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Grouping Salient Scatterers in InSAR Data for Recognition of Industrial Buildings

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Abstract

InSAR data are used to recognise large industrial building complexes. Such buildings often show salient regular patterns of strong scatterers on their roofs. A previous segmentation which uses the intensity, height and coherence information extracts building cues. Strong scatterers are filtered by a spot detector and localised by a cluster formation. Strong scatterers are grouped in rows by a process that uses the contours of the building cues as context. Such buildings are labelled as industrial buildings and serve as seeds to assemble adjacent buildings into complex structured building aggregates. The structure of the grouping process is depicted by a production net.

1. Introduction

Discriminating buildings in InSAR data is a very active field of research and some authors recently reported significant progress [1][4]. But the reconstruction of small buildings or buildings in dense urban areas from such data is limited by certain geometric properties of the SAR process [9]. Large buildings in rather open areas like industrial sites or airports often show flat roofs or roofs with flat superstructures. One other important feature is that most of such buildings have rectilinear outlines with long planar vertical faces leading to a significant step in height. So these features can be used to discriminate building candidates from many other large objects like roads, meadows or hills.

Particularly industrial sites exhibit roofs with regular rows of strong scatterers. This feature is perceived very dominantly by human observers in the intensity data (Figure 1). The scatterers correspond to ventilation, air-condition or natural lighting facilities necessary for the purpose of the building. This feature provides very strong evidence for large well-organised man-made assemblies making it suitable to infer an industrial building with high confidence. Large buildings close to such an industrial building are assumed to be an industrial building, too. The recognition of such a complex of industrial buildings can therefore use the industrial buildings with regular patterns of scatterers as a seed for a larger aggregate forming an industrial site.

Inherent relations of perceptual grouping (e.g. similarity, proximity, good continuation) can be modelled by production nets. In this paper we use such production nets to automatically utilise these relations in InSAR data.

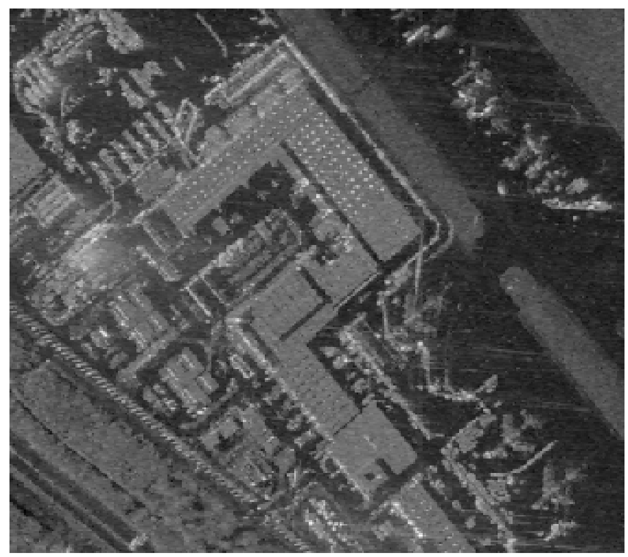
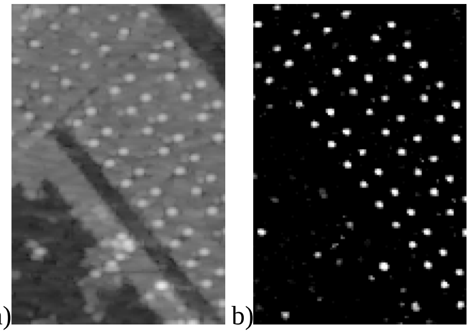


Figure 1. SAR image (intensity) of a site with large buildings (Frankfurt airport)

2. Feature Extraction

2.1. Iconic Spot Detection

For the detection of salient scatterers in the intensity data a spot detector is used. Although this detector has originally been designed for thermal images [5], it performs robustly and fast also on these SAR intensity data. Figure 2a shows an enlarged section of the intensity image and the result of spot filtering (Figure 2b).



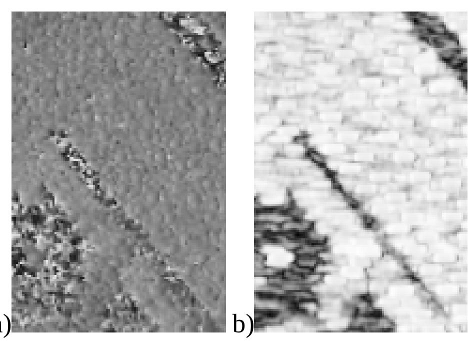
a) b)

Figure 2. a) Section of intensity image, b) Result of spot filtering.

2.2. Extraction of Building Cues by InSAR Segmentation

Buildings usually have vertical facades that are expected to produce a discontinuity in the elevation data. Furthermore the height is quite constant within a building or in one building part.

