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Digital Photogrammetric Camera Evaluation – The Initiative of the German Society of Photogrammetry, Remote Sensing and Geoinformation (DGPF)

The testing and independent evaluation of the new digital airborne photogrammetric camera systems is an ongoing issue since the last few years. Driven by individual institutions or even national or international organizations such tests primarily are done to gain experience in digital camera performance and to finally support decisions when changing from analogue to digital sensor flights. Meanwhile some national mapping agencies have already decided to completely switch to digital image recording, selling their old analogue cameras and film development equipment. Still, comprehensive testing of the latest generation digital sensor systems including the quality analysis of sensor products (i.e. covering the whole process line) was typically not considered so far. Already finished or ongoing tests mainly looked for the geometric performance and resolution potential of sensors. Some others additionally focused on the radiometric quality of sensor data. Since all these tests originated from different test scenarios, generalisation and comparison of results is somewhat limited. In addition, sensor validation from independent test sites seems to become one standard process for future system certification. Thus, the optimal design of test procedures and test site layouts is another topic of concern. Empirical performance tests will also support the development and optimization of such processes and test sites.

Based on this and additional requests from camera and data users in photogrammetric working environments the German society of Photogrammetry, Remote Sensing and Geoinformation (DGPF) already end of 2007 started to define a test bed to comprehensively analyse the performance of new photogrammetric digital airborne camera systems. Based on empirically test data flown in a controlled test site the evaluation is focusing not only on the analysis of geometric accuracy and sensor calibration, additionally the radiometric performance including on-site radiometric calibration and multi-spectral land classifications is of concern. Furthermore the performance of photogrammetric DSM generation is considered, which is delivering one of the classical photogrammetric products. In addition the potential of manual stereo plotting from digital images is evaluated and compared to results from analogue images.

In order to allow for such comprehensive analysis, the data first of all has to be captured in similar test flight conditions and controlled environments. Thus different flight campaigns were done in the Vaihingen/Enz photogrammetric test site, which was established and maintained by Institut fuer Photogrammetrie (ifp), Universitaet Stuttgart. This test site close to Stuttgart is already known from other performance tests. It comprises close to 200 signalized and coordinated reference ground points distributed in a 7.4 x 4.7 km² area. Table 1 lists the different flight campaigns from summer 2008. The imaging data was flown at 6 different flight days during a 10 weeks time window starting beginning of July till mid of September 2008. Originally a much shorter 2 weeks time period was planned for data acquisition, which could not be realized due to weather conditions. All sensors were flown in two different flying heights, resulting in two blocks with different ground sampling distance (GSD), namely GSD 20cm and GSD 8cm. The GSD 20cm blocks were flown with 60%/60% overlap conditions, whereas for the GSD 8cm block a higher forward overlap of 80% was aspired. Unfortunately not all cameras finally fulfilled these overlap requirements. Additionally, some of the sensors were only flown in one flying height (namely the AIC-x1 and 3K-camera flights), others were affected by technical problems (e.g. defocus of one camera head of the DigiCAM quattro system, total malfunction of one of the AIC-x4 camera heads, sub-optimal settings for JAS-150 flight, partially necessitating a second flight). Block geometry also slightly differs due to the fixed test site extensions and different sensor formats; all this slightly influences the later comparison of sensor performances. The variations in weather conditions also have to be considered especially when looking for the radiometric test performance. Thus, main focus of this project is to derive the sensor specific strengths and maybe weaknesses, which are of relevance when later choosing a sensor for specific applications.

Additional flights were done with LiDAR and hyperspectral scanners. This data later is used as reference for the photogrammetrically derived surface models and multi-spectral land cover classification. Since additional DMC images were taken parallel to the AISA+ flight (double-hole aircraft installation) hyperspectral data can directly be compared to the camera grey values, which allows for the radiometric calibration of that camera. Additional spectrometer measurements were done on the ground, parallel to the sensor flights to get ground references for the later atmospheric corrections and sensor calibrations. This was supported by sun-photometer measurements, which determines the optical depth of the atmosphere, and thus also reflects weather and cloud conditions during the flights. Spectrometer measurements were done for artificial and natural targets. Bidirectional reflectance values were acquired with special measurement set-up. Figure 1 shows the largest part of the radiometric test range and ground team members during reference measurements parallel to the sensor flights. The artificial colour targets and different resolution test targets (Siemens star) can be seen. It has to be mentioned that the relatively small colour targets (size 2 x 2 m^2) typically were only sufficient for the GSD 8cm flights, especially when the original colour information is acquired with less spatial resolution compared to pan-chromatic images. This is the case for the DMC and Ultracam-X frame based sensor systems, where coloured large format images are obtained from pan-sharpening. For radiometric analysis the original colour information before pan-sharpening is of main interest. The remaining frame sensors are all based on the Bayer pattern approach for colour generation. To complete the reference data for comprehensive radiometric performance analysis, extensive field-walkings have been done for documentation of different land use. This especially was quite time consuming, because surveys have been repeated several times in order to document the changes in land coverage due to the quite long flight interval.

After finishing the test flights the data was prepared by sensor manufacturers and then delivered to the project pilot centre. It has to be mentioned that a sub-set of 19 control points has been given to each manufacturer for validation of data before deliverance. Pilot centre than distributes data to interested institutions. Data in general can be accessed from all types of institutions ranging from science, mapping authorities, photogrammetric companies and sensor providers. Nevertheless, in order to prevent misuse of data a project agreement has to be signed, where the aspired topics of analysis and schedule have to be fixed in advance for each participant. Till now (mid of February 2009), 25 different institutions have signed this contract and 18 of them have already requested and received data sets. Altogether they are forming a network of expertise which is doing the analyses in close cooperation. In order to structure this evaluation phase, 4 different working groups have been formed, each focusing on one of the already mentioned main topics:

- geometry (headed by Dr. K. Jacobsen, Leibniz Universitaet Hannover),
- radiometry (headed by Dr. M. von Schoenermark, Universitaet Stuttgart),
- digital surface models (headed by Dr. N. Haala, Universitaet Stuttgart) and
- stereoplotting (headed by V. Spreckels, RAG Herne).

