GEOMETRIC CORRECTION OF AIRBORNE LINE-SCANNER IMAGERY

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ABSTRACT:

For many practical applications digital airborne scanner imagery has to be converted to orthoimages. The traditional approaches for this task are based on interpolation techniques. It is known from many studies, that these methods do not yield satisfying results, even if a large number of ground control points is available. The reason is, that the high frequent changes of the sensor orientation parameters can not be derived from control points. The result is rather a smoothed curve which represents only an approximation of the trajectory and its pointing. For a rigorous solution of the problem flight attitude parameters have therefore to be recorded.

A software program named »GASIS« has been developed, which makes use of the sensor orientation within the rectification of DAEDALUS AADS 1268 data. The existing program is able to generate orthoimages if flight attitude parameters and a DTM for terrain height information is provided. Furthermore a geometric mosaicking approach of neighbouring image strips is implemented. It is obvious that by this means the number of necessary ground control points is reduced compared with those approaches that do not take into account flight attitude data. According to the progress in the developement of low-cost inertial navigation systems (INS), the increase in accuracy characteristics and the availability of precise kinematic DGPS solutions it became more feasible to record also the high frequent movements. The paper describes the different aspects of various scanner types and its applications and the performance of the developed software system. Subsequently future concepts for further software components are sketched. It is intended to use GPS derived precise scanner positions to improve the model of the trajectory. A further reduction of the necessary ground control and an increase in accuracy can be anticipated.

KURZFASSUNG:

Bei vielen Praxisanwendungen digitaler Bilddaten müssen diese in Orthophotos umgewandelt werden. Traditionelle Ansätze, um dies für flugzeuggetragene Scannersysteme durchzuführen, basieren auf Interpolationstechniken. Aus zahlreichen Untersuchungen ist bekannt, daß diese Methoden zu keinen befriedigenden Ergebnissen führen, selbst wenn eine große Anzahl an Paßpunkten verfügbar ist, da sich die hochfrequenten Änderungen der Orientierungsparameter des Sensors nicht aus den Paßpunkten ableiten lassen. Das Ergebnis ist vielmehr eine geglättete Kurve, die nur eine Näherung der tatsächlichen Flugbahn darstellt. Für eine strenge Lösung des Problems müssen daher auch Fluglageparameter aufgezeichnet werden.

Es ist ein Programm »GASIS« entwickelt worden, das aufgezeichnete Fluglagedaten für die Entzerrung von Daten des DAEDALUS AADS 1268 nutzt. Mit diesem Programm ist es möglich, unter Berücksichtigung eines DGM Orthobilder zu erzeugen. Darüber hinaus besteht die Möglichkeit einer geometrischen Mosaikbildung aus benachbarten Streifen. Es konnte gezeigt werden, daß die Anzahl notwendiger Paßpunkte, verglichen mit den Ansätzen, die keine Fluglagedaten benutzten, stark abnahm. Mit dem Fortschritt in der Entwicklung von preiswerten Inertialsystemen (INS), einer Steigerung ihrer Genauigkeit und der Verfügbarkeit präziser kinematischer DGPS-Lösungen wurde es möglich, auch die hochfrequenten Änderungen der Fluglage zu erfassen. Im folgenden werden verschiedene Aspekte der unterschiedlichen Sensortypen und ihrer Anwendungsgebiete aufgezeigt sowie die Leistungsmerkmale des entwickelten Programmsystems. Anschließend werden zukünftige Konzepte für weitere Entwicklungen beschrieben. Es ist geplant, GPS-bestimmte präzise Scannerpositionen zu nutzen, um die Modellierung der Flugbahn weiter zu verbessern. Dadurch kann eine weitere Verringerung der erforderlichen Paßpunkte und eine höhere Genauigkeit erwartet werden.

1. AIRBORNE LINE-SCANNER SYSTEMS

In addition to traditional aerial photography and commonly used satellite image data, digital data acquired through airbore scanner systems have become more and more important for many geoscientific purposes. Some of the main reasons are the extended spectral range or the high spectral resolution which is provided through the majority of such sensors.

From a technical point of view three different categories of airborne scanning systems can be distinguished:

- Opto-mechanical scanners,
  (e.g. DAEDALUS AADS 1268, also called Airborne Thematic Mapper)
- Opto-electronical scanners
  (e.g. High Resolution Stereo Camera = HRSC and Wide Angle Optoelectronic Scanner = WAOSS)
- Imaging spectrometers
  (e.g. DAIS-7915 and CASI)

An imaging spectrometer might use opto-mechanical mirror techniques (e.g. DAIS) or opto-electronic CCD arrays (e.g. CASI) to cover the swath across flight direction.

