Orthorectification using a High Resolution DSM for Fusion of Data from Different Sensor Systems

Antje Thiele, Karsten Schulz, Ulrich Thoennessen and Erich Cadario

Research Institute for Optronics and Pattern Recognition
Gutleuthausstrasse 1
D 76275 Ettlingen
{thiele, schulz, thoennessen, cadario}@fom.fgan.de

Abstract: The employment of different airborne and spaceborne systems opens the opportunity for an exploitation of complementary as well as supplementary sensor information for many purposes. One of the main future tasks in the field of reconnaissance and surveillance is the fusion of these heterogeneous data. The use of different sensors enables the exploitation and the extraction of information on a higher level, supporting a value adding to the reconnaissance chain, which is especially helpful to interpret built up areas in urban terrain. Because of the different imaging properties of the sensor systems, it is necessary to transform the datasets into a common coordinate system. For each imaging device a specific transformation equation system has to be applied depending on the sensor parameters and supplementary metadata. These specific imaging transformations (orthorectification) using a high resolution Digital Surface Model (DSM) are applied to a multisensor data set. An orthorectification method especially for SAR images was developed and applied to airborne SAR data. Results are presented.

1 Introduction

The employment of different sensors opens the opportunity for an exploitation of complementary as well as supplementary sensor information for many purposes. By this a value added information concerning the reliability of the exploitation can be provided. In general, topographic mapping of urban areas is based on sensor data acquired from airborne platforms in nadir view under good weather conditions, e.g. aerial imagery in the VIS and IR spectral channel. An alternative part of the frequency spectrum of steadily growing importance in remote sensing is the RADAR domain. RADAR has some very significant advantages like independence of daytime, and the large signal wavelength provides almost insensitivity to weather conditions. Combining the data of different imaging sensors can be very complex depending on platform type (e.g. spaceborne or airborne), operation mode (active, passive), spectral range (VIS, IR, RADAR) and the used imaging device. Additionally often multi-temporal and multi-aspect data sets have to be combined.

In this proposal, orthorectification with a high resolution DSM as a preliminary step for automatic fusion [STTC06] and a combined exploitation of such inhomogeneous data sets is discussed. In section 2 the considered data sets are introduced. Necessary transformation steps into a common coordinate system are discussed in section 3. The assessment of results and the conclusions are presented in section 4 and 5.

2 Considered Data Sets

Three images from different sensor types were investigated covering the urban area of city Karlsruhe. The images were taken in the RADAR, VIS and thermal IR spectral range. A Synthetic Aperture Radar (SAR) sensor acquires data in an active mode from an oblique and side-looking viewing direction. The test data were recorded with the airborne AER-II sensor of FGAN [En98]. The ground resolution is approximately 1 m, off nadir angle θ about 55° and sensor altitude about 3000 m. The investigated VIS image was obtained from a linear array of CCD elements in central projection view. The panchromatic test data were delivered from the passive sensor QuickBird. The ground resolution is 0.6 m and the satellite orbit altitude is 450 km [Di06]. The considered infrared data were recorded by a frame scanner (Barr & Stroud IR-18) [PB01]. The resulting image points lie equidistant from the perspective centre of a spherical surface. The captured long wave infrared or thermal infrared signal occupies the range from 8 to 14 μm. The image data have an effective size of 768 x 500 pixels and were recorded by an airborne platform at approximately 800 m height. For the orthorectification process a LIDAR-DSM was recorded from the company Toposys [To04]. The height information was delivered as pre-processed data in a raster grid of a predefined ground resolution of about 1 m [TSTC06]. Additionally cadastral information was used.

3 Transformation into a Common Coordinate System using a High Resolution DSM

For a combined analysis of data sets from different sensor systems a transformation of the data into a common coordinate system is necessary to compensate the different imaging properties. This transformation step, also called orthorectification, tries to eliminate the geometric distortions of an image to get an orthographic projection. Independently from the imaging device, a high resolution DSM is necessary for this step, especially if the main focus lies on the observation of high density urban areas [TSTC06]. In the following, different transformation processes specified by projection geometry and sensor type, are shortly described.

