Improved Airborne SAR Data Processing by Blockwise Focusing, Mosaicking and Geocoding

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Abstract

Standard focusing of SAR data assumes a straight recording track of the sensor platform. Small non-linearities of airborne platform are corrected for during a motion compensation step while keeping the assumption of a stripmap geometry. In the case of high resolution and high frequency SAR systems, the navigation data may not be accurate enough to perform such a motion compensation; SAR systems mounted on small aircrafts or drones flying at low altitude do not follow a straight track but one dependent on topography and atmospheric conditions. We present a blockwise focusing, mosaicking and geocoding method which allows processing such data. For the experiments, MEMPHIS and E-SAR data were used.

1 Introduction

Conventional focusing methods of airborne raw synthetic aperture radar (SAR) data assume a perfectly straight flight path (stripmap SAR). Small deviations are corrected in a motion compensation step. However, high resolution systems mounted on small aircraft or even drones at low altitude require very accurate motion compensation while often flying not on a straight track but one dependent on topography and influences of weather and wind. In case of highly non-linear flights, or in case of navigation data not precise enough to realize the motion compensation step, a different approach needs to be developed to focus the SAR data.

In this paper, we present a processing algorithm working through a geocoding and mosaicking of individually focused patches. We show the improvements obtained with this method on MEMPHIS W-band data and the results of the focusing of E-SAR L-band data taken along a curved flight track.

2 Processing method

2.1 Multiple patches approach

Frequency domain processing algorithms such as the range-Doppler, Ω-k, or chirp scaling [1] approaches are featuring a high focusing accuracy and at the same time a high efficiency and performance. However, they all rely on regular data alignment. While for relatively small non-linear deviations, motion compensation before and during focusing restores focusing accuracy [2], large motion errors are more difficult to handle.

These limitations are overcome - or avoided - by approaches where patches of individually focused data are stepped together. To ensure a correct stepping of these single look complex (SLC) data patches from a strongly non-linear recording path, additional location corrections for the individual patches are required, either through matching or, as presented here, by geocoding.

The geocoding has been preferred to a matching, as eventual errors in matching amplify themselves along patches and deliver at the end an indescribable geometry.

2.2 Algorithm description

The algorithm described here is based on airborne SAR raw data. A first patch of the raw data is cut, i.e. a determined length in azimuth over the complete range is selected and focused with extended chirp scaling including motion compensation and linearization of the small patch as described in [2] or with Ω-k algorithm. The central part in azimuth of the focused patch - containing information of the full synthetic aperture - is subsequentially geocoded onto the underlying terrain [3]. A next patch of the raw data is cut, focused, and geocoded into the final geocoded and mosaicked image until all subsequent patches of raw data have been processed. The algorithm is illustrated in Fig. 1.

