

Assessment of Road Extraction Performance Using Photographic and Quasi-Photographic SAR Imagery

D. G. Corr, A. F. Rodrigues*, P. G. Ducksbury*, W. Harvey**, D. McKeown**, and A. Zmuda****

**QinetiQ Ltd*

Cody Technology Park, A8/1004 Ively Rd., Farnborough, GU14 0LX, UK
Tel: +44 (0)1252 392781, Fax: +44 (0)1252 396331, E-mail: dcorr@QinetiQ.com

*** School of Computer Science, Carnegie Mellon University, Pittsburgh, USA*

****ESA-ESRIN, Italy*

ABSTRACT

Speckle reduction techniques are applied to SAR imagery to produce images that are almost photographic in appearance ("quasi-photographic imagery"). A road tracking system designed for use with photographic imagery has been used to process this data. The road networks extracted from the quasi-photographic imagery are compared with those produced from optical imagery. It was found that the performance was affected by the SAR resolution. Additionally, urban road networks were better defined when they were parallel to the radar line of sight than when perpendicular to it.

1 INTRODUCTION

Synthetic aperture radar (SAR) provides a reliable means for the collection of imagery for mapping purposes, as the quality of the imagery is virtually unaffected by cloud cover. The objective of the research described in this paper is to extract road networks automatically from SAR imagery, for the production of maps.

Techniques for the automatic extraction of road networks from high-resolution optical imagery have been the subject of research and development for a number of years. There would be an immediate benefit if these techniques could be applied to SAR imagery. This might be achieved if SAR imagery could be made more like optical imagery in appearance. The principal difficulty to overcome is the speckle noise that is inherent to the synthetic aperture imaging process.

This paper describes processes by which SAR images were transformed into quasi-photographic image (QPI) products. This imagery was then processed to produce road networks using "RoadMap" [1], a semi-automatic procedure developed by the Carnegie Mellon University. The road networks extracted from QPI were compared to those extracted from optical imagery.

2 PRODUCTION OF QUASI-PHOTOGRAPHIC IMAGERY

2.1 SPECKLE REDUCTION TECHNIQUES

There are essentially two approaches to the reduction of speckle in SAR imagery. The first is to reduce image

variance by averaging. This can be performed either in spatial domain e.g. [2] or in time domain e.g. [3]. The second approach is to propose a statistical model for the speckle and to determine the mean scattering levels that best describe the image on the basis of the model e.g. [4,5]. These types of techniques have been designed specifically for use with SAR imagery. There are many other methods e.g. [6,7,8] that address the general problem of reducing noise in imagery.

The chief drawback of techniques that reduce speckle by spatial averaging is that they lower the resolution of the imagery. As a consequence of this there will be a loss in clarity of edge features within the imagery unless constraints are imposed. The method described in [2] preserves edge features by detecting edges within the imagery and selecting data for averaging that does not cross an edge. However *narrow* linear features are still degraded when their width is similar to the averaging window used by the filter.

If multi-temporal imagery is available speckle reduction without loss of resolution is possible by performing incoherent averaging. However a large number of images (e.g. ~25) are required to achieve the same degree of smoothing as is typically achieved by spatial filtering.

The method of simulated annealing [5] effectively eliminates speckle. There are various constraints (e.g. segment size) that can be made within this process that refine the final product. In this research, involving the tracking of linear features, the preservation of linear structures is an important constraint, but an implementation of simulated annealing with this constraint was unfortunately not available.

General image processing techniques for noise reduction, such as [6,7,8], were found to be relatively unsuccessful when applied directly to SAR imagery. However they were found to be beneficial when applied to SAR imagery that had undergone some initial speckle reduction processing. The necessary feature of these particular methods is that they reduce noise while being structure preservative. Two techniques with these properties were considered: an adaptive smoothing filter and an adaptive morphological process.

