve the FLG extraction automation in a way that it involves the automatic CLG definition through multi-scale pattern implementation. Related work in the field of FLG extraction will be presented in the second section of this paper with a focus on multi-scale patterns and parametric models. The third section will describe the global architecture of our system and its components, our methodology and the current project stage, before concluding.

2. RELATED WORK :

2.1 Overview of techniques to collect FLG

This section presents an overview of the approaches used for the extraction of FLG. It is based on three critical criteria in relation to our research context: the data source, the automation level and the level of a priori knowledge involved.

2.1.1 Geographic data sources

It stems from the literature that passive imagery and Digital Elevation Models (DEM) are the two main data sources used to extract building geometry. Both offer large scale geographic data production capacities by relying on aerial or space-borne sensors. Passive imagery provides a good geometric accuracy and is easy to understand by human. The DEM exploitation, preferred in (Vosselman and Dijkman, 2001), facilitates the scene automatic interpretation due to its immediate 3D object surface description (Brenner, 2000). However, it could show some limitations from a geometric accuracy point of view. The approach proposed in (Rottensteiner and Jansa, 2002) combines passive imagery with DEM in order to cumulate the benefits of each source. Relying on the same principle, (Flamanc et al., 2003; Jibrini et al., 2000; Suveg and Vosselman, 2004) involve some vector sources in addition to the passive imagery or the DEM source. Such an approach allows decreasing the search space of building’s boundaries and provides the extraction algorithm with some guidelines (e.g. building footprints). Even if adding vector data has proved to be very efficient, this option is too frequently neglected (Mayer, 2004).

2.1.2 Automation level and human interaction

In this paper, we consider an approach to be semi-automatic when it requires some human interaction before or during the building’s reconstruction process. Approaches requesting human to bypass failed cases or to validate results do not fall into the semi-automatic category and are considered as automatic. During the last decade, developing automatic or semi-automatic FLG extraction methods has motivated a lot of work. Though automatic approaches, as those proposed in (Baillard and Zisserman, 2000; Fischer et al., 1999; Rottensteiner and Jansa, 2002; Suveg and Vosselman, 2004), have shown interesting results, semi-automatic approaches, preferred in (Oriot and Michel, 2004; Tseng and Wang, 2003; Vosselman and Veldhuis, 1999) show more attractive performances to envision their future integration in the industrial data production workflow (Baltsavias, 2004; Förstner, 1999; Mayer, 2004).

The human operator interaction, involved in semi-automatic approaches, can range from the definition of the buildings’ approximate location (Oriot and Michel, 2004) to the nodes’ definition of the building geometry (Gruen and Wang, 1998). A frequently used principle in semi-automatic approaches consists in exploiting, on the one hand, the human ability to interpret the images and, on the other hand, the computer ability to locate boundaries (Oriot and Michel, 2004). This principle is usally coupled with parametric models (Brenner, 1999; Tseng and Wang, 2003; Vosselman and Veldhuis, 1999) where the human operator is used to identify and approximately locate the building parametric models (this concept will be described in 2.2.1) and the algorithms are used to compute afterwards the accurate values of the model parameters.

2.1.3 A Priori Knowledge involved

The a priori knowledge, exploited by a semi-automatic approach, is described in (Baltsavias, 2004) as the only viable alternative towards the development of useful object extraction systems. In this paper, we consider as a priori knowledge all the information that is available at the beginning of the extraction process and that describes: the object to extract, its context, the data sources, the processes and their performances. The reader should refer to (Baltsavias, 2004) for a rich review of a priori knowledge data collection approaches.

The a priori knowledge, involved in most of building’s extraction approaches to increase performance, can range from the approximate location of the building as proposed in (Flamanc et al., 2003; Oriot and Michel, 2004; Taillandier and Deriche, 2004), to an explicit geometric definition or to criteria for the algorithms selection. But, even if some knowledge is frequently present in the FLG extraction method, it is often in an implicit manner. For example, in (Oriot and Michel, 2004) the authors assume the roofs being flat while in (Suveg and Vosselman, 2004) they assume that the buildings can be described by parametric models fitting the provided footprints. Both examples involve a priori knowledge about the object to extract (e.g. flat roof, straight boundaries) but no explicit modelling of it is feeding the extraction algorithm. This lack of clear formulation of the hypotheses may be a source of failure when contradicting information arises. Thus, if a priori knowledge is a key element in the automatic process success, a better use of it imposes its explicit formulation.

