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ISPRS BENCHMARK FOR MULTI-PLATFORM PHOTOGRAMMETRY

REPORT OF THE SCIENTIFIC INITIATIVE

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MAIN OBJECTIVES AND PARTNERSHIPS

The main aim of the project is to assess the accuracy and reliability of current methods for image calibration and orientation of multi-platform imagery as well as their integration for dense point cloud generation. Data collection for this project has focused on two different areas, showing different terrain and building style and epochs.

The project has been realized in collaboration with EuroSDR which partially supported the oblique camera data acquisition as overlapping its Commission I research activities. The dense image matching assessment task is being conducted in close cooperation with the University of Stuttgart, in particular with Nobert Haala who is PI of another ISPRS Scientific Initiative (SI) and PI of the related EuroSDR research activity.

In the first year project (Jan 2014 till Dec 2014) we worked on the extensive data collection - which involved many parties, a huge organizational and time effort – and just partly on the data structuring and processing. In this second year (Jan 2015 till Dec 2015) the goals have been to acquire some missing Ground Control Points, develop evaluation methods and release the available data to the scientific community.

The PI and co-investigator of the SI hereafter reported are Francesco Nex (FBK, Italy - ITC / University of Twente, The Netherlands since May 2015) and Markus Gerke (ITC / University of Twente, Netherlands).

BENCHMARK DATA COLLECTION – COMPLETION OF THE WORK

In the first year of project two different test areas have been acquired over the city of Dortmund: 1) the city center of Dortmund and 2) the Museum area – Zeche Zollern. In both areas, complete terrestrial, UAV and

oblique aerial images were acquired. Several Terrestrial Laser Scans (TLS) were also acquired on several selected façades as ground truth. GNSS and Total Station (TS) surveys were also performed in the surrounding of the selected building (red rectangles in Image 1). However, this first survey was just sufficient to define the complete work for the terrestrial and UAV images, but it needed to be extended for the orientation of the Oblique dataset. For more information about the acquired data, please refer to the report of the first year.

(a)   (b)
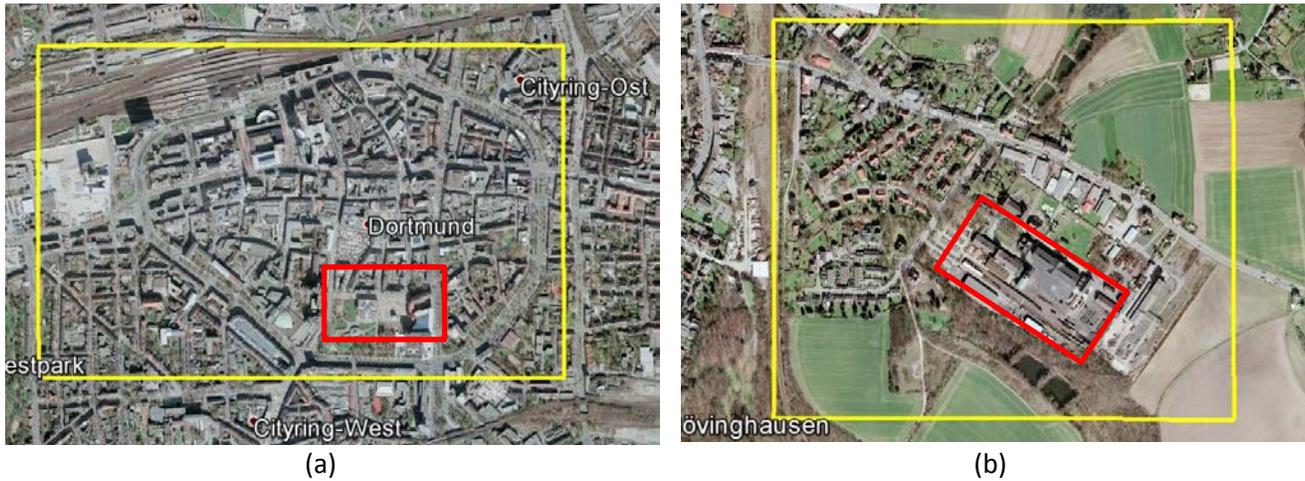
Figure 1: Areas in City center (a) and Museum – Zeche Zollern (b).

In the second year the GNSS acquisition has been completed, thanks to the collaboration with the Survey office Zurhorst (Olpe, Germany) that performed the survey on the area of interest (yellow rectangle in Figure 1). 30 points on the first area (city center) and 26 in the second area (Museum – Zeche Zollern) were acquired with a GNSS RTK survey. The points were homogeneously distributed according to the Principal Investigators' indications.