The InSAR elevation is derived from a phase difference of the coherent SAR measurements. Figure 3 shows that particularly in areas with low signal to noise ratio and low coherence the elevation data are severely disturbed. Averaging reduces the noise level but blurs elevation edges at the facades of buildings. For this reason again the intensity channel and also the coherence channel are used to guide the elevation channel noise filter.



a) b)

Figure 3. a) InSAR-height, b) coherence

We assume that due to homogeneity of the roof material the intensity will be locally constant (except for the scatterers). For this reason, after filtering with a special SAR-speckle filter [2], we segment the intensity image first using a region growing approach. Then the elevation data are averaged within the segments obtained from the intensity channel and weighted by the coherence channel. Segments of significant height above ground are building cues. These are approximated by polygons. Figure 4 shows all such polygons extracted from the example data.

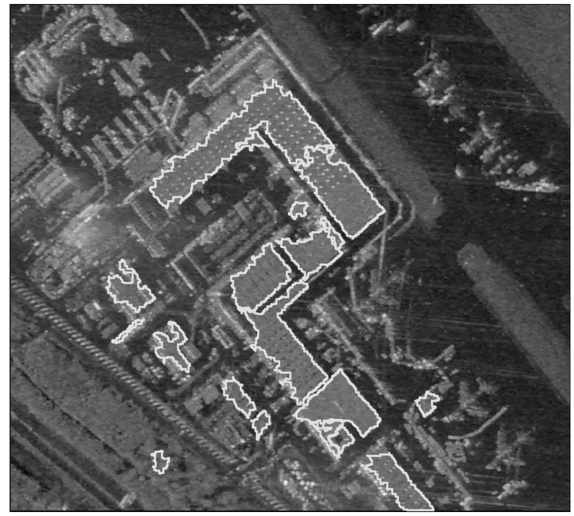


Figure 4. Building cues from the segmentation of INSAR data, the segmentation uses intensity, elevation and coherence channels, only the intensity channel is displayed here as background.

2.3. Exploiting Major Orientations

From the outlines of the building cues an orientation histogram is assembled giving two major orientations rectangular to each other. The margins of the segments are classified into these two orientations and corrected to the mean of each orientation. Figure 6 shows the resulting rectilinear polygons in black. Each such polygon is a building candidate. The amount of necessary correction can be stored with each candidate. If there is only little correction, the evidence for a building will be higher.

3. Symbolic Processing

3.1. Spot Formation by Clustering

Non-zero pixels in the iconic spot-filtered intensity data are entries to the symbolic process. Two thresholds are used. If the lower threshold is exceeded, a pixel will be allowed to participate in a cluster. If the higher threshold is exceeded, a pixel will be allowed to trigger the clustering process. A search area around the triggering pixel determines the subset of pixels assumed to form the cluster. A spot's position can be located with sub-pixel accuracy. Figure 5 shows examples of such spot clusters displayed as white circles of equal radius. White points indicate all pixel instances from the spot-filtered image. The corresponding part of the intensity image is used as background.

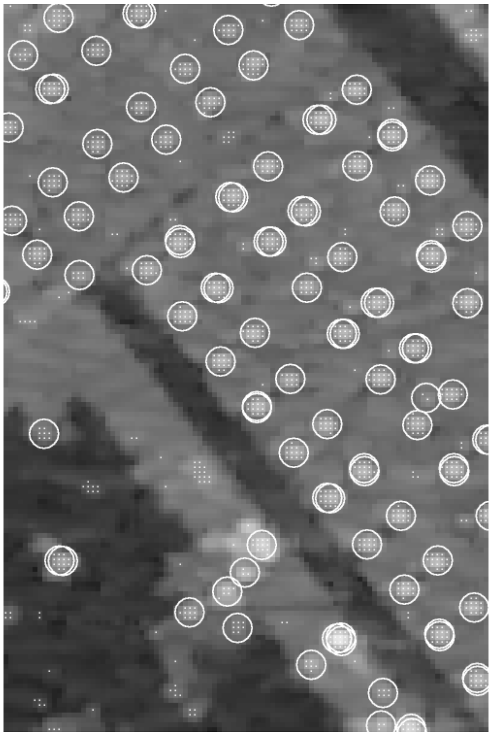


Figure 5. Spots found by the cluster formation production

3.2. Grouping Spot-Rows on the Roof parallel to the Facades

Bright spots in the intensity channel of SAR data on top of the roofs of buildings sometimes are due to antennas or other structures only appearing once. But often they are due to mostly metallic structures concerned with the ventilation, air-conditioning or lighting. These features are placed in equidistantly spaced rows parallel to the outline of the building. Grouping such rows of arbitrary length is performed by successively adding spots to the row. This is initialised by rows with only a single member, where the direction information is due to the major orientations of the building. With growing numbers of members the search areas become narrower and better regularity assessments can be calculated. A building will be accepted as industrial building if a row is assembled on its roof with sufficient regularity.

Performing such a recursive grouping on all spots in the intensity image in any direction and spacing leads to high computational effort. This can be significantly reduced if context is provided that limits possible locations and orientations. Here the buildings provide constraints for location and orientation. Figure 6 displays these rows as white lines. Some of them contain up to 20 member spots which are very precisely and regularly aligned.

