Detection and Reconstruction of Buildings from Multiple View Interferometric SAR Data

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Abstract **Geometric reconstruction of human scale features gets feasible from airborne single pass IFSAR sensors. IFSAR data is corrupted by blur, speckle noise, and other view dependent effects as e.g., layover and shadows. Especially in case of buildings, those phenomenological features may also provide valuable information about the underlying structure. Combining multiple views and multiple data types of the same scene the exploitation of this information gets feasible. In this paper we use information from the interferometric height and coherence data to separate regions containing buildings from other objects in the scene. Shadow information from magnitude images is then used to delimit the exact boundaries of the buildings further. Rectangles are fit to the selected points and compared to ground truth measurements manually derived from optical images.**

INTRODUCTION

The motivation for our work is the rapidly growing availability of interferometric radar data sources at very high geometric resolutions, detection and geometric reconstruction of buildings therefrom gets feasible. Data types are being produced in a single view such as an interferogram representing noisy approximations of 3D shape, a magnitude image representing a noisy analogy to an optical image, and a coherence image describing the surface characteristics of objects. Multiple views add the opportunity to use additional shape-from-X methods to enhance robustness, accuracy and completeness, but require an ability to overcome geometric disparities and radiometric dissimilarities.

Previous demonstrations of such measurements from SAR data were based on manual work, some limited automated methods can be found. In [7] fusion of IFSAR and multispectral optical image data results in boundary boxes of buildings. [6] describes an automated region growing approach to localize buildings starting from the shadows they cast. The reconstruction of building shapes of urban tower blocks from IFSAR data by applying a range segmentation algorithm is presented in [5]. Techniques for removing artifacts that are peculiar to IFSAR data are discussed in [4].

In contrast to these previous demonstrations, which were performed on a single data source we want to employ the best source for each single measurement and combine the results in an intelligent way. In this paper we resume the detection and reconstruction of buildings from multiple view interferometric height data and slant range shadows briefly. The measurements of the building dimensions from these two different approaches are compared and combined to enhance the overall result.

TEST DATA

For the detection and reconstruction of buildings test data from the McKenna MOUT site, Ft.Benning, GA is used. The buildings on this site are clustered in a compact group resembling a northern European village, surrounded by undeveloped land. An optical image of the testsite can be seen from Fig.1. From an airborne Sandia Spotlight IFSAR sensor the testsite was imaged from four cardinal azimuth directions. The original slant range magnitude images have a resolution of 0.3 m. The interferometric processing was done by Sandia, each pass was processed into four channels: magnitude, correlation, height and bin number, and converted to UTM coordinates with a resolution of 0.4 m. An ARC/INFO data set of the Fort Benning MOUT site is used as the ground truth to evaluate the building extraction results. This data set contains the UTM coordinates of building corners, building areas, perimeters as well as maximum building heights.

METHODS

Single view IFSAR data is disturbed by speckle noise and in case of the steep slopes of buildings and trees especially by view dependent layover and shadow effects. Combining multiple views and multiple data sources, which are easily available from IFSAR sensors, is necessary to overcome these problems.

For the combination of the interferometric height measurements from the four independent views available from the test data set we used a simple maximum decision strategy as described in [3]. For each pixel in the scene,

Figure 1: Optical image of the MOUT testsite

the maximum height value over all four independent measurements was chosen. Although due to the front porch effect this enlarges the buildings outlines, this strategy eases the detection of even small buildings.

Applying a large area minimum filter to this multiple view combined height map, a decision between bare earth and objects rising up from this bare earth could be drawn. Subtracting the resulting bare earth from the height map and applying a single threshold delivered a binary mask, where all objects rising up from the bare earth by more than the threshold were selected. From this binary mask startpoints for regions of interest, where buildings are supposed to be, were selected using morphological operations, minimum bounding rectangles around these start regions were calculated. See [1] for more details.

The differentiation between buildings and other objects rising up from the bare earth, e.g., trees, bushes, can not be drawn from the height measurements alone. Therefore during the height map combination step a corresponding combined coherency map was computed. For each position in the map, the coherency value corresponding to the selected maximum height value was chosen. Simple texture measures in the selected region from the height and coherency information were evaluated, therefrom a decision between natural and man-made objects rising up from the bare earth was made.