(a)   (b)

Figure 2: Collected GCPs in the City center and in Museum area – Zeche Zollern (not all the collected points are displayed in the image)

A complete record of the GNSS compensation was provided as well: 2-3 centimeter precisions were achieved on all the surveyed points. In Figure 2, the collected GCPs in both areas are shown (Yellow, blue and red crosses).

DATA PROCESSING

Several tests have been performed on the acquired images in order to preliminary check the quality of the data before their delivery to participants. In particular:

a) **Image matching task:** in addition to the tests performed in the first year, the image orientation of the delivered images and their corresponding camera calibration were checked in the test areas. Detailed documentation is also available for download in the website. Different calibration formats and orientation files (according to different software) can be used by participants to prepare the images before running their matching algorithm. For more information, please refer to the update webpage. A more detailed information on the performed tests can be found in (Nex et al., 2015). An example of some preliminary test is shown in Figure 3a.

b) **Image orientation task:** different image configuration were tested in order to check and verify the data before the delivery. The Pix4D software has been extensively used for the performed cases (see Figure 3b). Different camera calibration files and documentation (about the adopted convention) have been prepared and are they available for participants in the download page. In collaboration with Dr. K. Jacobsen (Leibniz University of Hannover) and IGI mbh, Dr. Kremer, image orientation got also computed for both areas. Preliminary results were presented at the EuroSDR workshop on oblique imagery and dense image matching in Southampton, October 2015.

(a)   (b)
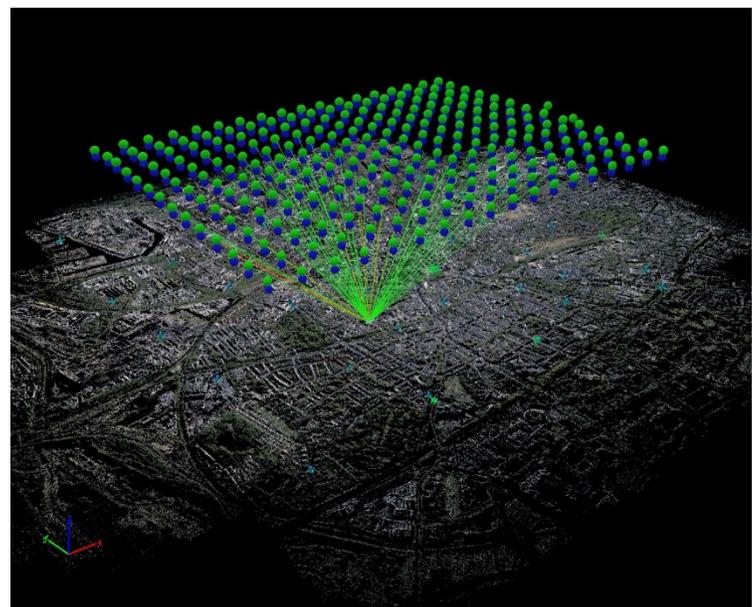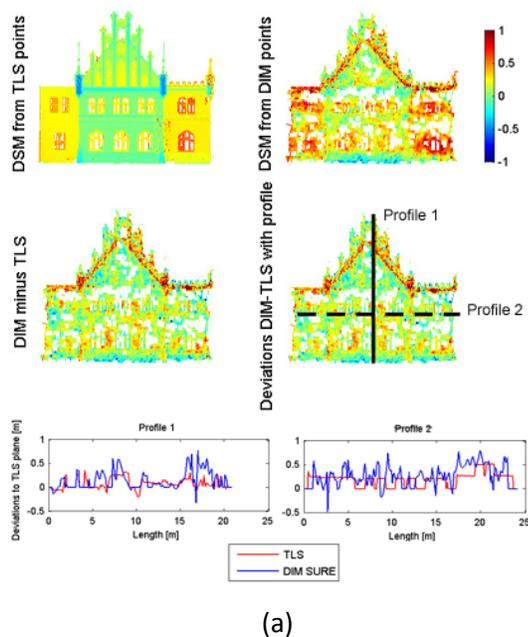
Figure 3. Examples of checks performed in the image matching (a) and the image orientation (b) tasks.

EVALUATION CRITERIA AND PROCEDURES

The benchmark focus is on two main goals: a) **dense image matching**, b) **image orientation**. Four different tasks have been set up to exploit the data acquired on both the test areas and to deliver to participants reliable and challenging datasets.