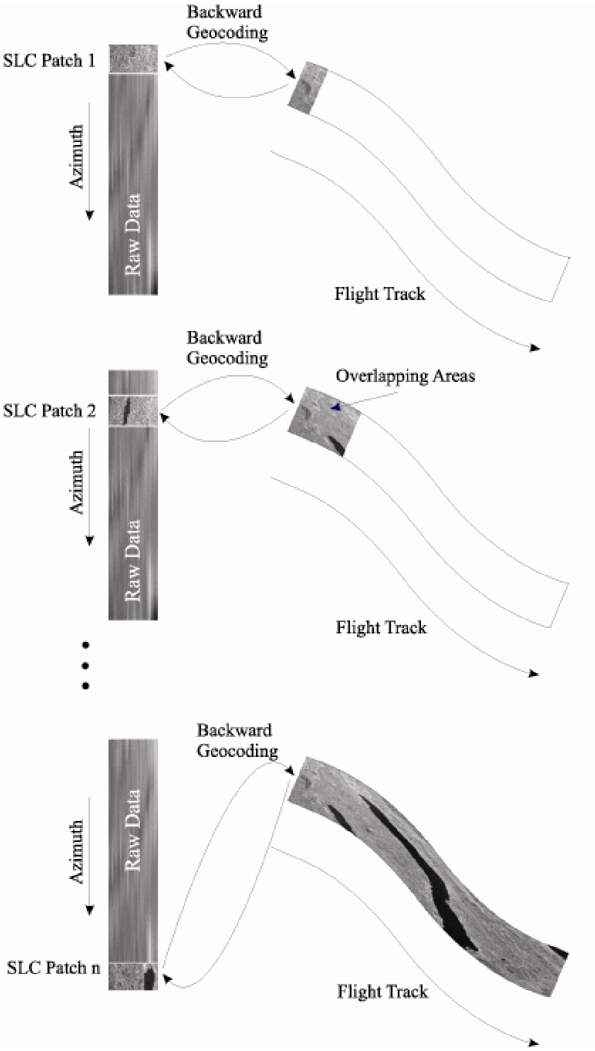


Figure 1 Schematic illustration of the mosaicking through geocoding.

The geocoding step begins with a forward geocoding of the patch corners to determine the area of interest. If it is the first patch, an empty geocoded image is created with the dimensions of the area of interest. Otherwise, the previous geocoded image is read and resized to contain the new area of interest. There is always an overlapping between the newly geocoded patch and the previous patches of the mosaic. Overlapping may be as much as 50% of the patch as it is the case for results presented in Section 3. A weighted average method may be applied to handle the overlaps.
The backward geocoding to append a patch to the mosaic starts from a set of coordinates and finds the corresponding position in the SAR image.
Both backward and forward geocoding processes are based on a standard range-Doppler approach.

Because fitting a focused SAR image onto a DEM is not a one-to-one operation, resampling or interpolation of the SAR data is needed. To receive a smooth geocoded image, an averaging filter must be applied when resampling and interpolation be used (e.g. cubic B-spline [4], [5]).

Consequently, the following main conditions are to be met to receive a precisely mosaicked and geocoded image from a non-linear flight track with the method described above: the flight direction should be nearly constant over the length of the patch. Otherwise a blurring will remain.

3 Results

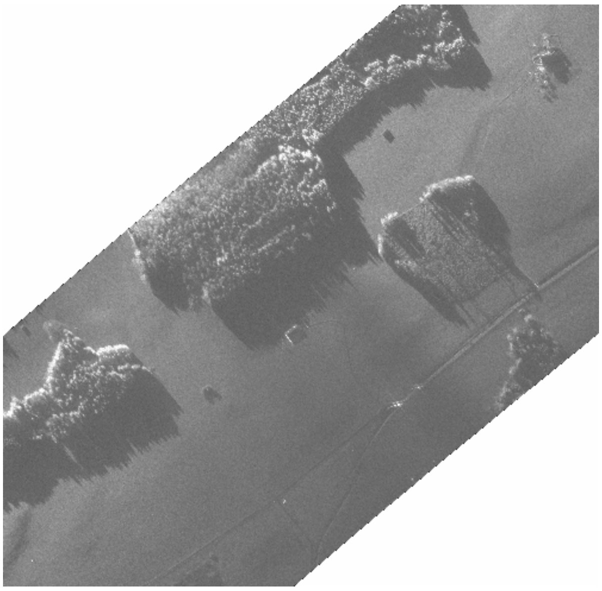
3.1 Focusing FGAN-MEMPHIS data

MEMPHIS high resolution SAR system is developed and operated by the German research institute FGAN [6]. It operates simultaneously at the 35 and 94 GHz radar bands (Ka and W bands) with a bandwidth of either 200 MHz in low resolution mode or 800 MHz in high resolution mode, using a synthetic stepped-frequency chirp. The obtained slant range resolutions are below 0.8 m and 0.2 m, respectively.

