ISPRS Journal of Photogrammetry and Remote Sensing 66 (2011) 732–742

Contents lists available at ScienceDirect

ISPRS Journal of Photogrammetry and Remote Sensing

journal homepage: www.elsevier.com/locate/isprsjprs

# Building footprint database improvement for 3D reconstruction: A split and merge approach and its evaluation

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ARTICLE INFO

*Article history:*
Received 19 August 2010
Received in revised form 22 June 2011
Accepted 26 June 2011
Available online 29 July 2011

*Keywords:*
Photogrammetry
Segmentation
Reconstruction
Urban scene
Building

ABSTRACT

We present a general framework to improve a vectorial building footprint database consisting of a set of 2D polygons. The aim of this improvement is to make the database more proper to subsequent 3D building reconstruction at a large scale. Each polygon is split into several simple polygons guided by a digital elevation model (DEM). We say that this segmentation is *vectorial* as we produce segmentations that *intrinsically* have simple polygonal shapes, instead of doing a raster segmentation of the DEM within the polygon then trying to simplify it in a vectorization step. The method is based on a Mumford and Shah like energy functional characterizing the quality of the segmentation. We simplify the problem by imposing that the segmentation edges have directions present in the input polygon over which the DEM is defined. We evaluate the validity of the proposed method on a very large dataset and discuss its pros and cons based on this evaluation.


## 1. Introduction

### *1.1. Problem statement*

The problem of urban reconstruction consists in finding a 3D model (in general a polyhedral surface) that is as coherent as possible with the input data and has been widely studied over the past 15 years. Transferring the methods developed into industrial production at the scale of a large city raises robustness issues as a broad variety of building types may be encountered and a reasonable building model should be produced in a reasonable time in any case. In our experience, such robustness can only be achieved if a very reliable ground plan of the building is available. In this case, we can use the method of (Durupt and Taillandier, 2006). This method enumerates plausible models based on planes supported by the (horizontal) edges of the footprint, and selects the one that fits the data best. The robustness achieved by this method comes however at the cost of generality because it is limited to reconstructing continuous ($C_0$) surfaces. Unfortunately, the 2D databases available in France correspond to an administrative partition, and a single footprint often contains $C_0$ discontinuities (see Fig. 1), for instance, when:

- Two (or more) adjacent buildings with different roof heights share the same footprint.
- The real footprint of a building is only a portion of the footprint in the database (gardens, inner courts, etc.)
- The building has some superstructures whose sizes and heights are not negligible with respect to the expected precision of the reconstruction. This problem becomes increasingly difficult as reconstructions gain in precision, and has already been tackled by Brédif et al. (2007) and Dornaika and Brédif (2008) in the context of photogrammetry.

More difficult cases are often a combination of the three cited above, and require a manual intervention to enable a further reconstruction. In general, this intervention consists in subdividing the footprint by cutting through all (or most of) the altimetric discontinuities. In a production framework, where large areas need to be extensively reconstructed, it appears that this building footprint database enhancement step is the most time consuming one. Hence, the problem that we tackle in this paper is that of automating this enhancement as a required pre-processing step to 3D reconstruction. More precisely, our problem is to segment a polygonal footprint into a set of non-overlapping polygonal sub-footprints that cover it entirely, such that the interface between the sub-footprints corresponds to altimetric discontinuities. This is a problem of segmentation of vector data (building footprints database) guided by raster data (photos, DEM, etc.)

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doi:10.1016/j.isprsjprs.2011.06.005

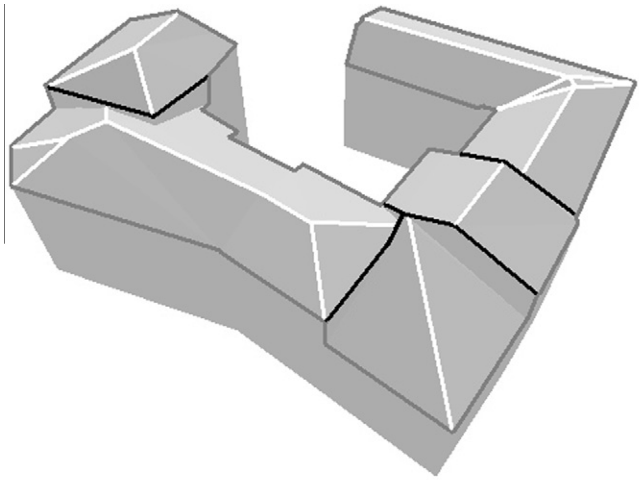

**Fig. 1.** Two types of (altimetric) discontinuities: $C_0$ (black) and $C_1$ (white) within a footprint (gray).

We will now present the data available for this study (Section 1.2), then review the previous works on related topics (Section 1.3) and eventually expose the approach that we propose to tackle the stated problem (Section 1.4).