2.2 Precision about the concepts

The parametric model concept, developed to support the FLG extraction will be described here after as well as the multi-scale pattern that has been developed to support the CLG extraction.

2.2.1 Parametric Models :

The principle of parametric models (illustrated in the Figure 1) is to predefine a library of fitting models that are defined by their geometry shape and a set of usable parameters (e.g. origin point, scale, rotation weight, height, roof slope). This library can then be used to facilitate the acquisition process by fitting parametric model onto the FLG of the instance. This acquisition process can be resumed in two successive steps:

(1) Identifying the parametric model
(2) Defining its shape parameters

Parametric models can also be combined, in Constructive Solid Geometry (Tseng and Wang, 2003), leading this way to complex geometries.

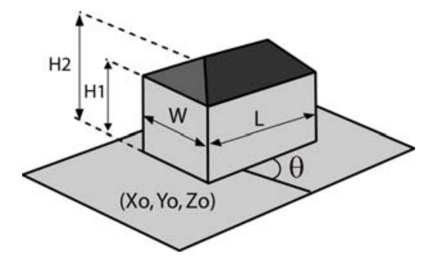

Figure 1: Parametric model

2.2.2 The multi-scale pattern concept :

The CLG capture involves creating several geometries describing the same semantic object at different levels of details. The multi-scale pattern concept aims at facilitating this step. The multi-scale pattern is defined as “a geometric object with basic geometric characteristics that are typical and representative of a large number of occurrences of a cartographic feature type or of a geometric primitive and that is able to adapt itself to the geometry of these occurrences of objects at different scales and that can be reused several times.” (Bédard, 2004; Cardenas, 2004). This definition is based on the statement that, in the coarse levels, a great number of occurrences of an object class have common geometric characteristics. The same pattern can thus be used to represent several occurrences. Multi-scale patterns are defined according to a range of scales, named the pattern scale domain. This domain, concerning only the CLG, is located, on the scale dimension, between the exact geometry domain and the symbol domain as illustrated in the Figure 2

To summarize, only one geometric pattern can be used to represent several occurrences of an object class, and this, at various levels of details. Thus, these patterns facilitate the operator’s task to obtain the CLG, since he will only have to associate the finest level of the pattern to the detailed geometry of the object.

All the geometric representations contained in a multi-scale pattern are linked ones to each others. The definition of the parameters of a level, the most detailed one among the levels contained in the pattern, implies the automatic definition of the corresponding parameters to the other levels. This does not prevent however, to specialize if necessary the geometric representation of an instance for a given level by removing a primitive or by modifying its shape.
It is important to note this hypothesis does not concern all the objects classes nor all the occurrences of an object class, but only classes with repetitive (i.e. concerning a large number of occurrences) geometries (e.g. cloverleaves, buildings, pools) for a large proportion of their occurrences.

The CLG definition for an occurrence using a multi-scale pattern requires four steps, simpler than a manual generalization process:

(1) Identifying the multi scale pattern
(2) Defining its global parameters according to the more detailed level of the pattern
(3) Specializing it if necessary
(4) Linking it to the FLG

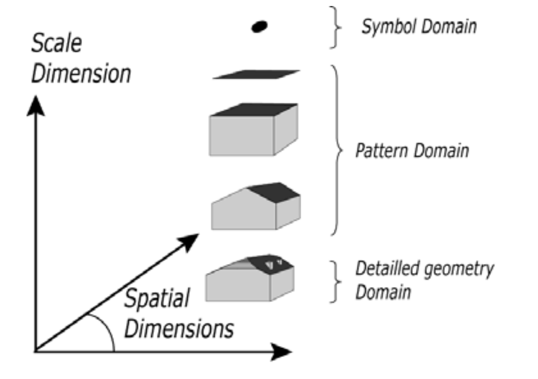

Figure 2: Multi-scale pattern

3. THE PROPOSED APPROACH

In the remaining part of the paper, we use the Instance Driven SASS acronym to refer to the Selection of the Algorithms, the Sources and the Settings driven by the instance context.
We suggest to use an a priori knowledge based Instance Driven SASS approach to improve the performance of the automatic processes used for the geometries extraction. We propose a semi-automatic approach introducing a priori knowledge at the process beginning and using parametric models that is a priori linked to a multi-scale pattern.
We suggest to decompose the acquisition process in three successive steps:

(1) to request the operator at the beginning of the process to introduce a priori knowledge about the context
(2) to automatically define a strategy to determine the model parameters according to the Instance Driven SASS concept
(3) to determine the model parameters.