From the position and length of shadows in a single slant range image, one can calculate the position and height of all walls facing away from the sensor. The principle is described in [2]. The accurate segmentation of the shadow boundaries is the crucial task for an exact reconstruction. This was accomplished using a rotating mask with a simple transition between two regions for edge detection. For each of the 16 rotation steps, mean and variance of the intensity within the two regions were calculated separately and the differences were exploited. From the segmented shadow areas position and height of the back wall of the object which caused the shadow could be calculated. The resulting measurements from

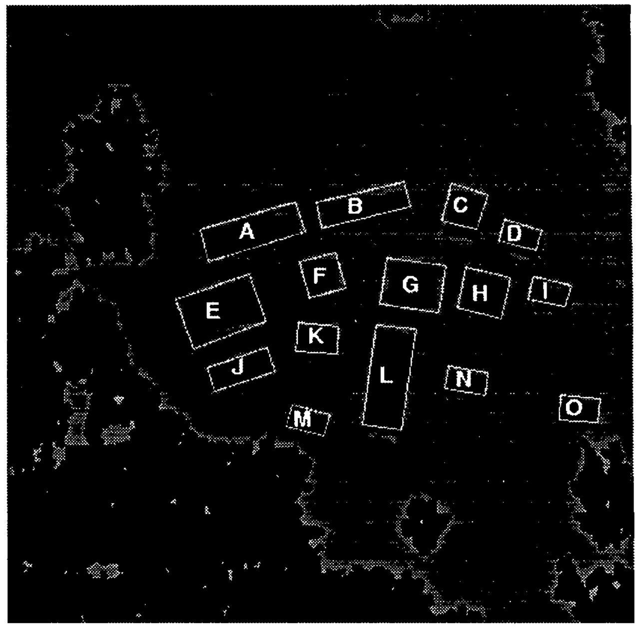

Figure 2: Segmentation result with overlaid building's footprints corresponding to the ground truth data. The area covers approximately 220 x 220 m^2.

four independent views were combined. This results in point clouds which resemble the buildings outlines. These buildings outlines are quite fuzzy defined, various gaps and outliers exist due to the noise still present in the segmented shadow areas. Using the information about where buildings are supposed to be obtained from interferometric data, the point clouds were grouped into 15 distinct buildings and rectangles were fit to these point clouds. For each point in the point cloud the distance to the nearest point on the rectangle was calculated for all reasonable rectangles and the rectangle with the minimum overall quadratic distance error was chosen.

RESULTS AND DISCUSSION

The overall result of a segmentation into three classes can be seen from Fig.2. The classification between bare earth, buildings and other objects rising up from the bare earth was drawn from interferometric height and coherency data, the exact buildings outlines result from the shadow reconstruction. The buildings outlines from ground truth data are overlaid for comparison. In Table 1 the resulting buildings areas from interferometric height and slant range shadow data are compared to ground truth measurements. The areas of large buildings tend to be overestimated from interferometric height data due to the front porch effect [4], whereas small buildings tend to be underestimated. The buildings areas are better defined from slant range shadows, significant deviations exist just

Bldg.	Opt.	IFSAR		Shadow	
	area	area	err.	area	err.
A	349.9	541.1	+191.1	309.2	-40.7
B	259.1	370.0	+110.9	221.3	-37.8
C	149.4	244.8	+95.4	161.9	+12.4
D	88.4	59.5	-28.9	109.0	+20.6
E	439.3	558.6	+119.3	333.0	-106.3
F	147.4	277.5	+130.1	124.9	-22.5
G	297.1	535.8	+238.7	238.5	-58.6
H	201.9	230.0	+28.1	185.0	-16.9
I	90.4	56.3	-34.1	86.2	-4.2
J	166.1	206.1	+40.0	172.6	+6.5
K	117.6	160.5	+42.9	126.8	+9.3
L	426.9	589.5	+162.6	433.4	+6.4
M	92.9	55.8	-37.1	98.3	+5.3
N	94.1	75.3	-18.8	97.3	+3.2
O	102.5	123.4	+20.9	109.0	+6.5
RMS			±109.6		±36.0

Table 1: Buildings area measurements in square meters from interferometric height data and slant range shadow information compared to ground truth data.

