DGPF PROJECT: EVALUATION OF DIGITAL PHOTOGRAMMETRIC AERIAL BASED IMAGING SYSTEMS - GENERATION OF DIGITAL SURFACE MODELS

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ABSTRACT:

The Chair of Photogrammetry and Remote Sensing, ETH Zurich is one of the contract partners of the project „Evaluierung digitaler photogrammetrischer Luftbildkamerasysteme“ which was initiated by different photogrammetric university groups and companies and set up by the German Society of Photogrammetry and Remote Sensing (DGPF). The main aim of the project is to evaluate the geometric and radiometric potential of current available digital aerial imaging systems and to determine their individual qualified areas of application.

Such an independent investigation of several systems over the same testfield and under similar conditions for the image acquisition is very rare and important as a good chance for our community to gain a better understanding of the properties of the different systems.

Here we will present our first quantitative and qualitative evaluation results for generating digital surface models. The first two sensors which we will use here are: DMC (Intergraph/ZI) and Ultracam-X (Vexel Imaging). For these sensors image blocks with 8 cm and 20 cm footprint together with a set of orientation parameters for DSM generation are given for the evaluation process. Our very first results of the DSM generation show a quality coming closer to that one resulting from LiDAR data and in addition with a very high level of detail.

For the testfield Vaihingen/Enz a reference DSM with a grid spacing of 25 cm is given. It was derived from a LiDAR point cloud with 5 points/ m^2, what is less dense than the point cloud which we can get from the matching process from the image data. This leads to several problems for the evaluation of the full potential of the image data. In addition, we have significant time depending changes between the reference data and the generated DSMs using the image data. For a detailed analysis the test area is subdivided into subareas with different terrain features and land use classes. By this the potential of the image matcher and the different imaging systems can be analyzed more specifically. The accuracy of the generated DSMs strongly depends on the used matching algorithm. For all our tests we will use our in-house software package SAT-PP, which has been applied already successfully in many other aerial, space-born and terrestrial digital camera projects.

1. INTRODUCTION

Since 2000 different models of digital photogrammetric cameras of large format have been introduced and the commercial usage has steadily increased. Some major aerial camera users, like national mapping agencies (e.g. in Switzerland, France and Sweden) have stopped using aerial film cameras and switched to fully digital image acquisition. In spite of this and the many promising characteristics of digital vs. film cameras, these new systems have been very poorly investigated. (Cramer et al. 2009) gives an overview of the small amount of publications.

Motivated by the lack of significant and independent quality tests and analysis of the performance of the new sensors, the *Deutsche Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation* (DGPS, German Society of Photogrammetry, Remote Sensing and Geoinformation) initiated a project for the evaluation of the potential of current available digital photogrammetric cameras in question of geometric accuracy, radiometric quality and the quality of derived products from automatically DSM generation and stereoplotting by an operator. The digital cameras which are part of the evaluation process are the DMC (Intergraph/ZI), ADS 40, 2nd (Leica Geosystems), JAS-150 (Jenaoptronik), Ultracam-X (Vexcel Imaging), DigiCAM Quattro (IGI), AIC-x1 and –x4 (Rolleimetric) and the DLR 3K-Kameras. The details about this project are given in (Cramer et al. 2009) and (DGPF 2009). The main idea of the project is to acquire the image data over the same testarea under similar conditions and acquisition geometry. The aim of the project is not to compare the results of the different sensors, but to analyze the potential of each sensor and to find their specific application areas.

The Institute of Geodesy and Photogrammetry, ETH Zurich is one of the contract partners of the evaluation project. This paper will present our very first results in the field of DSM generation, analyzing the panchromatic image data of the DMC and the Ultracam-X camera, using our in-house software package SAT-PP (Satellite Image Precise Processing). More details about the underlying algorithms of the software are given in (Zhang 2005) and (Zang and Gruen 2006). A unique set of parameters of the image orientation is given to all members of the DSM evaluation team of the project. The set was determined by the Institute of Photogrammetry, University of Stuttgart, Germany.

Beside the mentioned requirements for homogenous conditions of the image acquisition and the use of the same testfield, a sufficient reference DSM in terms of quality and level of details is required. This reference data, resulting from a LiDAR point cloud, are described in chapter 2.4. We will see that the reference data are not sufficient in terms of level of detail for all our purposes.