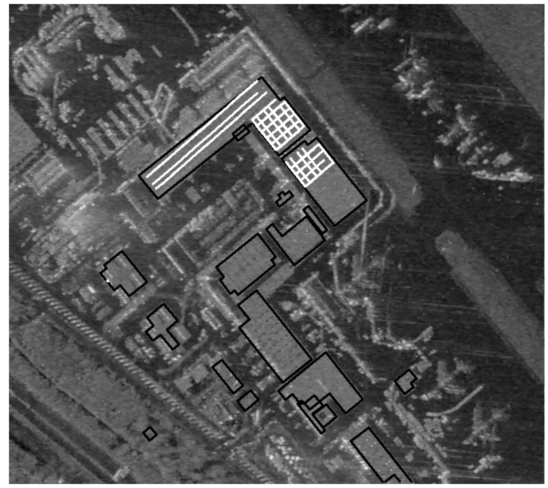


Figure 6. Grouping results

3.3. Grouping Aggregates of Buildings

Buildings tend to be grouped close to other buildings and form aggregates of building complexes in a site. Thus a building candidate with insufficient evidence from its corresponding measurements may become sufficiently evident if there is a neighbour candidate with sufficient evidence on its own. This may propagate through a chain of candidates which are all not sufficiently evident on their own except for one which initiates the evidence for all its indirect neighbours.

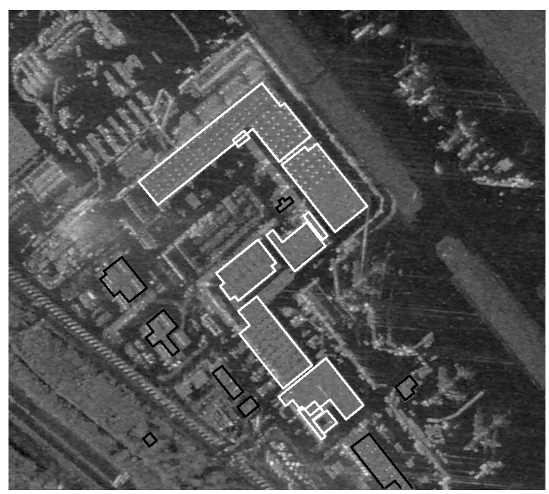


Figure 7. Final result: 10 candidates form an aggregate with high building evidence (white).

The grouping starts from one of the large buildings in the upper part (Figure 7), that gain significant evidence from the fit of the rectilinear polygons and particularly from the rows of scatterers on their roofs. Then the evidence propagates through candidates with only medium or minor evidence. The propagation stops at the gap between the small white drawn polygons and the black one at the bottom of the image, because this gap is considered to be too wide.

Technically the propagation is performed by the recursive production p5 of the production net displayed in Figure 8.

3.4. The Production Net

The automatic extraction of an object I-BUILDING-COMPLEX described in the previous sections is implemented in the production net shell described in [8]. An overview of the net topology is given in Figure 8.

The clustering production p1 assembles sets of objects PIXEL into a single object SPOT. In general such productions perform a search in the power-set of all objects PIXEL in the store. This is not critical in this case, because the nature of the spot-operator, that extracts the objects PIXEL from the iconic data, is to form rather isolated islands. No real hard segmentation problem occurs here.

The initialising production p2 starts the formation objects ROW only inside the objects BUILDING and only for objects SPOT with high significance.

The generic production p3 uses the orientation and location of the corresponding object BUILDING as context. This prevents it from grouping all possible rows of objects SPOT consistent with the model of the concept ROW.

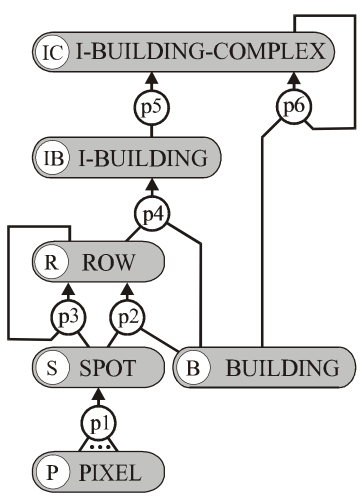


Figure 8. Production net

Production p4 uses objects ROW of sufficient size and regularity as context to infer objects I-BUILDING from objects BUILDING. The generic production p6 just aggregates building evidence using spatial neighbourhood. With production p5 only objects I-BUILDING are used as seed for this aggregation process, while all objects BUILDING are allowed to participate. This is not very critical here, because usually there is only a fairly small number of objects I_BUILDING. Objects I-BUILDING-COMPLEX that have no successor (are not part of a larger complex) are the result of the process. In the example there is only one such resulting object displayed in white in Figure 7.

4. Discussion

INSAR data provide intensity, height and coherence channels. All of these should be used to discriminate large buildings from other objects. Perceptual grouping techniques can be utilised to determine regularly grouped strong and coherent scatterers sometimes present on the roof. For such grouping context information on the dominant direction is helpful. In this kind of data, this information can be taken from the height channel which gives the orientation of the facades that will most likely also be the major orientation of the indoor organisation of the building. The utilisation of this additional data source makes the grouping process feasible.

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