Orthorectification of SAR Data

The geometric characteristic of imaging SAR is the projection of intensity values in slant range geometry representing the distance between sensor and scene objects. This is given by signal propagation delay, defining the geometric position of incoming signals in the image. Due to this kind of projection, elevated objects are displaced towards the sensor. This displacement depends on object height and off nadir angle. Hence for a correct geocoding of elevated objects, a DSM including these objects is needed. The geolocation of a pixel in a SAR-image can be determined based on the carrier navigation data and the known distance between sensor and corresponding ground points. Due to the side-looking SAR illumination, even small deviations of the navigation data from the true sensor position and pose might lead to large offsets on the ground. Hence, before the mapping of SAR pixels on their correct DSM position, usually a pre-processing step is required to align the DSM and the SAR-image. Because of the different scene information contained in SAR images and a DSM, it is often difficult to identify corresponding structures as tie points. So an extended approach of [SCT04] for the geocoding of SAR images was used. This approach is based on a correlation of predicted shadow and layover areas with potential shadow and layover regions in the original SAR image in slant range geometry. The prediction of these areas is based on the high resolution DSM. The result of the correlation leads to a correction of the carrier navigation data and is performed in an iterative manner. In Figure 1 the result of geocoding is overlaid with cadastral data (red).

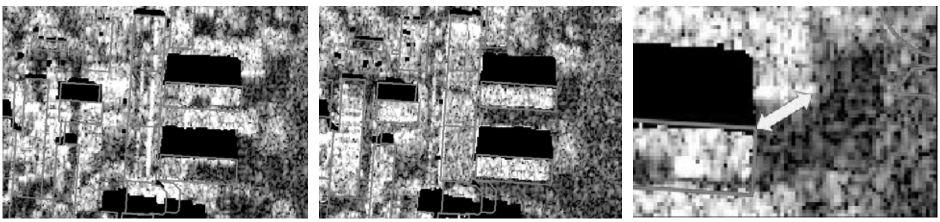


Figure 1: SAR geocoding without (left) and with (mid) improvement; zoom of displacement

Layover in front of a building (bright areas) is shifted away from the sensor dependent on the corresponding height in the DSM. Only in the middle image, these bright areas lie completely inside the building footprint of the cadastral data. Without improvement a displacement for the highest building of about 20 m can be observed (marked yellow in right image). Black areas in front of the buildings mask the shifted layover areas.

Orthorectification of Visible Data

Due to the mapping geometry of the scanning system working according to the central projection properties, elevated objects in the scene show a misalignment away from the sensor in an opposite way as described before. The necessary transformation (orthoprojection) to compensate these effects is presented e.g. in [Kr96]. For the investigated QuickBird image the camera model was given by a Rational Polynomial Coefficient (RPC) data set. An improvement of the orientation data was performed using Ground Control Points (GCP's) because the accuracy of the orientation data did not match the requirements. Since the sensor orientation was given by RPC's, a polynomial approach was chosen as described in [Ja05]. The orthorectification was performed using a high resolution DSM with a commercial software tool (ERDAS Imagine, LPS).

Transformation of Infrared Data

The special geometric properties concerning the interior orientation of the imaging device usually have to be specified by an appropriate mathematical model. The implementation of a correct mathematical model for the used frame scanner was not part of the investigation, but details can be found in [Bü03]. Due to the low flight height and the limited FOV the projective effects are limited; therefore a simplified transformation was applied. This process includes the registration and mosaicing of the different single frames of a scene to one image. For this purpose GCP's were measured in a suitable reference image (DSM) to receive 3D coordinates.

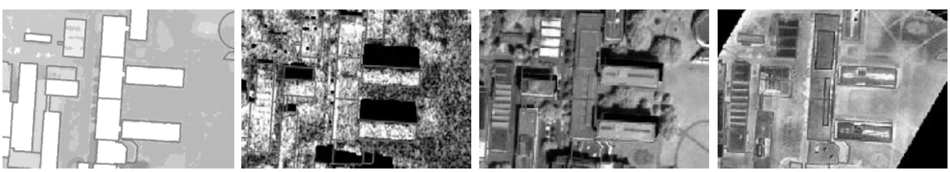
4 Assessment of Results

Orthorectification Results of SAR Data

The best orthorectification result of the SAR data was achieved by automatic alignment between SAR and DSM as mentioned in section 3. The layover effect at building walls occurs as bright area in front of the buildings. Within the orthorectification process these intensity areas were shifted to the building location in ground projection. Due to the fact that these intensity values in the layover areas result from multiple ground points, the shifting leads to information gaps in front of the buildings (masked black in Figure 2b). These areas can be replaced by information from other images recorded under different illumination direction.