The structure-preserving filter used was SUSAN (Smallest Univalue Segment Assimilating Nucleus) [7]. This filter only applies smoothing to pixels that belong to a homogeneous region. The adaptive morphological process [8] consists of a series of dilate and erode operations that are structure preservative.

The following section describes how the techniques discussed were used to produce QPI.

2.2 PRODUCTION OF QUASI-PHOTOGRAPHIC IMAGERY

The QPI imagery has to be produced as single channel 8 bit data to be suitable for input to the road tracking system described in Section 3.

The examples of QPI described in this paper were generated from fully polarimetric L band SAR imagery produced from data collected by the Deutsche Luft und Raumfahrt (DLR) airborne system E-SAR [9]. The resolution of this data is approximately 2 m in ground range and 1 m in azimuth.

Following a period of experimentation two procedures for the production of quasi-photographic imagery (QPI) were adopted. One procedure applied to single date imagery the other to multi-date imagery. The steps are summarised in Table 1. The table shows that except for the first step, the processing is similar.

Single acquisition	Multi-temporal data
Multi-polarimetric speckle filter	Form incoherent channel sums
Form Span image	
Convert to decibels	
Rescale into 8 bits	
Apply SUSAN and adaptive morphology	

Table 1: Processing steps for the production of QPI

For the single date imagery the first step involved the application of the edge preserving Lee filter (7 by 7 window) [2]. The data was also averaged to produce square pixels.

The multi-date imagery consisted of 3 images acquired over a period of 5 days. As the multi-date imagery was collected using precise repeat tracks it could be easily co-registered. Following this an incoherent average was formed on the data in each channel. The data was also averaged to produce square pixel dimensions.

In the second step the multi-polarimetric data channels allow speckle to be reduced further by the production of a "Span" image:

$$Span \equiv |HH|^2 + |VV|^2 + 2|HV|^2 \quad (1)$$

At this stage the single date imagery has approximately 120 looks and a resolution of about 7 m. The multi-date imagery has up to approximately 18 looks and a resolution of about 2 m. The degree of speckle reduction obtained from the multi-date imagery used was reduced by the high degree of correlation in imagery obtained over a relatively short time period.

The span data was then converted to decibel units and rescaled into the range 0 – 255 prior to further speckle reduction using SUSAN and adaptive morphological processing.

Figure 1 shows a portion of the airfield at DLR with neighbouring buildings and roads. Figure 1a shows a HH image without any speckle reduction processing, Figures 1b and 1c show QPI products produced from a single date image and a three image sequence respectively.

3 ROAD TRACKING

One approach for the extraction of road networks from imagery would be first to extract linear features, and then to connect those belonging to roads. In practice there are so many linear features within an image that the automatic association of those that only originate from roads is extremely difficult to do reliably. Figure 2 illustrates this showing a single date QPI and extracted linear features.

An alternative approach is for an operator to identify a feature segment that belongs to a road, and to present this to a tracking procedure that then automatically identifies the full extent of the road. RoadMap is such a software tool, developed by the MAPSLab of Carnegie Mellon University, for the production of road networks from high-resolution optical imagery. Typically monochrome imagery with resolution <1 m would be input. The tool provides a substantial time saving over a fully manual road network extraction.

4 PERFORMANCE

The RoadMap system was used to extract roads from optical imagery (0.8 m resolution) and QPIs produced from single and multi-date imagery. The town in the imagery is a suburban area with many trees and irregularly placed individual houses. Figure 3 shows examples of the extracted road features. Although the resolution of the multi-date QPI is higher than that for the single date QPI about the same fraction of roads (35%) relative to the optical imagery were detected.

Analysis of the detected roads shows that the measured widths of the road features were higher in the single date QPI; this is a direct consequence of the lower resolution of these products (Figure 4).

Roads that were perpendicular to the radar line of sight were more easily seen in the QPI products. This is partly a consequence of resolution, as a higher proportion of roads parallel to the line of sight were detected in multiple date QPI. However it is thought that irregular overlay and shadow effects break up the features of roads perpendicular to the line of sight.