The architecture, which will be presented hereafter, formalizes the various concepts introduced by this assumption and thus proposes the bases of a system to populate a building’s 3D-MRDB.

3.1 Architecture description

3.1.1 Main components and data flow:

The suggested system, illustrated in Figure 3, consists of three levels that occur successively in the definition process of the building’s geometries. The data (a priori knowledge and data sources) is conveyed initially from the “DATA” layer to the “REASONING” layer. The scene is then interpreted by the human operator (i.e. he identifies the main characteristics of the building to be extracted) who provides the system with information about the building to be extracted (e.g. the parametric model, the color model, the building parallelism with the road). All the a priori knowledge is then analyzed to automatically define a strategy (e.g. to infer the direction of the road from vector data, to carry out a directional gradient analysis according to this direction, then to exploit colorimetric information to segment the images) to determine the model parameters. Their definition leads then to the FLG and the CLG extraction. The strategy, involving not only the sources selection but also the algorithms and their settings, is then implemented in the “PROCESSING” layer. The extracted geometries, FLG and CLG, are then recorded in the 3D-MRDB.

Any arising failures in the processing layer are tackled by the human operator.

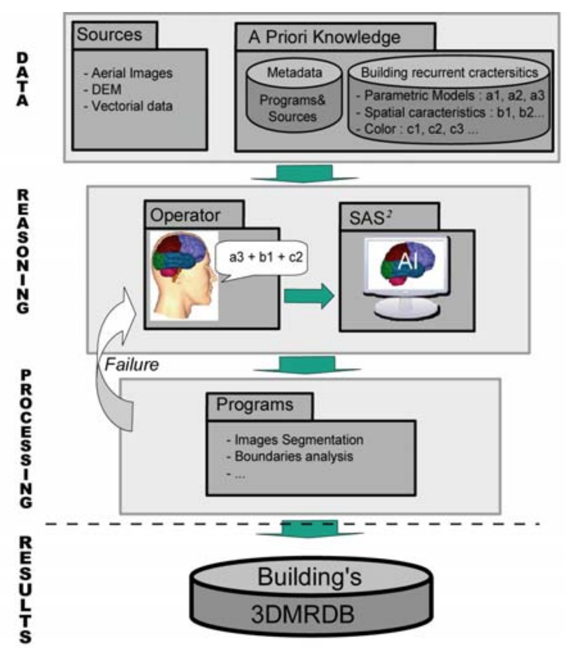

Figure 3: System Architecture

3.1.2 The « DATA » layer

The "DATA" layer involves two kinds of data: the data sources and the a priori knowledge. The data sources, for example aerial images, 2D vector data, are used by the human operator to interpret the scene and by the algorithms to locate the parametric model. Thus, their spatial resolutions must fulfill the FLG data acquisition specifications (we consider that, depending on the project, these resolutions range from few centimeters to 1 meter). High resolution images as well as a DEM (possibly computed automatically from the images) is the minimum requirement. Additional data sources may consist of vector data related to the buildings and the road network. Two categories of a priori knowledge are available: those relating to the building recurring characteristics and those relating to the useful resources to extract the building's geometries. The recurring characteristics not only relate to the building's geometries (parametric model a priori linked with the multi-scale pattern) but also to their radiometric properties (e.g. colors, textures) and to their spatial constraints and relationships (e.g. correlations between the building's main directions and those of the roads). The a priori knowledge relating to the useful resources encompasses the sources metadata (e.g. images resolution, sensors used, kind of vector data) and the algorithm metadata (e.g. speed of execution, reliability).