Since data distribution started end of 2008 / beginning of 2009, dependent on availability of data sets, the processing still is under current progress and final results cannot been given at the time of writing. Nevertheless first results are already available which clearly underline the potential of new digital airborne camera systems. Figure 2 is given as only one example reflecting the high performance of automatic DSM generation using digital imagery. In this case the result from automatic point matching for analogue scanned RMK-Top images is compared to the results from DMC image data, both with GSD 8cm resolution. Since both cameras were installed in the same double-hole aircraft, their images were almost simultaneously recorded, resulting in identical atmospheric conditions for both data sets. A flat grassy sports field was selected as test object. The DSM generation was done using the inpho DTMaster software. The LiDAR point cloud is also given as reference. LiDAR data was captured with more than 5 pts/m². Colour coding reflects the terrain height. The much higher density of matched points from DMC images (close to 18 pts/m²) compared to classical RMK images (less than 1 pt/m²) is clearly shown. The 3D point cloud generated from DMC images is even denser than the reference LiDAR data. The higher radiometric quality of digital images obviously allows for much denser point matching. The matched points from RMK-Top image data are not sufficient to derive high accurate surface models. The vertical accuracy of points can be seen from the standard deviations obtained from individual height differences relative to the flat sports field surface. For the LiDAR data the std.dev. is about 2cm, almost without any gross errors. For DMC data this value is about 10cm, which is in the range of 1 pix GSD. Nevertheless, as you can see from the original DMC image used for matching, the point cloud is affected by erroneous matched points due to moving shadows. The effects from tree and floodlight pole shadows are clearly seen in the point cloud. Note that for point cloud visualization an ortho-photo obtained from another sensor flight was used. Thus the shadows cannot be seen in the lower two sub-figures. The shadow effect is well known in automatic surface model generation. Nevertheless, such gross errors might be eliminated by later filter processes. If std.dev. of height differences is re-calculated after 1.2% of 3D points (gross errors) have been eliminated from the DMC point cloud, the accuracy increases up to 6cm (std.dev.). This filter process is supported by the high point density for this configuration.

A comprehensive presentation and discussion of results will be given at this year's annual meeting of the German Society of Photogrammetry, Remote Sensing and Geoinformation which will be held in Jena, March 24-26, 2009. Three sessions have been dedicated to present the projects results and status. Additional papers already are scheduled for the ISPRS Hannover workshop High-resolution Earth Imaging for Geospatial Information (June 2-5, 2009) and the Photogrammetric Week 2009 in Stuttgart (September 7-11, 2009). Within first week of October than a DGPF project workshop will be organized in Stuttgart, where all team members and other interested people will meet to deeply analyse the obtained results.

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Project web site (in German) can be accessed via http://www.dgpf.de/ ▶Projekte ▶ Kameraevaluierung

System	Manufacturer	Flight company	Day(s) of flight
DMC	Intergraph/ZI	RWE Power	24.07.08 + 06.08.08
ADS 40, 2nd	Leica Geosystems	Leica Geosystems	06.08.08
JAS-150	Jenaoptronik	RWE Power	09.09.08
Ultracam-X	Vexcel Imaging Graz	bsf Swissphoto	11.09.08
RMK-Top15	Intergraph/ZI	RWE Power	24.07.08 + 06.08.08
DigiCAM quattro	IGI	Geoplana	06.08.08
AIC-x1	Trimble/Rolleimetric	Alpha Luftbild	11.09.08
AIC-x4	Trimble/Rolleimetric	Vulcan Air	19.09.08
DLR 3K-camera	DLR Munich	DLR Munich	15.07.08
AISA+ hyperspectr.	specim-FH Anhalt	RWE Power	02.07.08
ROSIS hyperspectr.	DLR Munich	DLR Munich	15.07.08
ALS 50 LiDAR	Leica Geosystems	Leica Geosystems	21.08.08

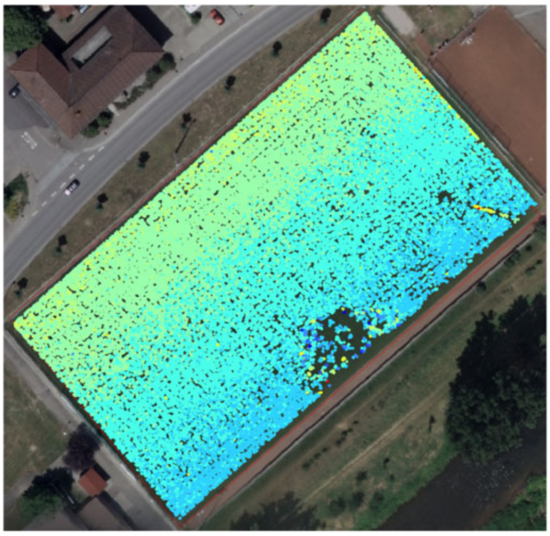
Table 1: Participating sensor systems and flight companies.

Figure 1: Ground teams performing reference measurements in radiometric test field.

LiDAR reference point cloud

DMC image used for DSM generation, test site sports field (GSD 8cm)

Point cloud from RMK-Top (GSD 8cm)



Point cloud from DMC (GSD 8cm)

Figure 2: Performance of photogrammetric surface model generation.