2. DATA

2.1 Testfield Vaihingen/Enz, Germany

The testfield Vaihingen/Enz, Germany, which is used for the DGPF camera evaluation project, was set up by the institute of photogrammetry, University Stuttgart, Germany. The testfield has a dimension of 7,5 x 5.0 km^2 and it exists since 1995. It was successfully used for different former evaluation projects. The area contains different types of topography and kinds of land use classes like open areas, urban areas, forests and agriculture areas and special classes like two areas with open cast mining. The maximum height difference of the area is 180m.

2.2 Image Data

For both sensors which we analyze here, the DMC and the Ultracam-X, two different ground sampling distances (GSD) with 8cm and 20cm were available. Table 1 gives an overview of the image data and their characteristics. The bundle of DMC images has a maximal overlap of 9 images and the one of UC-X images of 15 images. Our results are focused mainly on the 8cm GSD image data. The only preprocessing of the image data was a wallis filtering to improve the image feature extraction.

Table 1: Overview of the image data of the two sensors DMC and Ultracam-X (UC-X).

Sensor	GSD	Acquis. Day/Time	Weather	Overlap	# images
DMC	8cm	24.07.08 / 9:49	Sunny	p=60% q=63%	110
DMC	20cm	06.08.08 / 10:06	Sunny	p=60% q=60%	42
UC-X	8cm	11.09.08 / 12:50	Sunny, cloudy	p=75% q=70%	175
UC-X	20cm	11.09.08 / 11:53	Sunny, cloudy	p=75% q=70%	36

2.3 Image Orientation

For the matching process and the 3D determination a unique set of orientation parameters, determined by the Institute of Photogrammetry, University Stuttgart, was given to all members of the evaluation team of the DSM evaluation. The different evaluation teams use different software packages which can handle different kinds of additional orientation parameters. Therefore a first triangulation was realized with additional parameters (44 parameters according to Grün) using 200 ground control points. In a second step the triangulation was repeated by using image points which were corrected according to the additional parameters and the new estimated object coordinates of the ground control points. The sigma naught values of the object points are significant better than one GSD in object space and are discussed in detail in (Cramers et al.2009).

2.4 Reference Data

As refernce data, an ALS50 (Leica Geosystems) LiDAR data set was acquired over the testfield Vaihingen/Enz. The main characteristics of the data set are given in Table 2. With a GSD of 8cm and 20cm and the expected accuracy of the determined surface points, the time depending changes of the vegetation and other objects in the scene might be significant which has to be taken into account for the evaluation process.

Table 2: Characteristics of the ALS50 data set.

Acquis. day	**Point density**	**Point distance "along"**	**Point distance "across"**	**Interpolated grid size**
21.08.08	5 pts/m^2	70 cm	45 cm	25cm

3. DSM RESULTS AND ANALYSIS

The DSM generation for these investigations was realized by using the software package SAT-PP. Therefore, all results published here, are valid for the combination of the used image data and this software package.
Figure 1 shows the color coded (height) and shaded visualization of the automatically generated, not post processed DSM of the whole testarea using the DMC 20 cm GSD dataset. No big blunders are detectable. The testarea contains one river and two open cast mining areas.

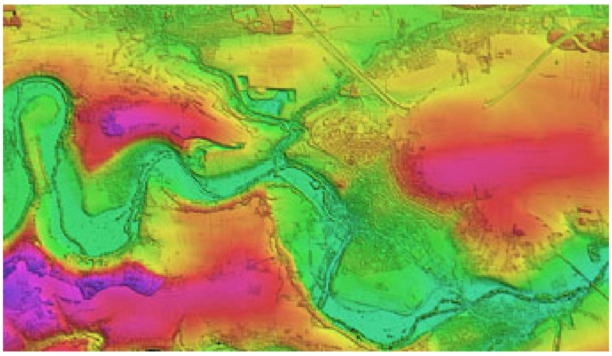


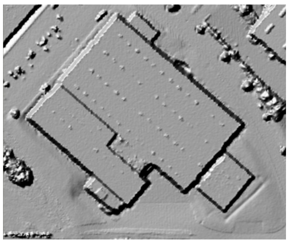
Figure 1: Color coded DSM of the testside Vaihingen, generated by using the DMC (20cm GSD) dataset and SAT-PP. No post processing was realized, no big blunders are detectable.