3.1.3 The « REASONING » layer

Two successive components are used to perform the reasoning task. The first one, the human operator, carries out the scene interpretation based on the image observation. Then, he feeds the automatic reasoning component (i.e. the 2nd component) with his interpretation of the scene, namely with the classes definition of the instance under study (parametric model and multi-scale pattern, radiometric model and spatial relations/correlations model). The reasoning component, named the AI component, can analyse the context according to the available sources, their properties and the available a priori knowledge. This automatic analysis leads to a strategy elaboration that takes advantage of the available resources (sources, algorithms and parameter setting) to perform the model parameters determination.

3.1.4 The « PROCESSING » layer

The "PROCESSING" layer involves simple pre-processes, applied to the raw data to improve their subsequent exploitation (e.g. low pass filters, high pass filters, image segmentation operators), as well as specific processes dedicated to the parametric models fitting (e.g. operators using the results of a segmentation to infer the parametric model parameters). These processes are characterized by their capacity to be set according to the context as well as by their low time consuming performance (to minimize the operator waiting time).

3.2 Related concepts

3.2.1 Instance Driven SASS

The variability of the available data sources (e.g only aerial images available, aerial images with cadastral vector data available), of their properties (geometric and radiometric resolutions of the images, specified vector data) as well as the variability of the urban landscape under study make the development of generic automatic approaches very difficult. We think, as it is suggested in (Flamanc and Al, 2003), that it is relevant to select the algorithms according to the context of the instance under study, but also that this suggestion should be extended to the selection of the sources and the settings. This is the purpose of the Instance Driven SASS concept, which used the a priori knowledge to drive the contextual Selection of the Algorithms, Sources and Settings.

3.2.2 A priori knowledge related to recurring characteristics

Like for the geometric characteristics (model parametric and multi-scale pattern), we suppose that a fair amount of buildings can be gathered in classes according to their additional characteristics. Those can relate to their spectral (colors and textures) and spatial properties (spatial relationships and constraints, e.g. correlation between the building's directions and road directions). The identification, by the human operator, of these classes before the positioning of the parametric model, is a simple and effective way to introduce a priori knowledge about the object to be extracted through the Instance Driven SASS component.

3.2.3 A priori link between parametric models and multi-scale patterns.

Although they were developed to achieve distinct goals, we think that parametric models (FLG) and multi-scale patterns (CLG) can be a priori linked to form an a priori knowledge database of building's geometries. Consequently, the model parameters definition (FLG) automatically involves the definition of the linked multi-scale pattern (CLG).

3.2.4 Human operator and computers to achieve reasoning tasks

The fact that the interpretation of a geographical scene, based on high-resolution images, is a particularly complex task to automate and which paradoxically is very simple and rapid for a human operator is acknowledged today. In the same way, the multi-criteria analysis of numerical data and the programs supervision are tasks that can prove to be difficult and tiresome especially if the operator is not a specialist in the domain

(Thonnat et al., 1999). In our context, dealing with high resolution images and analysing several criteria to define the optimal strategy to establish model parameters, we think that it is relevant to request, on the one hand, the human operator to interpret the scene and on the other hand a software operator, the AI component, to analyse the context (definition of the optimal strategy) and to supervise the program (strategy application).

3.3 Project development phases

The bases of the system dedicated to improve the 3D-MRDB population techniques have been set. Three phases, including a prototype development, will be performed successively to implement and to evaluate our system. These phases are described here after.

3.3.1 Phase 1 : algorithm selection and a priori knowledge database implementation

Algorithms will be selected, based on a literature review and on an analysis of their performances. This selection will be carried out according to their fitness to our needs (cf. 3.1.4). Our fitness analysis methodology, also used to define a priori knowledge, will be described hereafter.

The a priori knowledge database (algorithms performances and building's recurring characteristics), is particularly important because it is preliminary to the reasoning and the processes supervision. The parametric models (cf. 2.2.1) were determined by studying a test zone and reviewing the literature. The multi-scale patterns (cf 2.2.2) were determined during another research project. A multidimensional analysis will be performed using a SOLAP (Spatial One Line Analytical Processing) tool provided by the industrial chair of Doctor Yvan Bédard to populate our a priori knowledge database and to evaluate the algorithms. SOLAP tools are decisional tools able to support a human analysis of important data volumes. These tools, described in (Bédard et al., 2001), are helpful to stand out trends and correlations. The dimensions included in our analysis will concern geometric and radiometric properties, spatial relationships and constraints (particularly road network and buildings) and the algorithm performances. We are currently working on this first phase.

