BUILDING FAÇADE SEPARATION IN VERTICAL AERIAL IMAGES

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ABSTRACT:

Three-dimensional models of urban environments have great appeal and offer promises of interesting applications. While initially it was of interest to just have such 3D data, it increasingly becomes evident that one really would like to have interpreted urban objects.

To be able to interpret buildings we have to split a visible whole building block into its different single buildings. Usually this is done using cadastral information to divide the single land parcels. The problem in this case is that sometimes the building boundaries derived from the cadastre are insufficiently accurate due to several reasons like old databases with lower accuracies or inaccuracies due to transformation between two coordinate systems. For this reason it can happen that a cadastral boundary coming from an old map is displaced by up to several meters and therefore divides two buildings incorrectly.

To overcome such problems we incorporate the information from vertical aerial images. We introduce a façade separation method that is able to find individual building façades using multi view stereo. The purpose is to identify the individual façades and separate them from one another before on proceeds with the analysis of a façade's details. The source was a set of overlapping, thus "redundant" vertical aerial images taken by an UltraCam digital aerial camera.

Therefore in a first step we determine the building block outlines using the building classification and use the height values from the Digital Surface Model (DSM) to determine approximate "façade quadrilaterals". We also incorporate height discontinuities using the height profiles along the building outlines to enhance our façade separation. In a next step we detect repeated pattern in these "façade images" and use them to separate the façades respectively building blocks from one another.

We show that this method can be successfully used to separate building façades using vertical aerial images with a very high detection rate of 88%.

1. MOTIVATION

Accurate and realistic three-dimensional models of urban environments are increasingly important for applications like virtual tourism, city planning, internet search and many emerging opportunities in the context of ambient intelligence. Applications like Bing Maps or Google Earth are offering virtual models of many major urban areas worldwide. Initially such data were just used for visualization purposes, but this is on the way to change. On the horizon are urban models that consist of semantically interpreted objects. In its most sophisticated form, each building, tree, street detail, bridge and water body is modelled in three dimensions, details such as windows, doors, façade elements, sidewalks, manholes, parking meters, suspended wires, street signs etc. exist as separate objects.

To be able to interpret buildings we have to split a visible whole building block into its different single buildings. Usually this is done using cadastral information to divide the single land parcels. The problem in this case is that sometimes the building boundaries derived from the cadastre may be insufficiently accurate, for example due to old databases with lower accuracies or inaccuracies due to transformation between two coordinate systems. For this reason it can happen that a cadastral boundary coming from an old map is displaced by up to several meters (Feucht 2007) and therefore divides two buildings incorrectly (see Figure 1).

Figure 1. Overlaying the cadastral map (depicted in red) over the true orthophoto shows displacements of the cadastral boundaries versus the photography.

Therefore we incorporate the information from vertical aerial images. We employ a method introduced by Wendel et al. (2010) that is able to separate building façades in single images. Separate façades can then get analysed for their details. In this previous project, the source material consisted of a set of overlapping thus redundant images using a moving vehicle and calibrated automated cameras.

In the current project we adapt their method to vertical aerial images in the hope to increase the accuracy of a building block separation beyond that obtainable from previous approaches. We determine the building block outlines using the building classification and use the height values from the Digital Surface Model (DSM) to determine the approximated "façade quadrilaterals". We also incorporate height discontinuities using the height profiles along the building outlines to enhance our façade separation. In a next step we detect repeated pattern in these "façade images" and use them to separate the façades respectively building blocks from one another. As the major contribution of this paper, we show that it is possible to separate façades by just using vertical aerial images and height information derived from those images. We also show that the achieved accuracies are close to those available from street side images despite of a far lower geometric resolution of the aerial data compared to street side images.

We have evaluated the method for a test area that covers 400m x 400m near the core of the city of Graz (Austria) with 186 different buildings consisting of 65 major building blocks. We show that the proposed method can be successfully used to separate building façades using vertical aerial images with a detection rate of 88%. Figure 2 illustrates one result of the proposed façade separation approach.