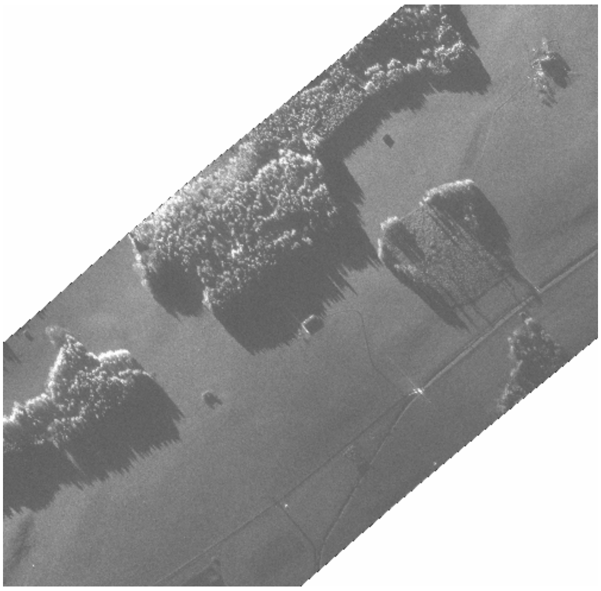
Two difficulties occur to obtain a high quality focusing of MEMPHIS data:

- A small change of the squint angle quickly causes a high variation of the Doppler centroid frequency compared to the azimuth bandwidth, and can lead to double representations of objects (see Fig. 2, (a), the bright object (a bridge) on the bottom-right side).
- The navigation data come from the GPS system of the aircraft. This is not a DGPS system, the lever arms between the GPS antenna, the INS system and the SAR antennas are unknown, the synchronizing of the time between both systems is a recurrent problem. Thus, conventional motion compensation algorithms are not usable.

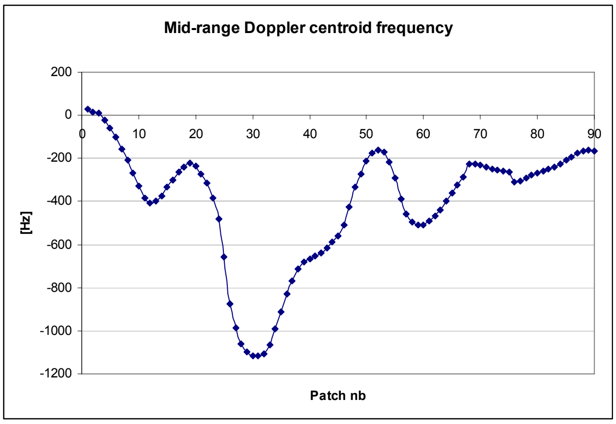
The presented algorithm offers a solution to focus these data with high quality. The focusing improvements using this algorithm can be seen on Fig. 2.



(a) Geocoded image of the conventionally (stripmap) focused data.



(b) Image obtained using the algorithm described above.



(c) Mid-range Doppler centroid frequency along azimuth.

Figure 2 MEMPHIS 94 GHz high resolution data from La Verrerie, Switzerland. (a) is the geocoded image of a stripmap focusing of the data, using an average Doppler centroid frequency of -300 Hz. The middle part is noisy and we can see a ghost image (the road bridge is represented twice). (b) is the result of the blockwise processing of the same data as in (a). The middle part is correctly focused. The patches have been focused using the Doppler centroid frequencies shown in (c). The PRF used was 1500 Hz for this data take.

3.2 Non-linear flight tracks with DLR E-SAR system

In 2006, an experiment took place in Switzerland with the DLR E-SAR system. Four tracks have been flown: a quasi-linear reference track, a drop in height, a double bend, and a 90-degree curve flight.

The blockwise focusing, mosaicking and geocoding method allows processing those data in a fair quality. E-SAR L-band antenna beam is quite large in azimuth (18°), thus large patches need to be taken to contain the whole aperture information. As the focusing of each patch assumes a linear flight path, the image is partially blurred.