Task A)

Dense image matching evaluation. As already mentioned, this task is performed in cooperation with the EuroSDR's Scientific Initiative "Benchmark on High Density Image Matching for DSM Computation" (http://www.ifp.uni-stuttgart.de/EuroSDR/ImageMatching), joining both the two available datasets (one EuroSDR dataset and our dataset) . The efforts of both the initiatives are contributing to set up a more complete and challenging dataset considering flights with different features (in terms of GSD size and overlap).

Participant results are evaluated according to the methodology described in (Cavegn et al., 2014). The necessary images, TLS and ALS data have been already oriented and registered together for the data delivery: on the other hand, no GCP or CP are provided since that kind of information is necessary for Task B, later.

Two different scenarios are considered:

Scenario A) *Dense image matching in oblique and nadir airborne imagery*

A sub-dataset of the Area 2 (Zoche Zollern) has been selected, in particular the "administration building" is used for dense matching evaluation. The 85 oblique images from this area and their exterior orientations, as well as camera calibration protocols, are delivered to participants. The results evaluation is performed using the TLS data of the administration building. In order to make ease participants' tasks, undistorted images have been recently added to the available dataset.

Scenario B) *Dense image matching in a combined terrestrial and UAV image block*

The (228) UAV and terrestrial images as well as their orientations are delivered on the same area. The point clouds provided by participants are compared to the ground truth according to the above mentioned methodology.

For more information, please refer to the following webpage:

http://www2.isprs.org/commissions/comm1/icwg15b/benchmark/description_Dortmund.html

Task B)

Image Orientation evaluation. This task is focused on the image orientation assessment of two different image block configurations. Compared to the original plan, it was decided to limit the work to these two configurations in order to focus on the options with an higher chance to be used by participants and get some results back.

For each scenario, a set of images are delivered together with GCPs coordinates; image coordinates of both GCPs and CPs are provided, too. Specifications about the adopted reference system and the features of the used camera are reported as well.

Participants are requested to deliver CPs coordinates in object space and the sparse tie-point clouds. The evaluation will be performed considering the residuals on CPs and the mean deviation of sparse point cloud from reference data (TLS and ALS) on some selected planar surfaces (as reported in Nex et al., 2015).

Scenario A) *Orientation of large airborne multi-view image image blocks*

The city center of Dortmund has been considered for this part of the benchmark. A sub-set of the complete oblique image block (1204 images, IGI Pentacam) is delivered: about 300 images with a 60% along-track and 60% across-track overlap is considered. The benchmark organizers decided to reduce the number of images in order to fasten the data download and make the image orientation of the image block more challenging.

The approximate orientation achieved by direct sensor orientation solution[1], and the lab camera calibration are disclosed. However, orientation parameters have been approximate to the closest integer value, to allow the exploitation of this information to guide the image concatenation without taking concrete advantage from the direct solution.

The benchmark organizers have prepared the orientation parameters and detailed documentations describing the configurations and the conventions adopted in the interior and exterior parameters.

Participants are requested to provide, in addition to the above listed outputs, the EO elements they computed for all images to enable us to ensure that all images got adjusted. The sparse point cloud is compared to some reference planes, derived from ALS and TLS (in correspondence of roof faces and large building facades) to assess the deformations, especially in the border of the block (as already mentioned).

In order to test better for remaining systematic errors in the bundle solution GCPs are NOT evenly distributed on the area (see Figure 1 a), but concentrate them on the sides of the block. In this way, the participants will need to extrapolate within the block and deformations will be better visible from the CPs residuals.

Scenario B) *Image orientation and calibration across UAV and terrestrial platforms*

This scenario will only focus on UAV and terrestrial images. The images in correspondence to the "Rathaus, city hall" building are provided together with a minimum number of GCPs placed just on one side building and the approximate position given by the onboard GPS devices (see Figure 4).
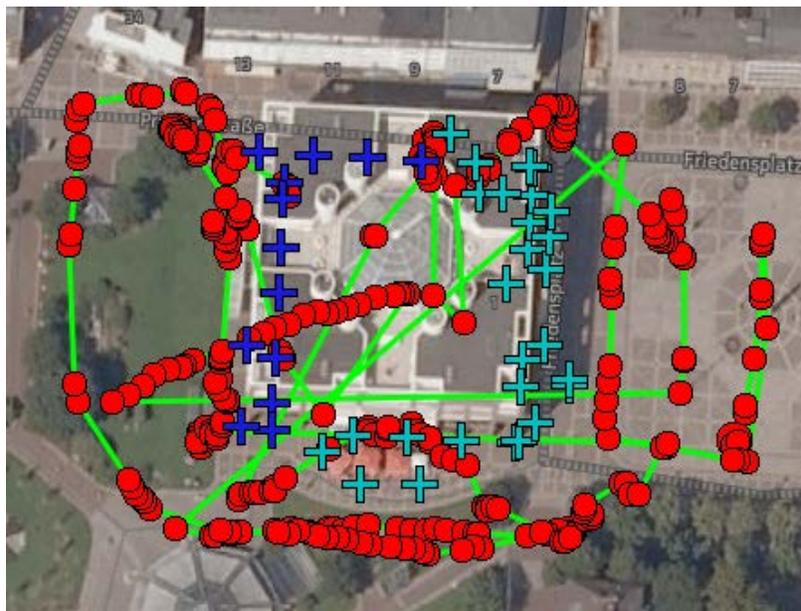