3.3.2 Phase 2 : Instance Driven SASS implementation

The Instance Driven SASS component implementation will be carried out according to two successive stages. A human operator will initially perform the two reasoning tasks: (1) the scene interpretation (2) the context analysis and program supervision (definition of the strategy and processing driving). In the second stage, the human operator will be replaced by an Artificial Intelligence component to perform the second reasoning task. This choice will allow us to validate, in a very controlled environment, the relevance of the Instance Driven SASS concept using a priori knowledge. We plan to start this second phase in September 2005.

3.3.3 Phase 3 : System global evaluation

The system evaluation will be carried out by testing the prototype on the GEMURE project (GEMURE, 2002-2005) test site: Quebec City. The FLG and the CLG results will be compared to the data warehouse obtained during the GEMURE project. We expect to start the system global evaluation in March 2005.

3.4 Area under study and development background

3.4.1 Area under study and data

The test zone includes several districts of Montreal Island. We have several high resolution images including IKONOS, QUICKBIRD and large scale color aerial images (1/4000, 14 microns). We also have additional 2D vector data describing the road network and the building's footprint as well as 3D reference data describing building's detailed geometries. A DEM will be obtained automatically from the aerial images.

3.4.2 Technologies

The prototype development involves the joint exploitation of various technologies. The DVP Vectorization© software provided by DVP-GS© will be used to support the interactions with the operator (image analysis, identification of the parametric models). The automatic reasoning techniques choice (multicriteria analysis and supervision of programs) and the approach to represent a priori knowledge are closely dependent. We currently consider several technologies to provide these functions and are in contact with the INRIA's ORION team, which has been working on these problems for more than ten years. The image and the photogrammetric processing will be performed using DVP© software components provided by DVP-GS©. The final results (i.e. model parameters and multi-scale pattern parameters) will be directly stored in a database through ODBC standards.

4. CONCLUSIONS

We have presented in this paper an original approach to improve the automation level of the building's 3D-MRDB population. We have proposed a system architecture implementing the a priori knowledge based Instance Driven SASS concept. We have proposed a simple semi-automatic way to involve a priori knowledge about the instance in order to improve the automation of the FLG and the CLG extraction.

We have described our methodology as well as the project main steps of our project.

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REFERENCES

Baillard, C. and Zisserman, A., 2000. A Plane-Sweep Strategy for the 3D Reconstruction of Buildings from Multiple Images. 19th ISPRS Congress and Exhibition, Amsterdam, Vol. 32, pp. 56-62.

Baltsavias, E., 2004. Object Extraction and Revision by Image Analysis Using Existing Geodata and Knowledge: Current Status and Steps Towards Operational Systems. *ISPRS Journal of Photogrammetry and Remote Sensing*, Vol.58, pp.129-151.

Bédard, Y., 2004. Combining Automatic Generalization and Multiple Representations for Highly Interactive Web-based Mapping. GeoSpatial Word 2004, Miami, Florida (USA),

Bédard, Y. et al., 2001. SOLAP: A New Tool for User-driven Geographic Knowledge Discovery with Application to Environmental Health Indicators. GIS Workshop: Mapping Health on the Internet, McMaster University,

Bernier, E., 2002. Utilisation de la représentation multiple comme support à la génération de vues de bases de données géospatiales dans un contexte SOLAP. Maîtrise en Science Thesis, Laval, Québec, 99 pp.

Bernier, E. and Bédard, Y., 2005. Using a data warehousing architecture to combine automatic generalization and multiple representation for web-based on-demand mapping. In: *Challenges in the Portrayal of Geographic Information: Issues of Generalisation and Multi Scale Representation in press.* A. Ruas, W. Mackaness, T. Kilpelainen and D. Richardson, pp.

Brenner, C., 1999. Interactive modeling tools for 3D building reconstruction. In: *Photogrammetric Week '99'*. D. Fritsch and R. Spiller, Wichmann Verlag, Stuttgart (Germany), pp. 23-24.