Orthorectification Results of Visible Data

For the orthorectification of the QuickBird image the camera model given by an RPC data set, and the introduced DSM were used. To compute a more exact orthophoto a correction polynomial was calculated based on the measured GCP's. The best overlay result between the computed orthorectified image and cadastral data was delivered by a first order correction polynomial. Of course the order of the chosen correction polynomial depends on the precision of the mapping geometry, the variation in the height of the scene, the geometric resolution, and the required accuracy. The result of the orthorectification is depicted in Figure 2c. It can be seen that after the orthorectification, the misalignment of elevated objects, caused by the central projection of the sensor, is completely corrected. The full building roof area is mapped inside the cadastral building footprint. The interpretation of VIS orthorectified data based on a high resolution DSM has to be accomplished carefully, because the dead view areas (sensor shadow) in the scene (masked black) are still present. These areas can be replaced by information from other images recorded under different illumination directions.



a b c d

Figure 2: DSM (a), orthorectification results of SAR (b) and VIS (c), transformation result of IR (d), all overlaid with cadastral data

Transformation Results of Infrared Data

Due to the low flight height and the limited FOV the projective effects are limited; therefore the simplified transformation was applied (section 3). In Figure 2d the result of the transformation overlaid with cadastral data is shown. The movement around the roll axis of the airborne platform has strong effects to the image data. This is documented by an undulated run of building edges which are normally observable as straight lines in the image. These effects were not compensated by the applied transformation.

5 Conclusion

In this proposal, orthorectification with a high resolution DSM as a preliminary step for fusion and a combined exploitation of inhomogeneous data sets was discussed. In particular in the case of sensors with a different mapping behaviour it was shown that adapted transformations have to be used. The quality of the used DSM has a not negligible influence to the orthorectification process. Especially in urban areas a high resolution DSM including all man made objects is necessary to achieve the aspired orthoprojection. These high resolution DSM's nowadays are commercially available by LIDAR scanning systems. An orthorectification method especially for SAR images was developed and applied to airborne SAR data. The orthorectification of the VIS image was improved by the use of a polynomial correction approach based on measured GCP's. Because the projective effects were not totally corrected, the exact camera model for orthorectification of the IR images will be implemented in the future. For a precise orthorectification of all the described sensor data a refinement of the given sensor orientation is necessary. The way of fusing this orthorectified multi sensor data to enable the exploitation and the extraction of information on a higher level, is given in [STTC06].

Acknowledgment

We want to thank Prof. Dr. Ender and Dr. Brenner (FGAN-FHR) for providing the SAR image data recorded by the AER II experimental system [En98] of FGAN.

References

[Bü03] G. Büyüksalih, "Geometric calibration models of infrared cameras and scanners for photogrammetric and remote sensing applications," Optical Engineering, Vol. 42(7), 2003, pp. 1923-1935

[Di06] DigitalGlobe (2006). QuickBird Imagery Products – Product Guide.

[En98] J. H. G. Ender, "Experimental results achieved with the airborne multi-channel SAR system AER-II," Proc. EUSAR'98, pp. 315-318

[Ja05] K. Jacobsen, "Vergleich der Orientierungsverfahren für Weltraumaufnahmen," In: Eckhard Seyfert (Hrsg.): Publikat. der DGPF. Band 14. Rostock, 2005, S. 467-474

[Kr96] K. Kraus, Photogrammetrie. Band 2, Ferd. Dümmler Verlag, Bonn, 1996

[PB01] G. Petrie, G. Büyüksalih, "Recent Developments in Airborne Infrared Imagers," GeoInformatics, 2001

[SCT04] U. Soergel, E. Cadario, U. Thoennessen, "Geocoding and fusion of airborne high-resolution multi-aspect SAR data," Proceedings EUSAR 2004, vol. 2, pp. 945-948

[STTC06] K. Schulz, A. Thiele, U. Thoennessen, E. Cadario, "Fusion of Heterogeneous Multisensor Data", accepted for publication, GI, Dresden, 2006

[To04] Toposys GmbH (2004, August). Airborne laser-scanning-A comparison with terrestrial surveying and photogrammetry.

[TSTC06] A. Thiele, K. Schulz, U. Thoennessen, E. Cadario, "Orthorectification as Preliminary Step for the Fusion of Data from Active and Passive Sensor Systems", accepted for publication, MFI, Heidelberg, 2006