Radar cross-views for road detection in dense urban areas

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ABSTRACT

This article studies the improvement of road detection using 2 SAR images of the same area taken with 2 different orientations. In the first part, some remarks about the visual appearance of the network in both images are made. In the second part, two experiments for merging the two images are presented, and the obtained results are compared.

1 INTRODUCTION

Automatic road detection on SAR images is a difficult problem due to the speckle noise, and there are really few robust methods to deal with these images [1] [2] [3]. However, roads are very interesting features, specially on urban areas where they provide a structural information about the city organization.

Nowadays, there are more and more SAR data available, which represent a great potential to improve image processing algorithms on this kind of images, quite hard to handle due to the speckle noise. Instead of the case of multi-temporal data, we are interested here in the use of images taken with different orientations (for instance a north-south oriented image and an east-west one) to improve the road detection, both for visual interpretation and for automatic extraction methods. This study has been made using 2 high resolution X-SAR images (HRMGD products with 6.5 m pixel-spacing) of New-York which have been manually registered.

The first part of this article is a discussion about the visibility of the roads in urban areas on SAR images. As usual, the roads which are parallel to the incident direction are much more visible than the other ones (specially the ones which are perpendicular to the incident direction). Examples of such areas where the roads are really clearly seen on one of the image and are not or hardly visible on the other one are given and analyzed using the urban density of the different parts of the image.

The second part of the article is the study of the improvement of an automatic extraction method when using 2 images with perpendicular looking directions. This method has been previously proposed [1], and is shortly described. Then some merging methods are studied. A first experiment is reported, which is based on the merging of the road extraction results on the 2 separate radar images. The final result is greatly improved compared to the 2 detections using only one image and many roads which were not detected are extracted. A second approach is described, doing the fusion of the 2 data inside the extraction process. Both approaches are eventually compared and discussed.

2 APPEARANCE OF THE ROAD NETWORK

We had at our disposal 2 HRMGD-XSAR products of Brooklyn in New-York with a pixel-spacing of 6.25m, 1.3 looks and the following directions and incidence angles:

- image 1: descending mode, incidence angle 62.7^o, taken 10/10/94;
- image 2: ascending mode, incidence angle 31.6^o, taken 12/04/94;

American cities are most of the time very urban and structured towns with straight roads and high buildings, having a privileged orientation in each quarter. This particularity implies that the looking direction of the radar sensor has a great influence on the road and building aspect in the acquired image [4].

This phenomenon is shown on figure 1 where the same area is seen with two almost perpendicular looking directions.

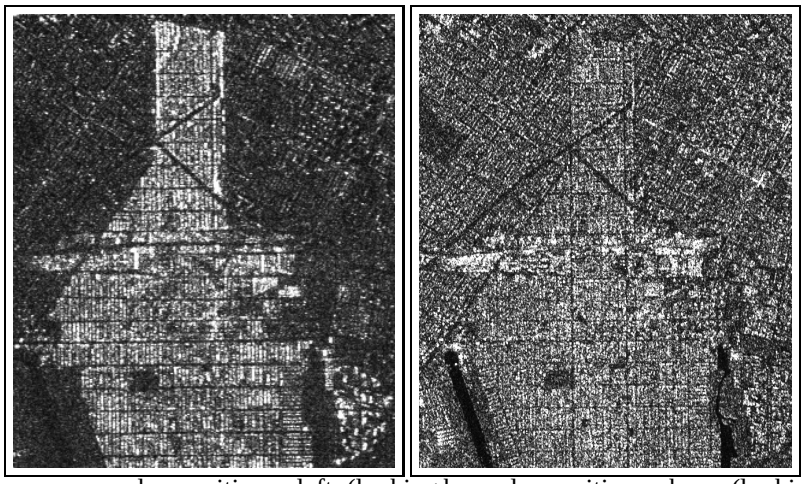
- In the first image (fig.1a.), the sensor is on the left, and therefore horizontal roads (in the same direction than the sensor look) are easily visible. The buildings, which are perpendicular to the looking direction appear very bright due to specular reflections in "favorable" orientation, and the selected area has a very high radiometry compared to the whole SAR image.

- In the second image (fig.1b.), the sensor is "above" the image, and therefore vertical roads are the most visible, whereas horizontal ones are more difficult to detect. The buildings have not the same appearance than in fig.1a., and have a globally lower radiometry.

The influence of the looking direction is particularly important in very dense urban areas as it is the case for the quarter of Brooklyn seen in fig.1.