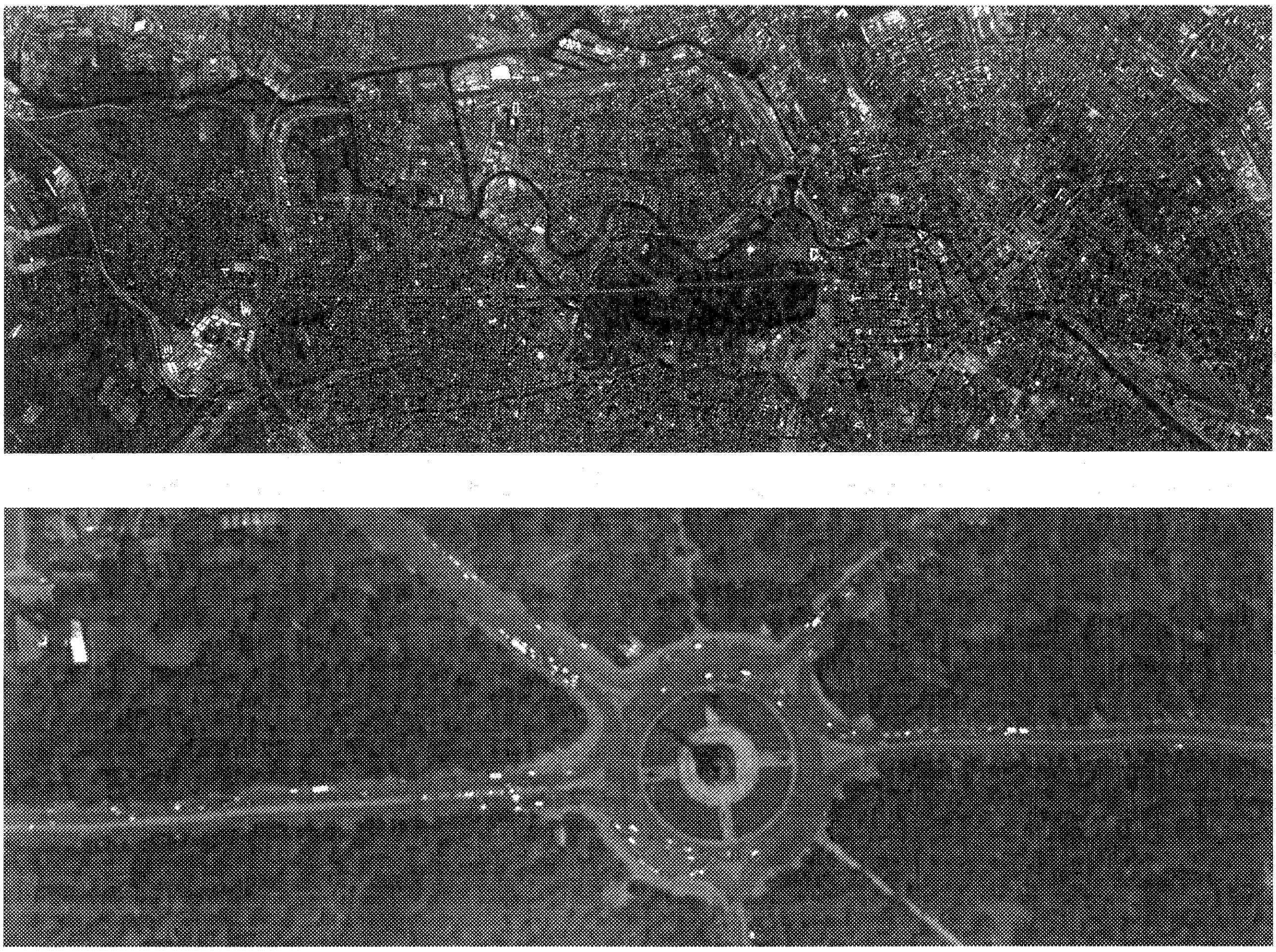

Figure 1: WAOSS image strip of the Berlin-Tiergarten (full strip and enlarged detail)

The special technical parameters have to be considered within every geometrical processing, especially during the orthoimage generation (see Chapter 3). Beside this, some sensor offer several operation modes which define different spatial and spectral resolutions as well as different fields of view (FOV).