Bldg.	Opt.	IFSAR		Shadow	
	hgt.	hgt.	err.	hgt.	err.
A	8.8	7.9	-0.9	8.6	-0.2
B	8.9	10.0	+1.1	8.8	-0.1
C	7.4	7.0	-0.4	8.9	+1.5
D	6.2	6.9	+0.7	6.3	+0.1
E	7.0	6.0	-1.0	9.3	+2.3
F	7.4	7.6	+0.2	8.1	+0.7
G	11.0	9.2	-1.8	13.8	+2.8
H	3.7	4.3	+0.6	6.2	+2.5
I	6.2	6.4	+0.2	7.0	+0.8
J	6.1	4.1	-2.0	6.5	+0.4
K	12.1	7.5	-4.6	7.3	-4.8
L	9.4	10.2	+0.8	10.6	+1.2
M	6.1	5.2	-0.9	6.2	+0.1
N	6.1	5.1	-1.0	6.5	+0.4
O	6.1	4.8	-1.3	7.0	+0.9
RMS			±1.6		±1.8

Table 2: Buildings height measurements in meters from interferometric height data and slant range shadow information compared to ground truth data.

for two buildings. The outline of building E does not corresponds exactly to a rectangle, as can be seen from the optical image in Fig.1, therefore the rectangle fitting procedure gives suboptimal results. The area of building G is underestimated because adjacent buildings interfere with the shadows casted from building G. Table 2 gives the resulting maximum building heights for the two methods presented. From ground truth data only the maximum buildings heights were available. The deviations from interferometric height and slant range shadow length measurements are comparable. However, slant range shadow measurements deliver only height measurements along the reconstructed buildings walls. Due to the maximum combination used for the interferometric data the interferometric height measurements within the buildings conform better to the actual data.

OUTLOOK

In this paper we presented our methods for automated measurements of building dimensions from interferometric and slant range SAR data. From shadows casted in slant range magnitude images, the buildings footprints can be measured more accurate than from interferometric height data. On the other hand, the buildings height inside the buildings footprints is better defined from interferometric height data. The combination of these two data sources enhances the overall building reconstruction result. Problems exist in case of occlusions, when adjacent buildings interfere with the shadow region of the actual building. To identify occluded shadows in the slant range image due to knowledge about the outlines and height of adjacent buildings, and correct the height measurements accordingly, remains a topic for further work.

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REFERENCES

[1] R. Bolter and F. Leberl. Detection and Reconstruction of Human Scale Features from High Resolution Interferometric SAR data. In *Proceedings of ICPR 2000, in press.*

[2] R. Bolter and F. Leberl. Shape-from-shadow building reconstruction from multiple view sar images. In *Proceedings of AAPR 2000, Villach.*

[3] R. Bolter and F. Leberl. Phenomenology-Based and Interferometry-Guided Building Reconstruction from Multiple SAR Images. In *Proceedings of EUSAR*, 2000.

[4] G. Burkhart, Z. Bergen, and R. Carande. Elevation Correction and Building Extraction from Interferometric SAR Imagery. In *Proceedings of IGARSS'96*, pages 659–661, 1996.

[5] P. Gamba, B. Houshmand, and M. Saccani. Detection and Extraction of Buildings from Interferometric SAR Data. *IEEE T-GRS*, 38(1):611–618, January 2000.

[6] K. Hoepfner, A. Hanson, and E. Riseman. Recovery of Building Structure from SAR and IFSAR Images. In *ARPA Image Understanding Workshop*, pages 559–563, 1998.

[7] R. Xiao, C. Lesher, and B. Wilson. Building Detection and Localization Using a Fusion of Interferometric Synthetic Aperture Radar and Multispectral image. In *ARPA Image Understanding Workshop*, pages 583–588, 1998.