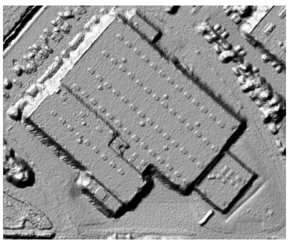
For a first evaluation of the results, we focused on the potential of the high resolution image data in general. Therefore we generated DSMs with a resolution of approximately 3 times the GSD which means 25 cm for the 8cm GSD data sets and 60cm for the 20cm GSD data sets. The time difference between the acquisition of the image data and the reference data is too huge to take the whole area for the quality tests. Especially the vegetation can change a lot. But also other changing objects like moving and parking cars influence the evaluation results because of the very high level of detail. Therefore, only small and manually defined areas can be used for a qualitative analysis. Also the reference LiDAR data set was acquired with a dense of 5 pts/m^2 which means, that the accuracy of the points is very high, but the density is not high enough for several purposes. The generated DSMs can contain more details than the reference DSM.
For the evaluation process, the acquired point cloud of the laser scan should be used as master data set instead of points of the interpolated DSM. By this you can get more independent evaluation results. However, for the results presented here, we had to realize the evaluation between the two interpolated DSMs.
In the following we will present our first results in an industrial, a residential and in an open area.

3.1 Industrial Area

Because of moving and changing objects and missing details in the reference data, we did not realize an area based comparison for a city area. Therefore we evaluated a DSM of a single industrial building (Figure 2) and its profiles (Figure 3) visually as well as the generation of the flat roof by determining the RMSE for only profiles (Figure 4) and the matched 2D points of the roof (Figure 5).
The length of the huge industrial building is 113 m (see Figure 2). The above mentioned leakage of details in the LiDAR DSM is visible. The small structures on the roof are only rudimentarily determined, fences and small walls got also lost in the LiDAR data set. What we can also see by comparing Figure 2a) and Figure 3a), is the different conditions of shadows in the two data sets.
The visual check of the profiles given in Figure 4, shows the high potential of the digital high resolution image data. We have no blunders and the main structure of the building is determined well. The roof is generated well, as expected the main error up to 6 m are in the areas of upright walls.
Figure 5 shows the density of the matched image points of the industrial area. We can see that the matcher has problems in the heavy shadowed areas of the DMC image data. In other areas the matcher has similar problems for both sensors. In these areas we had nearly no texture or a very regular texture. For one building, the matcher had only problems with the UC-X data. Comparing the original image texture of both image data, you can see that during the DMC image data acquisition the building was a construction side with an inhomogeneous image texture. When the UC-X image data were acquired, the building was finished and the roof had a very homogeneous texture (see Figure 6a)). In comparison to the DSM generated by using the UC-X, 20cm GSD image data, the influence of the texture on the resulting DSM was less.


a) UC-X, 8cm GSD.


b) ALS50, interpolated DSM.


c) DMC DSM,
6 image overlap.

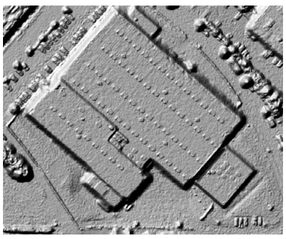
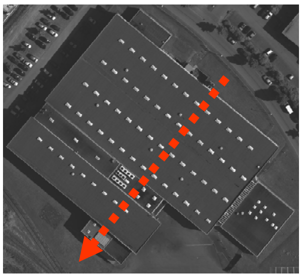
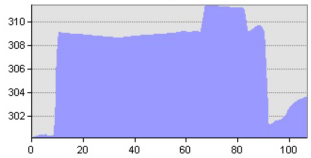
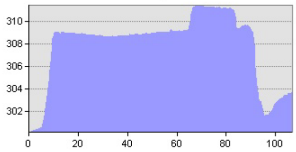
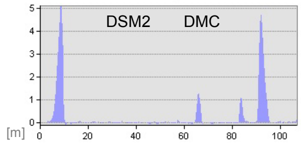

d) UC-X DSM,
10 image overlap.