While the CASI and DAEDALUS airborne scanners are in practical use since years and operational flight tests of DAIS have been made recently, the three-line-scanners HRSC and WAOSS are basicly imaging systems of the Mars96 Mission which is going to be launched to planet Mars in autumn 1996. But in addition to this planetary mission on a spacecraft both cameras are prepared and already used for airborne Earth observation.

HRSC is proposed to be flown over the vulcano Etna (Italy) in order to test data processing for the Mars96 Mission and also to generate high resolution Digital Terrain Models and orthoimages of the Etna region.

WAOSS has already been flown over brown coal mining regions and also very impressive images of the Berlin-Tiergarten region could be obtained. Fig. 1, showing the deformation of a »straight« road, visualizes the geometrical problems which arise from flight attitude variations.

Concerning the optical resolution up to now the scanner technology provides a much lower resolution than it is known from the photographic films. Although there are tendencies to develop digital matrix cameras with high optical resolution characteristics, line-scanning systems will not become obsolete because of their extended spectral range and their spectrometer capabilities.

Tab. 1 shows a few technical parameters of the above mentioned sensors (note, that WAOSS consists of clear channels only and HRSC offers 5 clear as well as 4 colour channels).

	number of channels	resolution at height = 2000 m		FOV (deg)	Number of pixel/line
		m	mrad		
DAEDALUS	11	2.5	1.25	42.96	716
DAIS	up to 79	6.6	3.30	78	512
CASI	up to 288	2.3	1.20	34.2	512
WAOSS	3	0.5	0.27	80	5184
HRSC	9	0.08	0.04	12	5184

Table 1: Technical characteristics of some line-scanning sensors

It becomes obvious that for the geometrical processing of these image data with pixel- or subpixel-accuracy sensor position and pointing has to be provided with a quality and density which can only be realized by modern techniques like INS, GPS and DGPS.

2. FIELDS OF APPLICATION

Image data of airborne scanners are widely used and processed with respect to environmental studies and thematic investigations. Due to the lack of sophisticated tools for accurate geometric processing, an enormous amount of time and cost consuming interactive operations, in particular the selection and definition of ground control points, are necessary up to now.

Nevertheless, there have been many investigations demonstrating the typical capabilities of this type of image data. The applications cover a broad variety of different disciplines as there are hydrology, agriculture, climatology, forestry, urban planning, etc.

Without appropiate geometrical correction the results of such investigations can be regarded as helpful if geometrical concerns are supposed to be of minor importance. This implies that the relations to other types of information which are commonly provided in geoinformation systems (GIS) are not relevant. However, the general trend to merge information from different sources and to analyse dynamic changes by means of multitemporal data impose a strong need for the provision of geometrically corrected scanner imagery.

3. GEOMETRIC CHARACTERISTICS OF AIRBORNE SCANNER IMAGERY

The principal idea of using a line-scanner is to image the Earth's surface by the combination of scanning operations and the sensor movement above the ground. Because it is a time dependent procedure it becomes obvious that

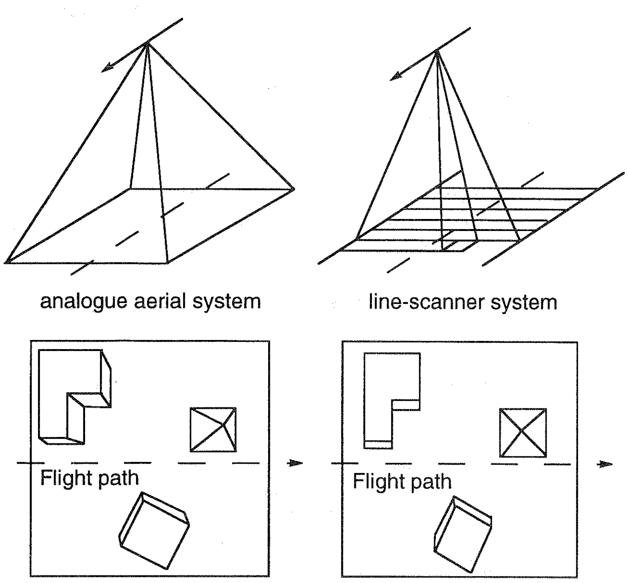

Figure 2: Simplification of the projection geometry of a photographic and a line-scanner system

sensor velocity and scan rate must be synchronized. Deviations cause underscans (gaps in image information) or overscans (redundant image information). Another reason for such effects can be changes in terrain heights. Therefore scan lines should adjoin each other in an optimal way for maximum altitude of the actual flight area. This is how underscans can be avoided.