5 CONCLUSIONS

By the use of speckle reduction techniques quasi-photographic images could be produced from SAR imagery. This allowed the use of tools for the analysis of optical imagery to be applied to SAR data, in particular the RoadMap system for the extraction of road networks.

The performance reported was limited primarily by the resolution of the source data. This resulted in an over estimation of road widths in the single date QPI. On balance therefore, for the data available, the multi-date procedure gave the most useful information.

In the town the definition of roads perpendicular to the radar line of sight was less than that of the roads parallel to the line of sight. A similar finding was reported in [10].

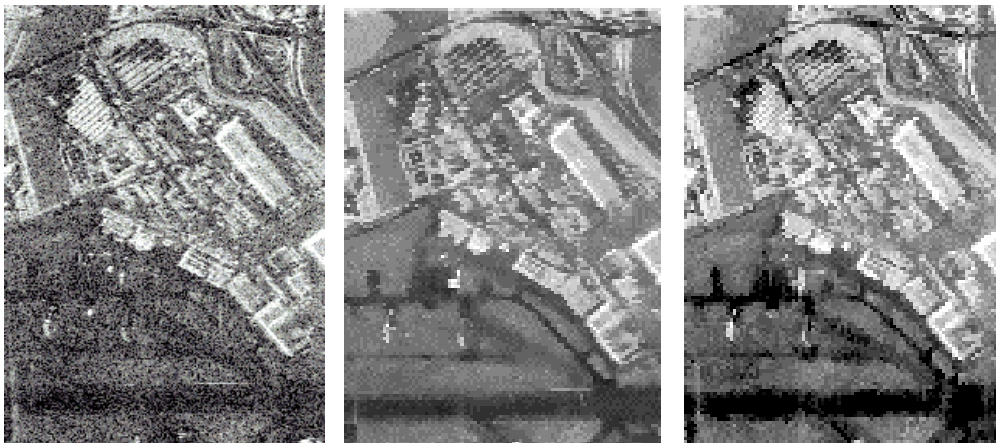
6 ACKNOWLEDGEMENT

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a) HH unprocessed image b) Single data QPI c) Multi date QPI

Figure 1: QPI products compared to a single HH channel unprocessed image.