Figure 2: Industrial building with a length of 113m. a) DMC original image data, b) reference LiDAR data, shaded visualization of the interpolated DSM, c) DMC, 8cm GSD, DSM 25cm, d) UC-X, GSD 8cm, DSM, 25cm.

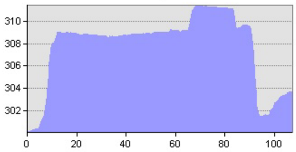

a) DMC, 8cm GSD with the direction of the profile

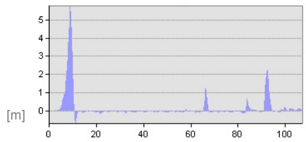

b) Profile in the reference LiDAR data set.


c) Profile in the DMC, 8cm GSD, 25cm DSM.



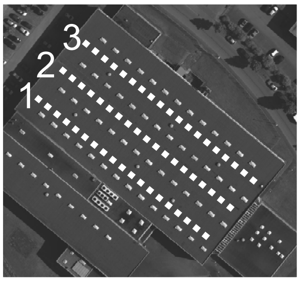
d) Differences along the profile


e) Profile in the DSM, UC-X, 8cm GSD, 25cm DSM.

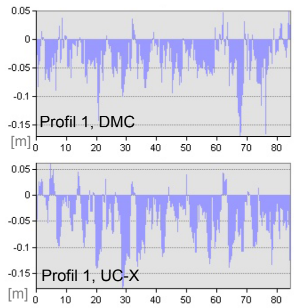


f) Differences along the profile

Figure 3: Profiles of the industrial building and their errors along the profiles..



a) DMC, 8cm GSD with the profile positions (length 85m).

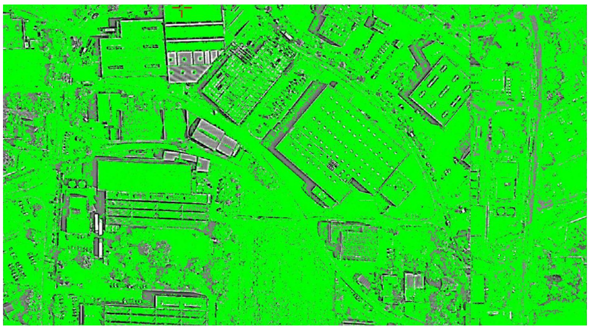


b) Profile 1 in the DMC and the UC-X, 8cm GSD DSM.

Figure 4: Three profiles of the industrial building for RMSE determination.

Table 3: RMSEs for the three profiles of the industrial building. The profile length is 85m.

Profil	RMSE [m]	Mittel [m]	Min [m]	Max [m]
1 DMC	0.05	-0.04	-0.17	0.05
2 DMC	0.03	-0.02	-0.1	0.07
3 DMC	0.03	-0.06	-0.09	0.05
1 UC-X	0.07	-0.05	-0.18	0.06
2 UC-X	0.06	-0.04	-0.13	0.09
3 UC-X	0.08	-0.06	-0.18	0.06



a) Matched image points in a DMC, 8cm GSD image.

b) Matched image points in a UC-X, 8cm GSD image.

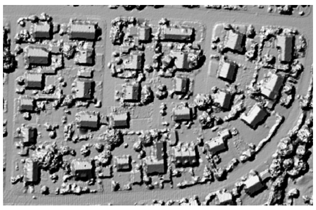
Figure 5: Matched image points in an industrial area.

Figure 6: Problems with a homogeneous texture of a flat roof. Left: the original UC-X image. Middle: the resulting DMC, 8cm GSD DMS. Right: the resulting DMC, 20cm GSD DMS.

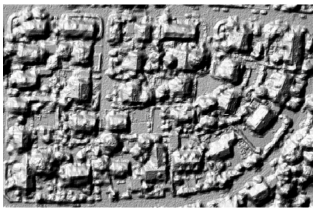
3.2 Residential Area

In a second sub area of the city we have focused on a residential area (see Figure 7). Comparing the interpolated DSM of the reference data and the generated DMC DSM and UC-X DSM, the difference in level of detail for both image data sets are again visible. Small walls are missing in the LiDAR data set.