Because of the basic principles of line-scanner techniques the geometric characteristics of the imagery acquired differ generally from that of aerial photography. Whereas photographs show central perspectivity the scanner image data are mixed projections. The terrain is imaged in parallel projection in the direction of the flight and in central projection across the flight line. This effect is schematically sketched in Fig. 2. It is obvious, that this is valid only if we assume an ideal trajectory without any distortions.

However, the operational conditions are much more complicated. The real trajectory of an airplane shows considerable deviations from an ideal one. Atmospheric turbulences and other influences result in rather irregular distortions of higher or lower frequencies. This is why the trajectory cannot be assumed to be a straight line. Furthermore sensor orientation varies due to changes of the flight attitude parameters, and therefore sensor pointing differs from nadir viewing, introducing roll, pitch and yaw angles.

The geometric correction of scanner image data requires a full reconstruction of the dynamic changes of the sensor orientation during the flight. This can not be achieved if the reconstruction is based only on ground control points. Therefore orientation parameters for each scan line are necessary. Due to the high frequency components of the orientation changes it is necessary to record flight attitude parameters with the same density as the scan frequency. This is possible with a combination comprising DGPS and INS systems. With DGPS precise scanner positions with an appropriate absolute accuracy up to some centimetres can be provided.

Some systems for the measurement of the flight attitude parameters which are in use do not fulfil these requirements. While angular variations are recorded mostly with lower density and accuracy, the sensor positions can only be estimated using secondary information like height above ground or above sea level, velocity, drift and scan rate. Also the standard GPS, which is part of nearly every aerial navigation equipment, normally does not meet the requirements.

4. THE SOFTWARE SYSTEM »GASIS«

»GASIS« is the abbreviation for *General Airborne Scanner Imaging System* and was developed at the Technical University of Berlin. The system was originally designed for processing data acquired through the opto-mechanical scanner DAEDALUS AADS 1268, but its principles are applicable or can be adapted also to any other type of line-scanner imagery.

The transformation of the image data to the ground is based on the well-known equations of collinearity. The system uses adjusted orientation parameters that are derived from INS, velocity, drift and scan rate measurements. The local heights of the terrain must be provided in a Digital Terrain Model (DTM). The geometric correction makes use of a ray tracing algorithm in an iteration procedure (Zhang et al., 1994).