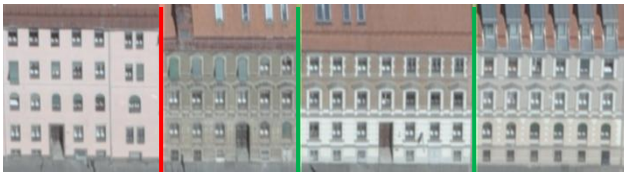

Figure 2. Result of façade separation for one building block from the test area. As one can notice all buildings were separated correctly. Separations marked in red correspond to splits based on building height, while those marked in green are the result of repetitive pattern analysis.

2. SOURCE DATA

In order to produce good results one needs (a) a Digital Surface Model (DSM) with well-defined building roof lines to avoid ragged building edges, as well as (b) a precise classification image from the test area. We want to present an overview of these two products that are derived fully automatically from vertical aerial images. Figure 3 shows an example of these two products covering the test area.

The Digital Surface Model is created by "dense matching". The input consists of the triangulated aerial photographs. In the process, one develops point clouds from subsets of the overlapping images and then merges (fuses) the separately developed point clouds of a given area. The process is described by Klaus (2007). The postings of the DSM and DTM are at two pixel intervals, thus far denser than traditional photogrammetry rules would support. The conversion of the surface model DSM into a Bald Earth Digital Terrain Model DTM is a post-process of the dense matching and has been described by Zebedin et al. (2006).

Any urban area of interest is being covered by multiple color aerial images. These can be subjected to an automated classification to develop information layers about the area. We consider these to be an input into our characterization procedures. The classification approach used here has been described by Zebedin et al. (2006). However, classification and segmentation methods are topics of intense research. For example, Kluckner et al. (2009) have proposed Random Forests as an alternative novel method with good results specifically interpreting urban scenes imaged by the UltraCam digital aerial camera.

Standard classification of 4-channel digital aerial photography typically leads to 7 separate areas for buildings; grass; trees; sealed surfaces; bare Earth; water; and other objects shown as "unclassified". The unclassified areas may show lamp posts, cars, buses, people etc.

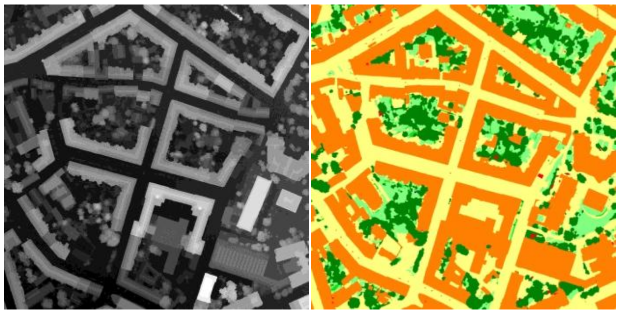

Figure 3. (a) Digital surface model from the test area (b) Classification image (orange: buildings, yellow: sealed surfaces, turquoise: bare earth, light green: grass, dark green: trees, blue: water, unclassified: red)

3. PROPOSED METHOD

This section describes how we separate buildings from vertical aerial images by applying a façade separation method introduced by Wendel et al. (2009). The proposed method consists of three steps. First we extract the building block outlines using the classification image. To generate the necessary straight lines we apply a recursive line simplification scheme on the building block footprints. In a second step the height values coming from the DSM are assigned to the extracted building block outlines. In the original façade separation algorithm this additional information is not necessary but for vertical aerial images it is crucial for the outcome due to the fewer façade details caused by the lower resolution of the façade images. After this is done all façade strips are projected into the vertical aerial images and rectified. In a last step the façade separation is performed on the rectified façade strips.

3.1 Building Block Outlines

For each building block we have to determine its outline. The building objects obtained from the image classification are an approximation of the intersection of a façade with the ground. The goal is to isolate the contour of each building block. Initially, this contour is in the form of pixels in need of a vectorization. This has for a long time been studied and a choice of different methods exists. In our case we employ the recursive line simplification by Douglas-Peucker (1973). The goal is to replace the number of vertices in a piecewise linear curve. The contour pixels get replaced by straight lines, each defining one side of the building block. Figure 4 illustrates the result of this calculation for our test area.