

Line scanner in combination with inertial measurement unit

D. Griessbach *, A. Börner*, M. Scheele*, K. Scheibe*, S. Sujew**

German Aerospace Center (DLR), Optical Information Systems, Rutherfordstraße 2, 12489 Berlin, Germany

German Aerospace Center (DLR), Institute of Transport Research, Rutherfordstraße 2, 12489 Berlin, Germany
(anko.boerner, karsten.scheibe, martin.scheele, sergej.sujew)@dlr.de

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ABSTRACT:

Capturing images with a line scanner is always connected with a motion, e.g. a translation or a rotation. Since the motion is not free of disturbance it is necessary to measure it. The motion of the imaging system is described by these measurement. The following image correction is similar to airborne photogrammetry. The imaging system consists of the line scanner, its electronic parts are identical in construction to EYESCAN M3metric KST, and the initial measurement unit (IMU) by Applanix Position and Orientation System POS-AV 410. First field tests were performed for a panoramic scan. The rotation and the orientation of the rotation axis were measured in order to correct the motion disturbed images. Further tests with a car were made for a linear motion scan. It demonstrates the high resolution imaging capabilities and stereo possibilities of a single RGB line.



Figure 1: motion corrected image, overview

1. INTRODUCTION

Digital line scanners are used in airborne photogrammetry as well as in close-up photogrammetry. The line scanner used in this case is a development model of the EYESCAN M3metric (Scheibe K, et al, 2001). A single RGB line with 10290 pixels for each channel is located at the focal plane. In order to use a line camera like this an exact scan motion is necessary. For disturbed motions a sufficient precise position measurement system is required to correct the image. The measurement system used in this work is the integrated Inertial/GPS system POS-AV 410 by Applanix Corp. with an IMU LN200. The disturbances of two particular motions were investigated, firstly a rotation and secondly a translation.

2. ROTATION

The line scanner is a Panoramic camera which scans an object by rotating the camera head. The rotation has been disturbed due to external influences. The used test assembly is shown in Figure 2.



Figure 2: Measuring setup

2.1 Mathematical Model

The used mathematical model is described in equation 1. The motion disturbed image vector (right side of equation) is transformed into an ideal cylinder by using the measured rotation angles (left side of equation).

$$\begin{pmatrix} f \cdot \sin(j' \cdot \Delta\varphi') \\ i' \cdot \delta \\ -f \cdot \cos(j' \cdot \Delta\varphi') \end{pmatrix} = \lambda \cdot A(\gamma, \vartheta, j \cdot \Delta\varphi) \cdot \begin{pmatrix} 0 \\ i \cdot \delta \\ -f \end{pmatrix} \quad (1)$$

where f = focal length
 i', j' = image coordinates of corrected image
 i, j = coordinates of disturbed image
 δ = pixel size of CCD line
 $\Delta\varphi$ = y-axis rotation increment
 $\Delta\varphi'$ = instantaneous field of view (IFOV)
 γ = rotation of z-axis
 ϑ = rotation of x-axis

That results in equations 2 and 3 for the corrected image coordinates i', j' are:

$$j' = \frac{\arctan\left(\frac{a}{c}\right)}{\Delta\varphi} \quad (2)$$

$$i' = \frac{f \cdot \sin(j' \cdot \Delta\varphi)}{\delta} \cdot \frac{b}{a} \quad (3)$$

where:

$$\begin{pmatrix} a \\ b \\ c \end{pmatrix} = A(\gamma, \vartheta, j \cdot \Delta\varphi) \cdot \begin{pmatrix} 0 \\ i \cdot \delta \\ -f \end{pmatrix} \quad (4)$$

2.2 Results



Figure 3: Original image (5° clip from panorama)

The integration time was set to 10 ms, the focal length with 45 mm and the instantaneous field of view was 32 arcsec.

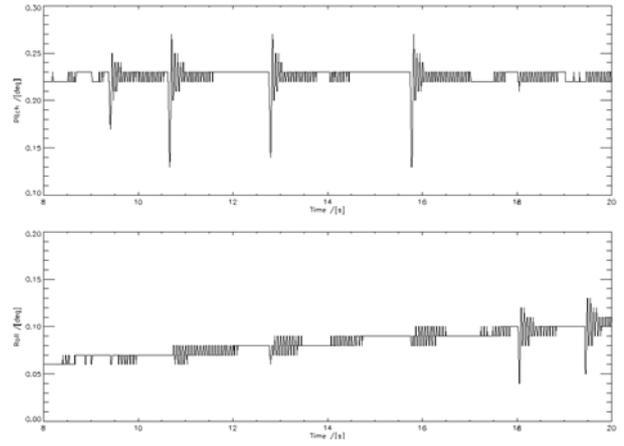


Figure 4: Plot of the disturbance variable (γ, ϑ)

The measurement was sampled with 200 Hz. The result of the image correction (equation 2, 3) is shown in Figure 5.