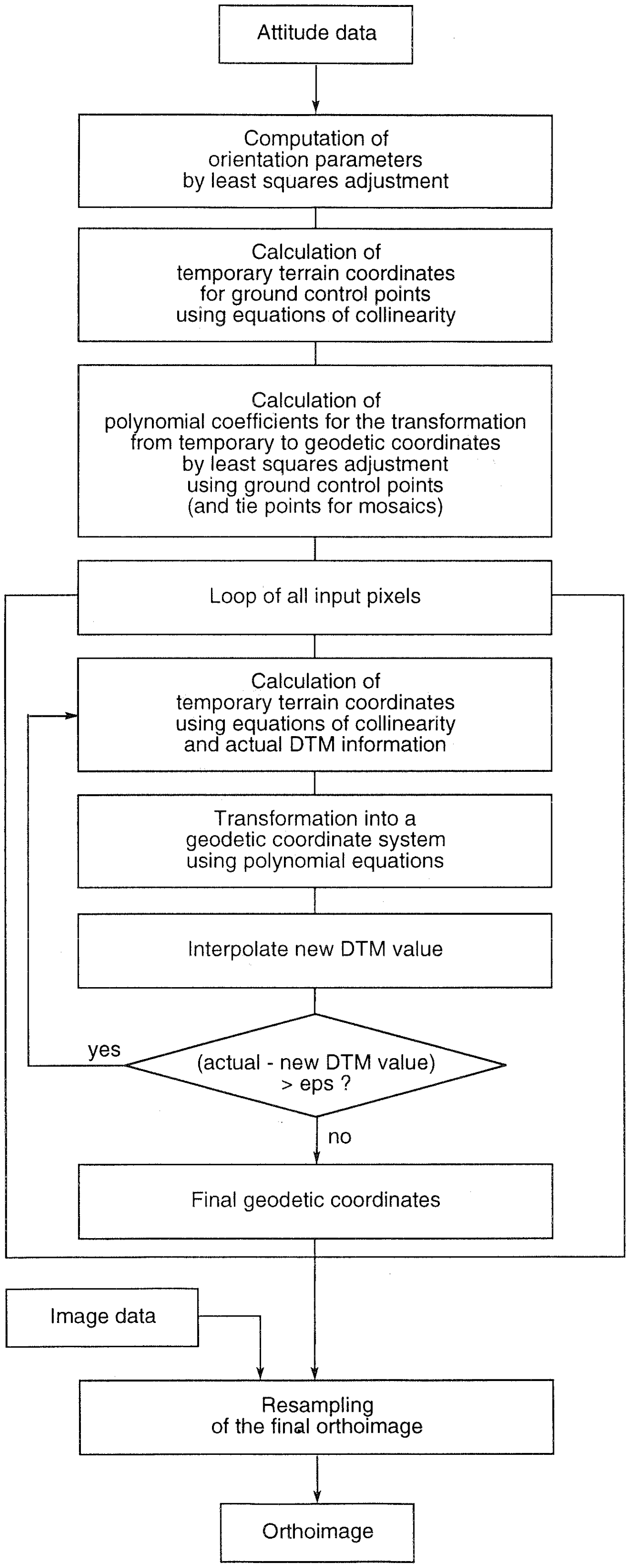

Figure 3: The »GASIS« approach
for the geometric correction of airborne scanner data

The result of these calculations is a set of data where all image points (pixels) are converted to temporary ground points. They are transformed to the »true surface« using polynomial equations, which can be derived by only a few ground control points. These polynomial equations are necessary in order to correct the low frequency trends that may be inherent in the original measurements of the flight attitude parameters. However, the resulting »true« positions form an irregular pattern. In order to derive a regular grid of pixels, as it is necessary to generate the final orthoimage, appropriate interpolation algorithms are applied for resampling.

In many cases it is necessary to combine adjacent strips to an image mosaic. This is achieved by the simultaneous determination of the coefficients of all polynomial equations in a least squares adjustment. This procedure uses not only ground control but also additional tie points, thus reducing again the number of necessary ground control point measurements.

The principle of the approach is outlined in Fig. 3. Although up to now only data of the DAEDALUS scanner have been processed with GASIS. The reason for this is, that only for this system, which is operated by the German Aerospace Research Establishment (DLR) in Oberpfaffenhofen and equipped with a special flight attitude measurement system, image data and precisely specified attitude data have been provided. This data was flown in the context of several research projects. But in principle the developed approach and its proved functions can be applied to any other type of airborne line-scanner data.

The only modules, which have to be adapted to new types of data, are the interfaces to the image and attitude data formats as well as the derivation of the classical orientation parameters from these recorded flight attitude data. This procedure, however, is in any case one of the most important processing steps.

5. FURTHER DEVELOPMENTS

In order to fulfil common requirements for the processing of airborne line-scanner imagery, the main extentions of GASIS will be:

- the generation of interfaces to data formats of other line-scanner data and their associated flight attitude data, especially GPS and DGPS,
- the development of a general module for the derivation of the classical orientation parameters from any recorded flight attitude data,
- the integration of powerful radiometric mosaicking techniques,
- the generation of standard file exchange formats.

Allthough a standard of input data can not be expected in the near future in scanner technologies it should be discussed to define an experimental data standard for line-scanner raw-data which includes the full performance of image and attitude data. This aspect will become still more important with respect to the developments in digital aerial photogrammetry.

In addition to the desribed approach an other solution of the geometric correction problem is under discussion. While at the moment orientation parameters are calculated from attitude data before the first adjustment is carried out, it is desirable to introduce the original attitude data as observations in a general adjustment process. As a result of this process the accuracy of the attitude data could be determined and the quality of the results could be improved.

6. REFERENCES

Zhang, W., Albertz, J., Li, Z., 1994. Digital Ortho-image from Airborne Line-scanner Imagery Utilizing flight Parameters. In: Internat. Archives of Photogrammetry and Remote Sensing, Munich, Germany, Vol. 30, Part 3/2, pp. 945-950.

Zhang, W., Albertz, J., Li, Z., 1994. Rectification of Airborne Line-Scanner Imagery Utilizing Flight Parameters. In: Proceedings of the First Internat. Airborne Remote Sensing Conference and Exhibition, Strasbourg, France, pp. II-447 - II-455.