However, the results show a high geometric fidelity, and the focusing quality is incomparably better than with conventional stripmap processing.

Fig 3. shows the result of the curvilinear acquisition mode.

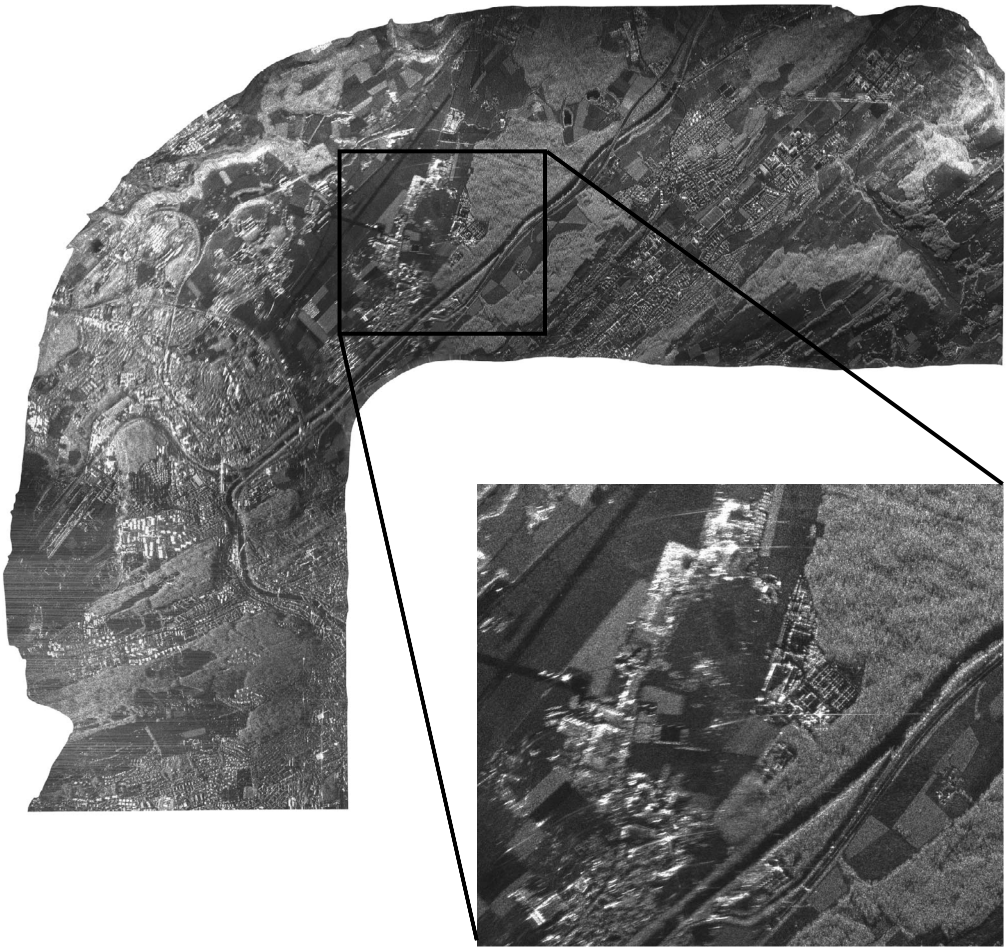


Figure 3 E-SAR L-band HH SAR image in map geometry acquired from curvilinear flight track (over the airfield of Emmen, Switzerland).

4 Conclusion

We have presented a processing algorithm able to focus airborne high resolution, high frequency SAR data in excellent quality despite non-precise navigation data.

This algorithm can also be used to focus SAR data from non linear flight tracks; results show a high geometric fidelity, but the obtained quality is not optimal using the E-SAR system due to the large antenna beam. Such an experiment will be repeated soon with the MEMPHIS system.

Please note that there is a companion paper by Frey et al. on this subject where a different processing approach in the form of a time-domain back-projection algorithm is presented.

References

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