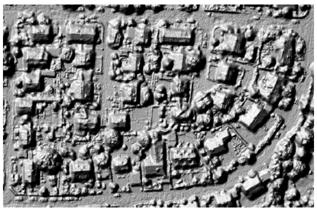
a) Original UC-X image data.



b) Reference LiDAR data.



c) DMC, 8cm GSD DSM.



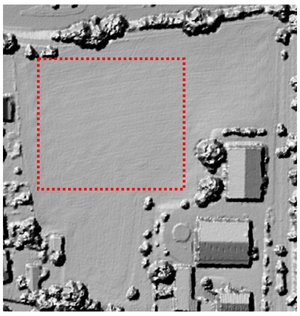
d) UC-X, 8cm GSD DSM.

Figure 7: DSM examples of a residential area.

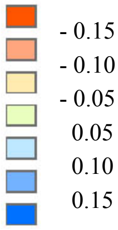
3.3 Open Area

The open area which is shown in Figure 8 could be used for a determination of an area based RMSE. The time depending differences between the data sets are not significant. The 2.5D RMSEs, given in Table 4, are for all data sets better than one pixel. There might be still small time depending differences. The regular structure of the error image of the UC-X sensor in Figure 8 f) shows small changes, resulting from different cuttings.

The results are in the same range like the results represented in (Haala and Wolff 2009) for a soccer ground.

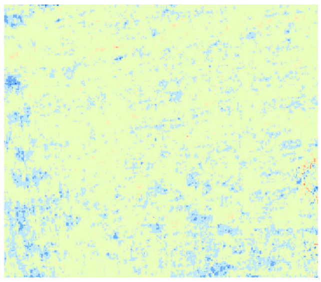


a) Reference DSM



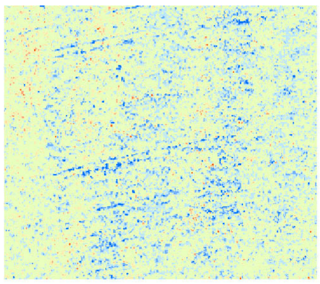
b) Caption of differences

c) DMC, 8cm GSD



d) Color coded differences

e) UC-X, 8cm GSD



f) Color coded differences

Figure 8: Evaluation in an open area

Table 4: 2.5D RMSE for the evaluation of an open area (78624 analyzed points).

Sensor	RMSE [m]	Mittel [m]	Min [m]	Max [m]
DMC, 8cm	0.03	-0.02	-0.19	0.20
UC-X, 8cm	0.05	-0.02	-0.37	0.23
DMC, 20cm	0.07	0.10	-0.42	0.42
UC-X, 20cm	0.10	-0.14	-0.69	0.32

3.4 Additional Investigations and Examples

The image overlaps of the data are very high (DMC up to 9 images, UC-X up to 15 images). Figure 9 shows the differences of the generated surface for a 3 images overlap and for a 5 images overlap, which makes the surface much smoother.

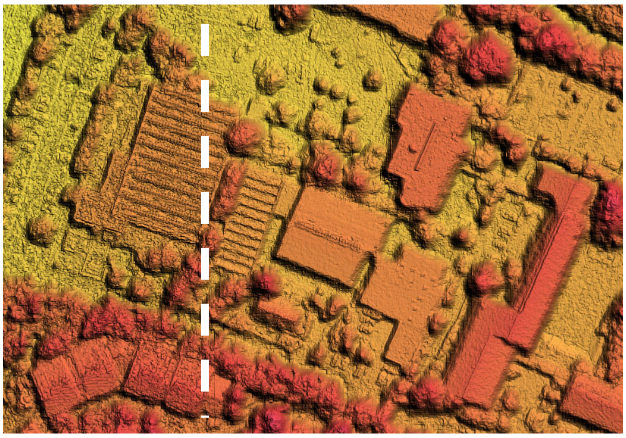


Figure 9: Visual evaluation of the influence of the degree of overlap for the UC-X, 8cm GSD DSM. On the left side we have an overlap of only three images. On the right side we have an overlap of 5 images which makes the surface much smoother.