Not only the orientation has a great influence on the human-made structure aspect, but also the incidence angle value [8]; this is the case for instance for streets where high buildings stand along both sides of the road; in this situation, depending on the incidence angle, on the width of the streets and the height of the buildings, the roads may or not be visible on the radar image.

We are in our study in a very favorable situation since we have at our disposal 2 images with almost perpendicular looking directions (the real rotation between the 2 images which can be deduced from the sensor parameters is 93^o). Anyway, the use of 2 or more SAR images with different orientations should improve a lot automatic extraction algorithms, since roads are more or less visible depending on their orientations compared to the sensor one.



a. radar position: left (looking right)

b. radar position: above (looking top to bottom)

Figure 1: *Two SAR data with different looking directions*

3 MERGING OF 2 SAR IMAGES FOR ROAD EXTRACTION

This section aims at describing some experiments we did to improve the automatic extraction of the road network using 2 views with different orientations of the same area.

We first recall the method we propose in some previous work to extract the network, before trying to merge the 2 radar data. The registering of the images has been made manually[1].

3.1 A road extraction method in urban areas

This part is based on our previous work on the road and hydrological network detection [5]. The main steps of the method are summed up here:

- in a local step, a line detector adapted to the speckle statistics of SAR images is applied (thresholding and linking provide segments that are candidates to belong to the network);
- in a global step, a closure method based on a Markovian approach defined on a graph of segments is performed; this step is a labeling of the segment graph with labels "road" and "not-road" minimizing an energy function; this function, derived from probabilities and from a Markovian hypothesis made on the label field, takes both original data and a priori knowledge about the road shape (probability of crossings and bending limitations) into account.

The reader may refer to [5] [6] to have a detailed description of the method. The adaptation of the method to deal with dense urban areas will be the subject of a further publication and is based on 2 main improvements:

- clique potential modification to better take into account the cross-roads;
- multi-resolution approach to extract networks with different widths;

[1] Automatic registering is the scope of some future work.

This automatic method has of course some limitations: some of the roads miss and some connections of parts of roads are wrong (see an example fig.3 for the SAR image of fig.2). Besides, there are many confusions with the hydrological networks (bottom of the image). As we will see in the next section, the use of 2 images with different orientations may improve the obtained results (except for the last point -hydrological network- which needs high level information to be solved).

Figure 2: *Original X-SAR image ©DLR-DFD*

3.2 Merging of the two extracted networks

The first experiment we did is very simple and consist in merging the 2 networks which have been extracted independently on each image. The result is shown on figure 4.

Comparing the result of figure 3 with the one of figure 4, we observe a clear improvement of the detected networks, as expected:

- some of the vertical streets which were not detected in a single view are now extracted (see for instance right bottom part of the image);
- some of the discontinuous roads are now complete which give a better structuration of the urban landscape (see for instance the left top of the image);
- some of the missed roads have been detected, so there are less undetected network parts (see for instance the darker area in-between the two very bright quarters).

As seen with this simple experiment, the road network extraction can be greatly improved using 2 views with different orientations. Nevertheless, this approach is limited, since it does not benefit from the 2 radar images to improve the road detection, specially for reducing the false alarm or false connection rate, which is even increased with this method. Besides, when a road is detected both, the 2

Figure 3: *Automatic extraction of the road network (using one view)*

Figure 4: *Automatic extraction of the road network using two views: the networks extracted on each view are superimposed.*

roads are superimposed without trying to find the "best" road which could replace the 2 other ones. The aim of the following section is to experiment a merging process during the road detection method to exploit simultaneously the 2 images.

3.3 Merging of the 2 SAR data in the extraction process

We propose to include the knowledge of 2 or many SAR images in the initially proposed method by the following method:

- Building of the initial graph of segments: the segments are detected on each image separately in the low-level step and then a unique graph of segments is built using all of them (which means that we include the connections between all the segments, apart from their origins);

- Connection step in the Markovian framework: this step uses an energy minimization procedure which gives the "best" graph labeling. The energy definition involves 2 terms: one which is related to the SAR data and evaluates the confidence we have for a segment knowing the radar image; a second one which takes into account some information about the shape of the road networks. The second term is not modified since it represents our a priori knowledge. The first one is corrected to be able to use simultaneously both SAR images. Indeed, instead of computing a measure on each segment, two measures computed on each image are merged. Many merging operators could be used. Let us note by m_1 the segment measure in image 1, and m_2 the one in image 2. Then, the new measure m_2 could be defined as (for instance): $\min(m_1, m_2)$, $\max(m_1, m_2)$, $\frac{m_1 m_2}{0.5 - m_1 - m_2 + 2 m_1 m_2}$, etc. Since in our case a road may be visible in one view and not at all in the other one, we decided to use a disjunctive operator [7] and we did the experiment with a maximum, but some refinements could improved the results (particularly reinforcing the measure when both segment responses are high).