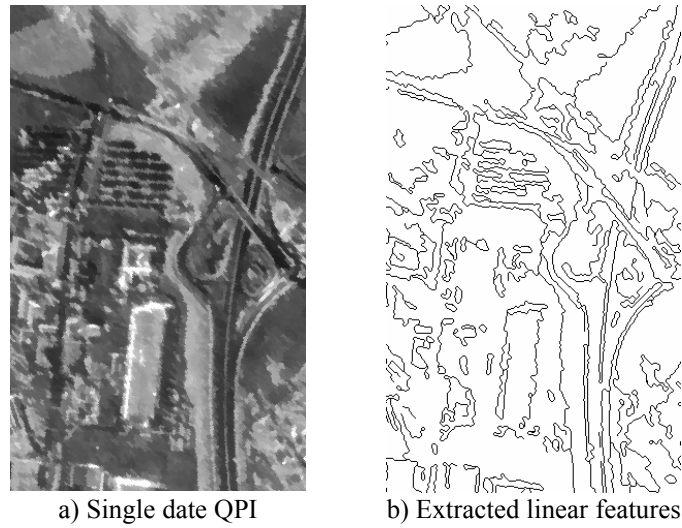


Figure 2: Example of linear features in a QPI

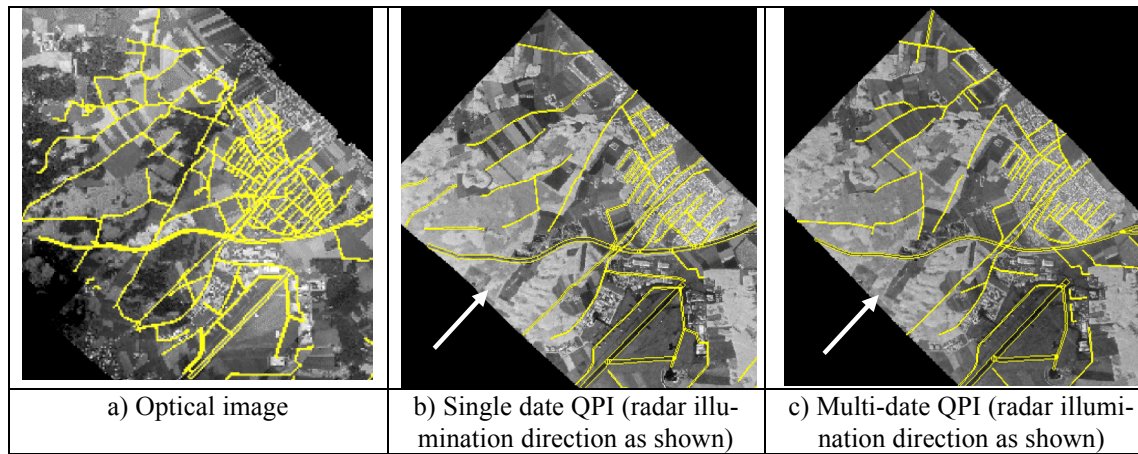


Figure 3: Road networks extracted from optical and QPI imagery

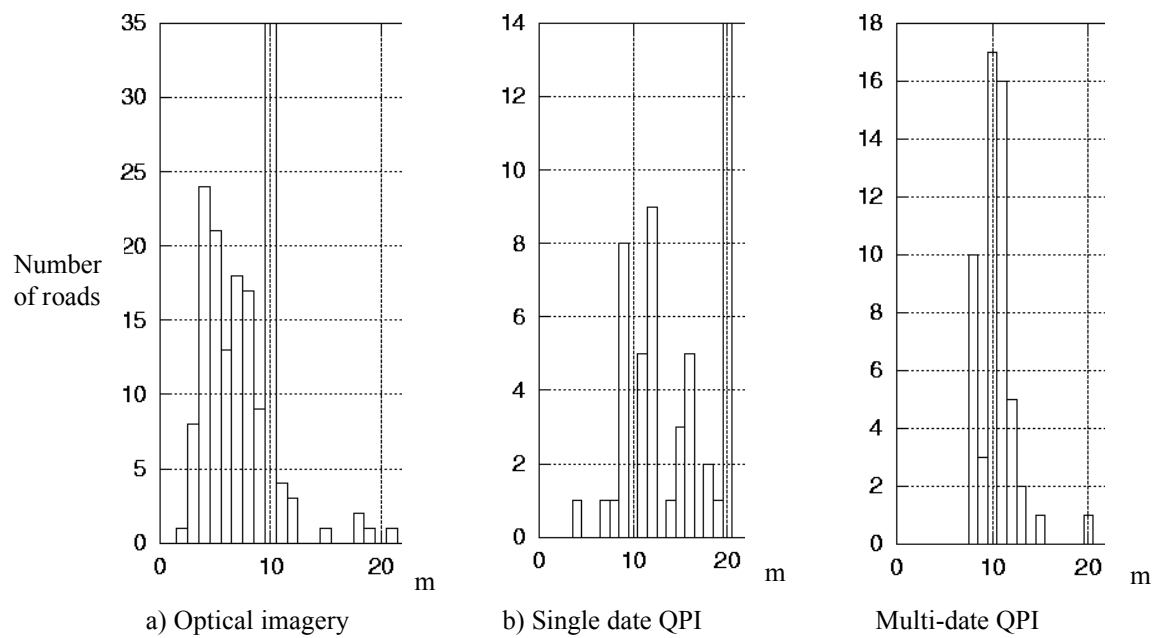


Figure 4: Numbers of roads with specific widths