Figure 10 and Figure 11 show two more examples of special observation objects: the DMC, 8cm GSD DSM of a vineyard and the UC-X, 8cm GSD DSM of an industrial building with solar panels on the roof. Both results show the high level of details and potential of the image data.

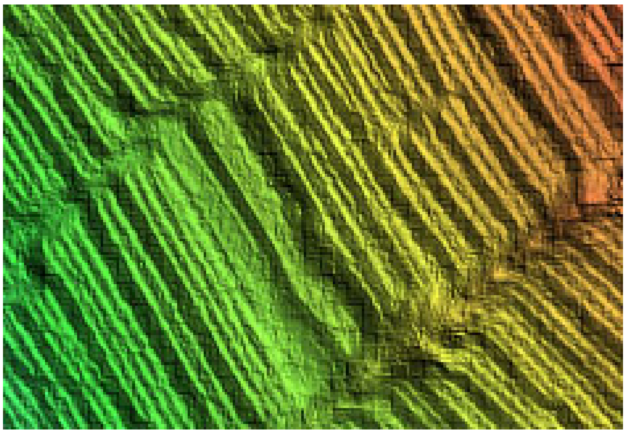


Figure 10: Example: DMC, 8cm GSD DSM of a vineyard.

Figure 11: Example: UC-X, 8cm GSD DSM of a industrial building with solar panels on the roof.

4. CONCLUSIONS

This paper reports about the first evaluation results of the DGPF camera evaluation project for DSM generation using SAT-PP. The results were obtained for two cameras, the DMC, (Intergraph/ZI) and the Ultracam-X (Vexcel Imaging Graz). These results give a first reference of the high potential of digital photogrammetric image data for DSM generation.

In detail we did a first visual and qualitative analysis in an industrial, a residential and in an open agriculture area, mainly for the 8cm GSD data sets. To get a first impression of the potential of the image data, we analysed the DSMs for a very small grid size:approximately 3 times the GSD, resulting in 25cm for the 8cm GSD and 60 cm for the 20cm GSD data sets.

The given reference DSM was generated by interpolating a LiDAR point cloud (ALS50, Leica Geosystems) with a point density of 5 pts/m^2. The accuracy of the elements of the point cloud is sufficient, but their density is especially in areas like industrial and residential areas not sufficient. The point density of the matching results and the level of detail are very high. Therefore, the reference DSM should be 2 to 3 times denser. Many details which could be reconstructed by using the digital image data are not included in the reference data. This gives in addition to many time depending significant changes restrictions to the evaluation process.

The promising first results give us motivation for going on with the investigations and with the work with digital high resolution aerial image data for automatic DSM generation. For our future investigations, we will realize analysis for more different land use classes and special problems and questions, e.g. focusing on shadow areas. For the evaluation we will not use only the interpolated DSMs, but also the 3D point clouds of the laser scan and the matching process. The idea of the DGPF project is also to use the results of the other teams, like e.g. the manual measurements of the stereo plotting team as reference data. We will report further developments and analysis also for the other digital sensors in the future.

REFERENCES

Cramer M., Krauß H., Jacobsen K., von Schönemark M., Haala N., Spreckels V., 2009. Das DGPF-Projekt zur Evaluierung digitaler Photogrammetrischer Kamerasysteme. Tagungsband 18 / 2009, Jahrestagung DGPF Jena, Germany.

DGPF 2009: DGPF Projekt: Evaluierung digitaler photogrammetrischer Kamerasysteme. Homepage of the DGPF project, http://www.dgpf.de/neu/projekt/DKEP-Allg.html.

Haala N., Wolff K., 2009. Digitale photogrammetrische Luftbildkamerasysteme – Evaluation der automatischen Generierung von Höhenmodellen. Tagungsband 18 / 2009, Jahrestagung DGPF Jena, Germany.

Zhang L., 2005. Automatic Digital Surface Model (DSM) Generation from Linear Array Images. PhD Dissertation, Mitteilungen Nr 88, Institute of Geodesy and Photogrammetry, ETH Zurich.

Zhang L., Gruen A., 2006. Multi-image matching for DSM generation from IKONOS imagery. ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 60, No. 3, pp. 195-211.