Figure 5: Corrected image

2.3 Evaluation

The remaining pixel error is ± 1 pixel. A better accuracy couldn't be achieved due to the following reasons: The Applanix POS-AV measurement system is originally made for a dynamic applications and not for a stationary application. It needs to be initialised by a closed loop movement, e.g. by flying loops with an airplane. The test image was made without sufficient initialisation from indoors, so the Applanix system was not aligned and the corresponding real time attitude measurements were not within the specification. Further on the resolution of the applanix system is given with 36 arcsec whereas the IFOV with a 45 mm lens is 32 arcsec. Nevertheless a nutation of the rotation axis could be measured.

3. TRANSLATION

Based on the experiences of airborne photogrammetry (e.g. Börner A., et al 1997) with CCD-line sensors combined with a translation movement it is possible to use basic algorithms for close range applications as well. First results in this field were presented in 2003 where a CCD-line camera was combined with an IMU (R. Reulke, et al 2003). In the following the stereo possibilities of a RGB CCD-line camera like the Eyescan Metric M3 will be investigated. A focal length of 45 mm and a spacing of 0,154 mm between each line results in a stereo angle of $\gamma=0.3669^\circ$. That means that there should be considerable parallaxes (>10 pixel) for an object range between 10 m and 100 m. Experiment and Results

The translation movement was realised by using a measurement car (Figure 6).

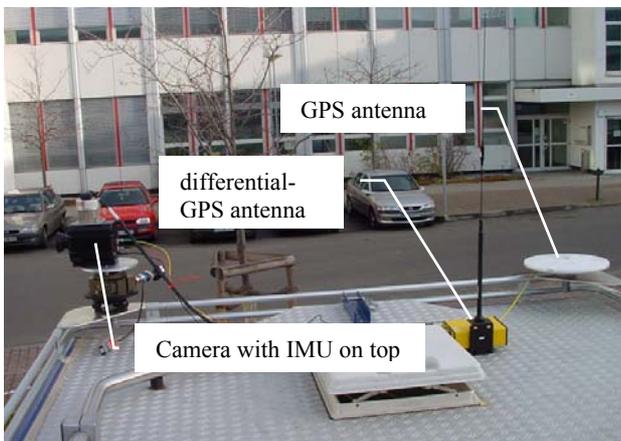


Figure 6: Measuring setup on top of the car

The scanned object was about 100 m long. The trajectory of the car is shown in Figure 7.

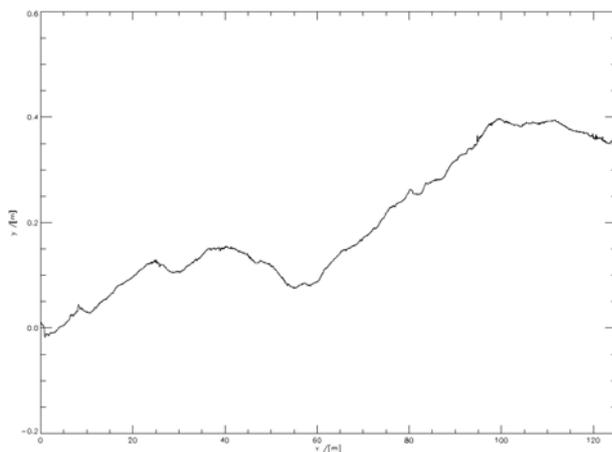


Figure 7: Trajectory of the camera

Figure 8 shows a detail of the original, uncorrected image (see white box in Figure 1). The associated disturbance variables can be seen in Figure 9. The heading angle was nearly constant for the displayed section.



Figure 8: Original image (detail)

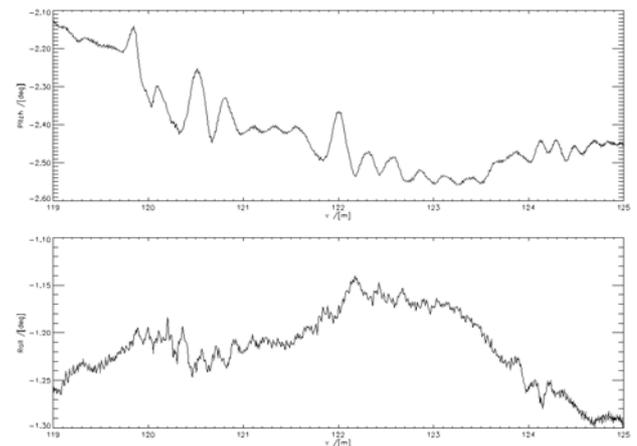


Figure 9: Plot of the disturbance variable (γ, θ)

The transformation of the image is already described (e.g. Börner et al 1997).



Figure 10: Motion corrected image (detail)

3.1 Evaluation

In comparison to the rotation the translation correction was more accurate due to a better initialisation of the applanix system combined with an additional differential GPS signal. The camera position could be determined with an accuracy of about 6 cm. The distance between camera and projection plane for the corrected image was set to 10 m.

