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General Model for Multi-Line CCD Array Sensors. Application for Cloud-top Height Estimation.

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ABSTRACT

A general sensor model for direct and indirect georeferencing of multi-line CCD array sensors carried on airplane or satellite is under development at our Institute. Currently the model for the direct georeferencing has been tested on stereoimages from airborne sensors and will be used on images from satellite sensors for cloud-top height estimation. The results will be validated with other sources.

1.INTRODUCTION

Today, a wide class of pushbroom sensors with different characteristics (dimensions, design, stereo-geometry, resolution, etc.) exists and satisfies the requirements for remote sensing and photogrammetric applications. For an accurate photogrammetric mapping, a classic bundle adjustment is not realistic, because each line is independently acquired and has a different external orientation. The sensor position and attitude are usually modeled as a polynomial function depending on time, using some physical properties of the trajectory (i.e. satellite orbit) as constraints (Kratky, 1989). As concerns airborne sensors, in most cases the exterior orientation is directly measured with high precision with GPS/INS instruments carried on board and used for the georeferencing and image rectification. Our institute is developing a general sensor model for a wide class of CCD array.

2. MODEL DESCRIPTION

The model is designed for sensors carried on both spacecraft and aircraft. If the direct measurement of the sensor position and attitude is available, photogrammetric mapping is performed by direct georeferencing: the model computes the approximations of the ground coordinates with a linear forward intersection of two lines (Figure 1) and refines them with least squares methods, using all the available lines and according to collinearity equations. All computations are set in a tangent local coordinate system. For these operations, no Ground Control Points (GCPs) are needed. On the other hand, if the sensor external orientation is not provided by additional information, the sensor position and attitude are modeled with 2^{nd} order polynomial functions depending on time. In this case a sufficient number of well-distributed GCPs are needed (Poli, 2001). This part of the algorithm is still under development.

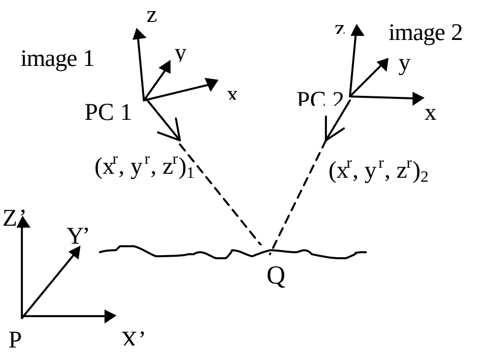
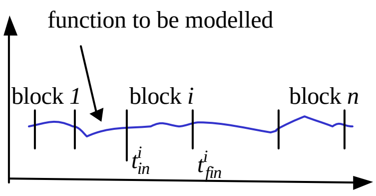


Figure 1. Geometric intersection of two homologous rays from perspective center (PC) of image 1 and image 2.



for each block i:

$$X(\Delta t) = p_0^i + p_1^i \Delta t + p_2^i \Delta t^2$$
$$Y(\Delta t) = p_3^i + p_4^i \Delta t + p_5^i \Delta t^2$$
$$Z(\Delta t) = p_6^i + p_7^i \Delta t + p_8^i \Delta t^2$$
$$?(\Delta t) = p_9^i + p_{10}^i \Delta t + p_{11}^i \Delta t^2$$
$$j(\Delta t) = p_{12}^i + p_{13}^i \Delta t + p_{14}^i \Delta t^2$$
$$?(\Delta t) = p_{15}^i + p_{16}^i \Delta t + p_{17}^i \Delta t^2$$

Figure 2. Modeling of sensor position (X, Y, Z) and orientation (ω, φ, κ). p_j^i: parameters for block i, t_{in}^i, t_{fin}^i : initial and final time of block i and $\Delta t = t - t_i^i$.

The model has been tested on a stereopair from the Japanese TLS (Three Line Sensor), carried on helicopter. The sensor consists of one optical system and three lines of 10200 elements each, scanning in forward (+21.5°), nadir and backward (-21.5°) directions (Murai, 1995). The internal orientation and the pixels' positions in the focal plane were available from calibration, while a GPS receiver and an INS instrument mounted on the helicopter provided the attitude and position for each exposure, but without any information about their accuracy. The ground coordinates of 47 GCPs were available and used as reference data for the results' analysis. These first results from the direct georeferencing showed that a correction of the orientation data for systematic errors was required (Figure 3).