### 1.2. Available data

The *initial data* available in our study mainly consisted of:

- A set of 10 cm resolution aerial images with a high overlap around 60% (along and across track) in order to ensure that each ground point is seen in at least four images, covering an area of one square kilometer. The images are in IrRGB (the infrared channel is used to obtain a vegetation mask).
- A vectorized cadastral map giving building footprints for the same area. It consists in a set of polygonal footprints given by their ordered list of points in ground coordinates (Fig. 2, white).

From this initial data, we can extract:

- A digital elevation model (DEM) over the whole area (Fig. 2, bottom left). It was obtained by dense correlation following (Roy and Cox, 1998) with the multiresolution implementation described in Pierrot-Deseilligny and Paparoditis (2006).
- The gradient of the DEM (Fig. 2, right). We chose the Canny–Deriche filter described in Deriche (1987) for its robustness.
- An orthophotography of the area (Fig. 2, top left).
- A vegetation mask (Fig. 2, black) obtained by the method exposed in Iovan et al. (2008).

### 1.3. Previous works

3D building reconstruction methods are usually classified between:

- Bottom-up approaches: low level primitives are extracted from the data then merged into a high level model. For instance, Kim et al. (2000) extract multiscopic 3D linears from images, and Huber et al. (2003) extract *blobs* and *edges*.
- Top-down approaches: the data is used to evaluate and instances of high level primitives and choose the best one as explained in Suveg and Vosselman (2002). Top-down approaches are now mostly used to extract roof super structures as done in Haala and Brenner (1999).
- Both bottom-up and top-down approaches, also called *hypothesize and verify*: low level primitives are used to build a set of building hypothesis (bottom-up), and then the best hypothesis is evaluated based on the data and on various geometric knowledge about the building to reconstruct.

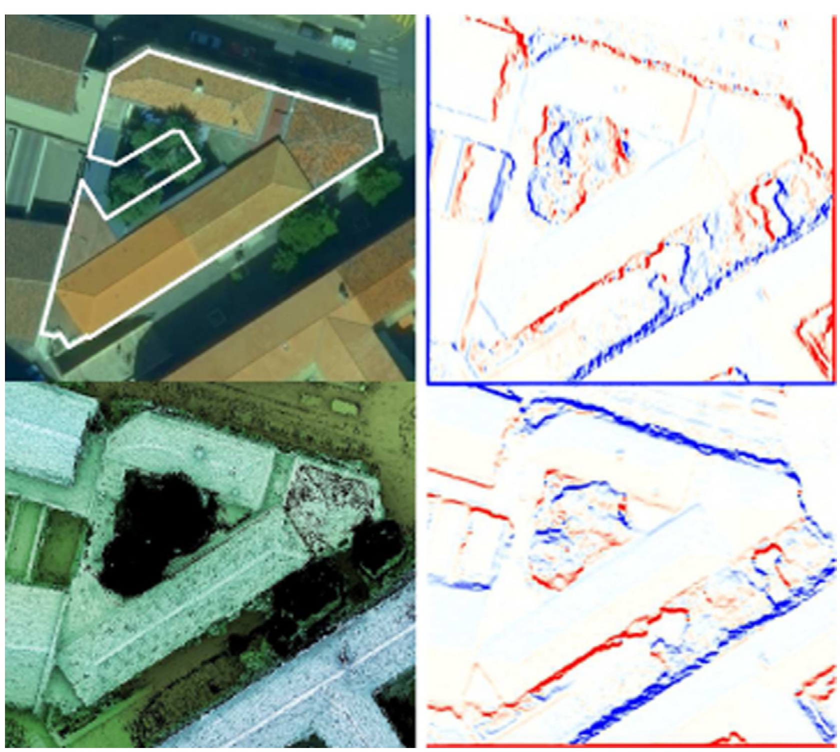

**Fig. 2.** Inputs to our algorithm: top left, orthophotography and footprint; bottom left, shaded DEM and vegetation mask; right, horizontal and vertical DEM gradients.