Figure 4. Examples of checks performed in the image matching (a) and the image orientation (b) tasks.

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[1] According to H.J. Benfer from Aerowest we can expect an error of the direct sensor orientation solution of about 10pix.

The image coordinates of GCPs and CPs are provided to the users as well. As in the other scenarios, the output for the test evaluation are the 3D coordinates of CPs as well as the sparse point cloud generated with tie-points, and the final EO elements.

For more information, please refer to the following webpage:

http://www2.isprs.org/commissions/comm1/icwg15b/benchmark/data-description-Image-orientation.html

DATA DELIVERY

The dedicated webpage on the ISPRS website have been improved with the developments of the second year of the project (http://www2.isprs.org/commissions/comm1/icwg15b/benchmark.html). Any new participants provide his/her credentials (name, institution, mail, etc.) on this webpage and can directly download the available data. Both the data for the image matching evaluation and image orientation (since August 2015) are available for download.

As already mentioned, the matching part is in collaboration with EuroSDR. For this reason, every participant will receive the credential to download both our and the EuroSDR's dataset. The results provided by participants are shared on a dedicated webpage that will be constantly updated in the following months/years.

DOWNLOAD, STATISTICS AND NEWSLETTER

The benchmark data have been appreciated by the scientific community, with a quite high number of downloads performed in the last months. A list of Scientists who downloaded each dataset has been collected. This mailing list has been already used to communicate the last news and/or the new releases of the benchmark data. A table reporting the number of downloads is shown below (as of mid-December 2015).

Task	Data available from:	Downloads
Image Matching	15 February 2015	198
Image Orientation	15 August 2015	44

Table 1. Downloads of the benchmark data

The above reported numbers refer to the direct downloads: unofficial copies of the data among scientists or copies requested to the benchmark organizers during conferences of meetings are not included in these statistics so far. The high number of downloads is so far not reflected in a high number of results for the benchmark evaluation. The benchmark organizers are still actively advertising the benchmark aims. On the Benchmark's webpage, only the last advertisement is reported, but many other actions have been performed in these months. Many newsletters have been sent to the mailing list without great reaction from their side. Researchers involved in the EuroSDR's Scientific Initiative "Benchmark on High Density Image Matching for DSM Computation" have undertaken similar actions, without succeeding as well.

DISSEMINATION

The Scientific Initiative has been largely advertised during some events held in 2014 (see report first year). In 2015, this work has been continued by the two researcher involved. One **paper** has been presented in the PIA conference 2015 (March 2015, Munich, Germany); a **poster** and the **flyers** for attendants have been presented and distributed at the Geospatial Week 2015 (September 2015, Grande Motte, Germany).

The benchmark aims have been presented in other national and international events related to the use of UAV and oblique images.

The EuroSDR (Commission I) organized a workshop on the use of oblique images in Southampton (19-21 October 2015). A **special session** of the conference was dedicated to the benchmarks: the benchmark investigators had the opportunity to advertise the Scientific Initiative to a more focused audience. This was also the right opportunity to present the next incoming scientific events and highlight the importance of feedbacks from participants. EuroSDR is also advertising the initiative in several meetings and conference held with NMCAs and private sector companies.

An **abstract paper** (Archives) has been just submitted for the ISPRS Conference that will held in Prague next year. In this paper, the very first results provided by participants will be shown.

As already mentioned, two **mailing lists** (one for each task of the benchmark) have been set up (http://www2.isprs.org/newsletter.html) in order to promote and quickly disseminate the news about the future progress of the Scientific Initiative. The benchmark webpage (in the ISPRS WG I/Vb website) is continuously updated with the last news and progresses.

ACKNOWLEDGEMENTS

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