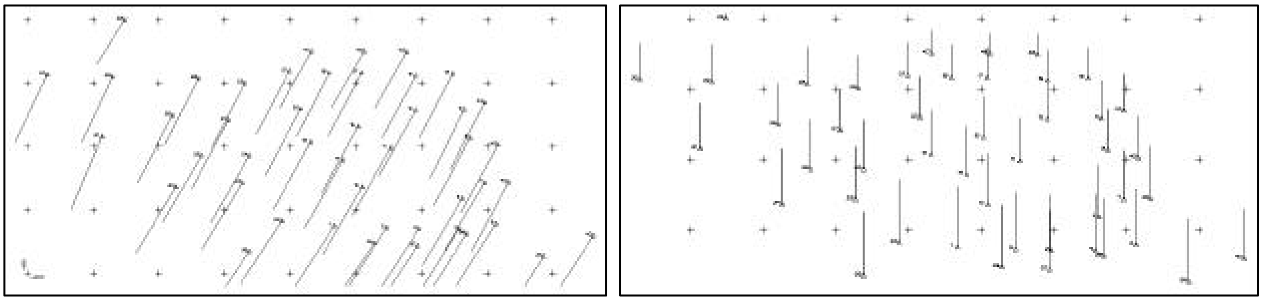


Figure 3. Plot of difference in XY (left) and Z (right) between correct coordinates and computed coordinates of 46 GCPs (1cm corresponds to 3 m).

So, the offset vector between GPS antenna and the camera center of projection was estimated using 10 GCPs and used to correct the position data. The results improved considerably (Figure 4). Anyway the sensor position and attitude will be improved.

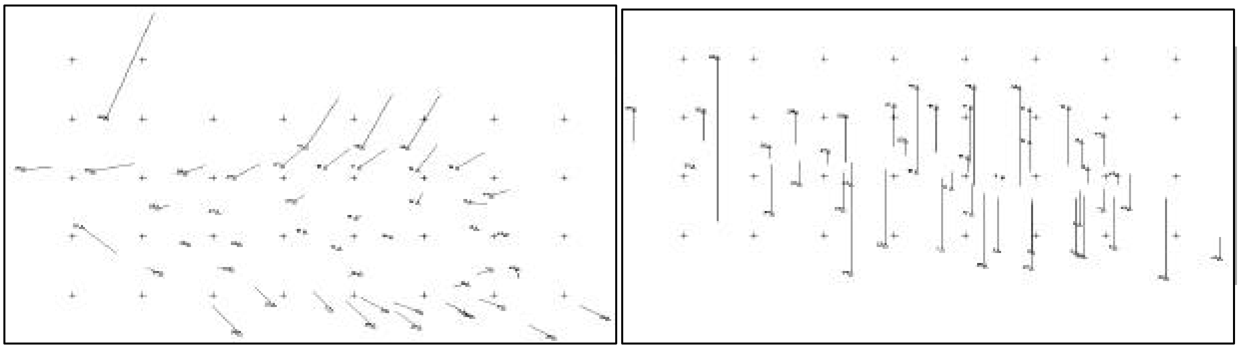


Figure 4. Plot of difference in XY (left) and Z (right) between correct coordinates and calculated coordinates of 38 Check Points (CPs) after correction of sensor position (1 cm corresponds to 0.65 m).

3. CLOUD-TOP HEIGHT ESTIMATION

The model will be used for the estimation of cloud-top height, within the EU-CLOUDMAP2 project. It will be applied to stereoimages (level 1B1) from MISR sensor (Fig. 5), carried on EOS-AM1 platform. The sensor consists of nine lenses viewing backwards and forwards along track in nine different directions. Using the ephemeris data and the orbit characteristics for the sensor position and orientation, a forward intersection will be performed. The estimated height will be compared to the results obtained from other sources (ATSR2 –Fig. 6-, MISR level1B2). The results will be validated with ground-based imagers (Seiz, 2000, Fig. 7).

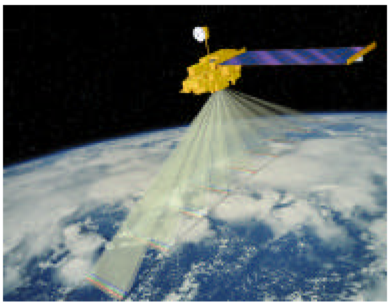


Figure 5. MISR sensor on EOS-AM1 platform.

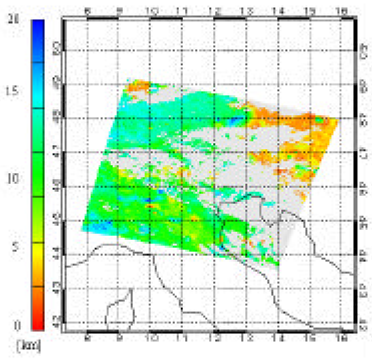


Figure 6. Cloud-top height estimation from ATSR2.

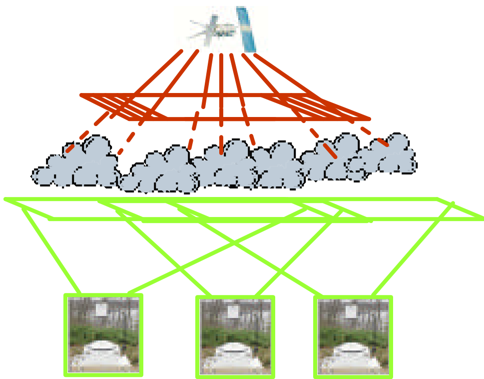


Figure 7. Cloud-top height estimation from satellite and validation with ground-based imagers.

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