4. STEREO POSSIBILITIES

Due to the spacing between the RGB lines parallaxes occur. (Equation 5)

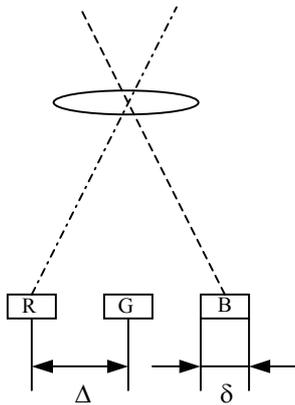


Figure 11: CCD line

$$p = \frac{2 \cdot \Delta}{\delta} \cdot \frac{h}{h_0} \quad (5)$$

where

- p = parallax [pixel]
- h = distance between camera and object
- h₀ = distance between camera and projection plane
- Δ = spacing between each RGB-line
- δ = Pixel size of CCD line

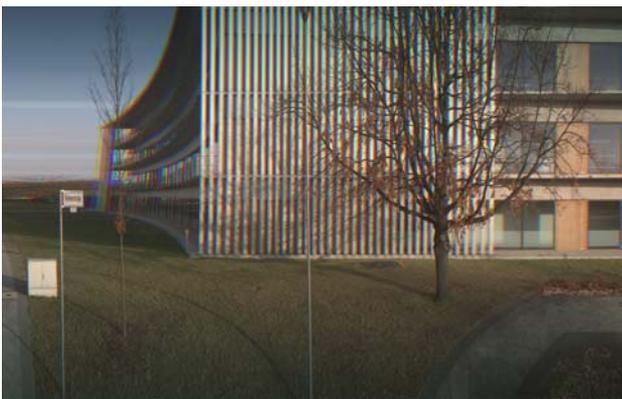


Figure 12: Anaglyph image

Due to the parallaxes an anaglyph image is produced during translation scans. A detail of the image is shown in Figure 12.

The red and the green channel are the sources for the stereo image processing. Using a cross correlation approach a disparity map was created. A small detail is depicted in Figure 13.

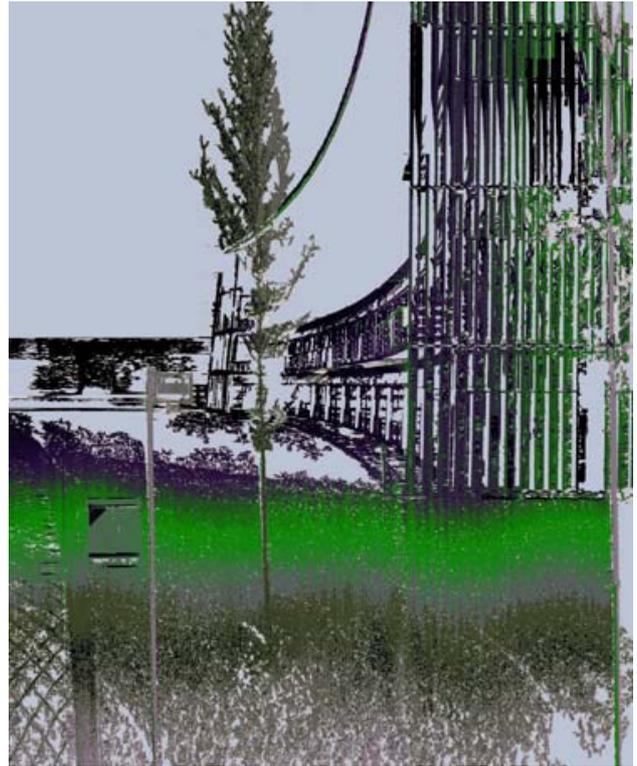


Figure 13: Disparity map

5. CONCLUSION

The combination of a CCD-line scanner and an IMU can get a practical meaning for scanning long objects, especially due to a further miniaturisation of inertial navigation systems. Algorithms and programs of airborne photogrammetry based on CCD-line cameras are nearly identical.

Because of the insufficient initialisation of the Applanix system while a stationary application the quality of a corrected panoramic image was not as good as necessary.

6. REFERENCES

- Scheibe K., Korsitzky H., Reulke R., Scheele M., Solbrig M.: 2001. EYESCAN – A High Resolution Digital Panoramic Camera: Lecture Notes in Computer Science, Proceeding New Zealand, pp. 77-83
- Börner A., Reulke R., Scheele M., Terzibaschian T.: Stereo Processing of Image Data from an Airborne Three Line CCD Scanner, Proceedings of the Third International Airborn Remote Sensing Conference and Exhibition, Vol. I, pp. 423 - 430, Copenhagen, 1997
- Reulke, R., Wehr, A., Klette, R., Scheele, M., Scheibe, K.: Panoramic Mapping using CCD-Line Camera and Laser Scanner with Integrated Position and Orientation System, IVCNZ2003, Palmerston North, pp. 72 –77

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