Let us make a remark here. It is important to avoid really applying the registering of the radar image to compute the measure of the segments. Indeed, the registering process does some interpolations which modify the radiometric properties and statistics of the SAR image. In this case, the performances of speckle adapted detectors may be spoiled. Therefore, a better solution is to compute the coordinates of the segments in both images and measure the detector responses in the original images.

A result of this approach is shown figure 5. Once again we note a real improvement compared to the extraction obtained using only one view (for the same reasons than in the previous sections).

3.4 Comparison of the 2 approaches

If we do a finer comparison of the results obtained by the 2 methods, the following conclusions can be made:

Figure 5: *Automatic extraction of the road network using two views: the network is directly extracted using the 2 SAR images in the detection process.*

- the global aspect of the results are more coherent in the second approach since the knowledge on the shape are introduced in a better manner; the false alarm rate is reduced a little but the number of missed roads is slightly higher than with the first approach;

- the second approach is slightly faster than the first one (in the first case the whole multi-resolution process must be applied twice, whereas in the second approach this is done only one time); nevertheless, the time decrease is not very important since the graph size is increased a lot and therefore the simulated annealing is significantly longer.

Let us say that the comparison of both methods is not really easy, since, as usual, false alarm and missed detection rates do not decrease simultaneously. Besides, since a "maximum" operator is used to merge the detector responses, the input parameters of the algorithm must be modified. Nevertheless, the detected network is not clearly better with the second method than with the first one. One explanation could be the problem of the displacement of the network between the 2 views; indeed, and even for flat areas, the accurate localization of the road is hard to define, and using 2 different incidence angles implies a different delimitation of the dark line constituting the road (this phenomenon is visible in the top left of the image, where 2 lines are detected, although the registering has been manually made). Therefore, the connection step could be wrongly influenced by many possible connections, disturbing the search of the "straight" lines. This problem is difficult to handle, since the displacement depends on the building height and could not be computed using the sensor parameters for the whole image.

4 CONCLUSION

We have shown in the article how the manual and automatic extraction of the road network can be improved when two images with different orientations are available. In this study we were in a very favorable case since the 2 views were almost perpendicular, but this can be a recommendation for aerial acquisition, and the improvement should also be significant in other situations although it is difficult to quantify. We have compared in this article two approaches, both giving improved results and having specific characteristics.

Many problems remain to solve, and among them:

- the automatic registering of the SAR images (but some preliminary experiments showed that the network extraction is a good initial step for that purpose);

- the problem of the displacement of the network between the 2 views.

A third approach, which has not been experimented here (but could be a solution to the problem of road displacement), would be an improved merging of the 2 networks. Some rules including high level knowledge on the detected roads could be introduced to limit the "double" connections and discard some false alarms (small lines detected near a real road).

Acknowledgments We thank the DLR-DFD center for providing the X-SAR images and specially Mihai Datcu for many interesting discussions on radar image processing .

5 REFERENCES

[1] Wood, "Line finding algorithms for SAR", Royal Signals and Radar Establishment (Memorandum 3 841), 85.

[2] Samadani et al.,"Finding Curvilinear Features in Speckled Images",IEEE Transactions on Geoscience and Remote Sensing, vol.28, num.4, pp.669-673, 90.

[3] Hellwich et al., "Detection of Lines in Synthetic Aperture Radar (SAR) Scenes",ISPRS, Int. Arch. of Photogrammetry and Rem. Sens., (Vienna), vol.31, pp.312-320, 96.

[4] Hendry et al., "The visibility of linear features in SAR images",IGARSS'88 (Edinburgh, Scotland),pp.1517-1520, 88.

[5] Tupin et al., "Detection of linear features in SAR images: application to road network extraction", IEEE Trans. Geosci. and Rem. Sens., vol. 36, no. 2, mars 98.

[6] Tupin et al., "A graph-based representation to detect linear features", Journal Computing, Archives for Informatics and Numerical Computation, Suppl.12, 98.

[7] Bloch, "Information Combination Operators for Data Fusion: A comparative Review with Classification", IEEE Trans. on Systems, Man and Cyber., vol.26, num.1, pp.52-67,96.

[8] Gouinaud et al., "Potential and use of radar images for characterization and detection of urban areas", IGARSS'96 (Nebraska), pp.474-476, vol.1, 96.