Brenner, C., 2000. Towards fully automatic generation of city models. XIX ISPRS Congress, Commission III, WGIII/1, Amsterdam, Vol. 33(B3), pp. 85-92.

Cardenas, A., 2004. Utilisation de Patrons Géométriques comme support à la Généralisation Automatique. Maîtrise en Sciences Thesis, Laval, Québec, 110 pp.

Fischer, A., Kolbe, T.H. and Lang, F., 1999. On the Use of Geometric and Semantic Models for Component-Based Building Reconstruction. In: *Semantic Modeling for the Acquisition of Topographic Information from Images and Maps SMATI '99*. W. Förstner, C.-E. Liedtke and J. Bückner, Institut für Photogrammetrie, Universität Bonn, Bonn, pp. 101-119.

Flamanc, D., Maillet, G. and Jibrini, H., 2003. 3D City Models: An Operational Approach using Aerial Images and Cadastral Maps. ISPRS Workshop on "Photogrammetric Image Analysis", Munich (Germany), Vol. 34 (3/W8),

Förstner, W., 1999. 3D-city Models: Automatic and Semiautomatic Acquisition Methods. In: *Photogrammetric Week '99'*. D. Fritsch and R. Spiller, Wichmann Verlag, Heidelberg, Stuttgart (Germany), pp. 291-303.

GEMURE, 2002-2005. Generalisation and Multiple Representations for On-Demand Map Production and Delivery. A project financed by GEOIDE from april 2002 to march 2005. Accessed the: 2 April 2005 http://sirs.scg.ulaval.ca/gemure/en/home.asp

Gruen, A. and Wang, X., 1998. CC-Modeler: A Topology Generator for 3D City Models. ISPRS - Commission IV Symposium "GIS - Between Visions and Applications", Stuttgart (Germany), Vol. 32(4), pp. 188-196.

Jibrini, H., Paparoditis, N., Desseilligny, M.P. and Maitre, H., 2000. Automatic building reconstruction from very high resolution aerial stereopairs using cadastral groung plans. XIX ISPRS Congress, Commission III, WGIII/1, Amsterdam (The Netherlands), Vol. 33 (B3),

Mayer, H., 2004. Object Extraction for Digital Photogrammetric Workstations. XXth ISPRS Congress - Geo-Imagery Bridging Continents - Commission II, Istanbul (Turkey), Vol. 35(B2),

Oriot, H. and Michel, A., 2004. Building Extraction from Stereoscopic Aerial Images. *Applied optics (Optical Society of America)*, Vol.43(2), pp.218-226.

Rottensteiner, F. and Jansa, J., 2002. Automatic Extraction of Buildings from Lidar Data and Aerial Images. Commission IV Symposium "Geospatial Theory, Processing and Applications" - WG3, Ottawa (Canada), Vol. 34(3),

Suveg, I. and Vosselman, G., 2004. Reconstruction of 3D Building Models from Aerial Images and Maps. *ISPRS Journal of Photogrammetry & Remote Sensing*, Vol.58, pp.202-224.

Taillandier, F. and Deriche, R., 2004. Automatic Building Reconstruction from Aerial Images: A Generic Bayesian Framework. XXth ISPRS Congress - Geo-Imagery Bridging Continents - Commission III - WGIII/4, Istanbul (Turkey), Vol. 35(B3),

Thonnat, M., Moisan, S. and Crubézy, M., 1999. Experience in Integrating Image Processing Programs. 1st International Conference on Vision Systems (ICVS'99), Las Palmas, Gran Canarias, Spain,

Tseng, Y.-H. and Wang, S., 2003. Semiautomated Building Extraction Based on CSG Model-Image Fitting. *Photogrammetric Engineering and Remote Sensing*, Vol.69(2), pp.171-180.

Vosselman, G. and Dijkman, S., 2001. 3D Building Reconstruction from Point Clouds and Ground Plans. ISPRS WGIII/3-6 Workshop on "Land Surface Mapping en Characterization Using Laser Altimetry", Annapolis, Maryland (USA), Vol. 34 (3/W4), pp. 37-44.

Vosselman, G. and Veldhuis, H., 1999. Mapping by Dragging and Fitting of Wire-Frame Models. *Photogrammetric Engineering and Remote Sensing*, Vol.65(7), pp.769-776.