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 focusses on two different areas, showing different terrain and building style and epochs.

The project has been managed 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 this reporting period (Jan 2014 till Dec 2014) we have been concentrating 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 a follow-up SI project (see separate application) the goals are to acquire some missing ground truth, develop evaluation methods and release the available data (other than the data we publish this year in the dense image matching context) to the scientific community.

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

BENCHMARK AREAS, DATA ACQUISITIONS AND PRE-PROCESSING

Two different test areas have been acquired over the city of Dortmund. These areas have been chosen according to different criteria, such as: (i) different typologies of buildings; (ii) security for people and instruments and easy accessibility to the whole area; (iii) technical support and availability of local surveying companies. We worked with ÖbVI Zurhorst (Aerometrics, Olpe, Germany) for drone image acquisition and the

Bochum University of Applied Sciences for TLS and control point surveying by GNSS and total station; (iv) possibility to get flight permission over build-up areas (for UAV flights).

1)   **City center – Dortmund** (Figure 1): it is a dense urban area with tall modern buildings as well as historical façades (churches and public buildings) as shown in Figure 1. The **yellow area** defines the area acquired by the airborne oblique image system (IGI PentaCam) while the **red area** shows the areas acquired by UAV platforms and terrestrial images as well as by TLS. This second area contains besides others the Dortmund town hall and public offices. Dortmund's cadastral authorities actively supported the data acquisition and, as a consequence, we were permitted to glue some markers (for GCPs collection and TLS scans registration) on the windows of these buildings.

Figure 1: City center (Dortmund) test area.

Data acquired on that area are listed below:
-   **a) Oblique images**: 1210 images (252 images for each camera) were acquired with PentaCam IGI (flown by AeroWest - Dortmund) on May 19, 2014, around approximately 10-12h CET. The GSD is 10 cm in nadir images and varies from 8 to 12cm in the oblique views. The overlap is 75% / 80% (along / across-track directions) for the nadir images while it is 80% / 80% for oblique images.
-   **b) UAV**: A multi-rotor DIJ S800 (provided by ÖbVI Zurhorst) was used for the data acquisition on June 8, 2014: 1073 images were acquired with this drone over the "Rathaus (city hall)", the "Stadthaus" as well as the obelisk and the surrounding square area. The images were acquired during 4 different flights and an image GSD ranging from 1 to 3 cm was adopted in each flight. Both nadir and oblique images were acquired on the area. The camera used with the drone was a Sony Nex-7 (the same as used for terrestrial acquisition, see below). Note that because of bad weather the UAV flight needed to be done some weeks after the terrestrial acquisition. Targets at the buildings were no more available then.
-   **c) Terrestrial images**: The whole area was surveyed using three different cameras on May 11, 2014: Ricoh GXR (1724 images), Sony Nex-7 (2858 images) and Canon 600D (1452 images). The images were

acquired considering different distances from the analyzed object and using convergent and rotated views in order to enable the complete object reconstruction.

d) **Terrestrial Laser Scanner (TLS):** Terrestrial Laserscans were acquired by Hochschule Bochum (person in charge Prof. Przybilla) using a ZF 5010C scanner, a scanner with 1 mm accuracy on May 11, 2014 as well. The two main buildings and the surrounding square were acquired using a 2 mm resolution step.

e) **Aerial Laser Scanner (ALS):** Point clouds over the test area were provided by the Municipality of Dortmund for free. The point clouds have an approximate 10 pts/m^2 resolution.

f) **Total station (and GNSS RTK in the red area):** A topographic network and a GNSS survey were finally set up by Hochschule Bochum (Prof. Przybilla) for the geo-localization of the data. This data was acquired on the same day with the terrestrial images and TLS. 17 ground control points with a good distribution, as well as 91 target coordinates on the building façades where surveyed as GCPs and CKs. Two GNSS Leica-1200 and Leica total stations were used for this task. All points were transformed to UTM, Zone 32N. The TLS scans were registered in that system, as well.

g) **GNSS survey in the yellow area:** as it will be explained in the following sections, this is the **missing part of the benchmark**.

2)   **Museum area - Zeche Zollern** (Figure 2). The area covered by oblique image system is depicted in **yellow** while the area surveyed by UAV, terrestrial images as well as TLS is defined by the **red rectangle**. As in the former case, yellow rectangles comprise areas where complete information will be assured (i.e. 5 looking directions provided by oblique system). The museum administration actively supported the data acquisition and collaborated during the survey: targets were glued on façades of some test buildings. We were lucky with the weather this time: the entire on-site acquisition (UAV, terrestrial images plus control and TLS) took place on one day: May 19, 2014, i.e. at the same day with the airborne image flight: most of the targets at the buildings are also visible in the airborne images.

Data acquired on that area are listed below:

a) **Oblique images**: 905 images taken by AeroWest (Dortmund) with the PentaCam IGI system. The image GSDs and the overlaps are the same of the former test area; the images were taken during the same flight (i.e. on May 19, 2014).

b) **UAV**: Two different UAVs have been used for the image acquisition task: the DIJ S800 multi-rotor platform and the Mavinci fixed wing airplane. Both the platforms were provided by ÖbVI Zurhorst. A Sony Nex-7 was installed onboard the multi-rotor system, while a (lighter) Panasonic GX-1 was mounted on the Mavinci UAV (584 images). The multi-rotor UAV allowed to take both nadir and oblique image views of the Zeche museum areas (1305 images). Using the fixed-wing platform we captured 584 nadir images on a wider area (i.e. the museum as well as the surrounding buildings).

c) **Terrestrial images**: Two different cameras were used for the data acquisition (Canon D600 with Voigtländer fix focus lens, Sony Nex-7). Three different buildings ("lohnhalle", "pferdestall" and "verwaltung") were acquired with both the cameras. Canon D600 captured 720 images while Nex-7 968 images. A sub-centimeter GSD was assured in all the acquisitions.

d) **Terrestrial Laser Scanner (TLS):** Again the group from Hochschule Bochum joined to retrieve high quality scans of the objects of interest, see c) above.

e) **Aerial Laser Scanner (ALS):** Point clouds over the test area were provided by the Municipality of Dortmund for free. The point clouds have a 10 pts/m^2 resolution.

Figure 2: City Zeche Zollern test area.

f) **Total station**: A topographic network was realized using Leica instruments: 176 targets on the building façades and 46 points on the ground of the museum area and the surrounding car-park were acquired as GCP / CP.

g) **GNSS acquisitions**: Static acquisitions were performed on several points in the museum area to assure a better acquisition. Two Leica-1200 instruments were used for this task.

h) **GNSS survey in the yellow area:** as it will be explained in the following sections, this is the **missing part of the benchmark**.
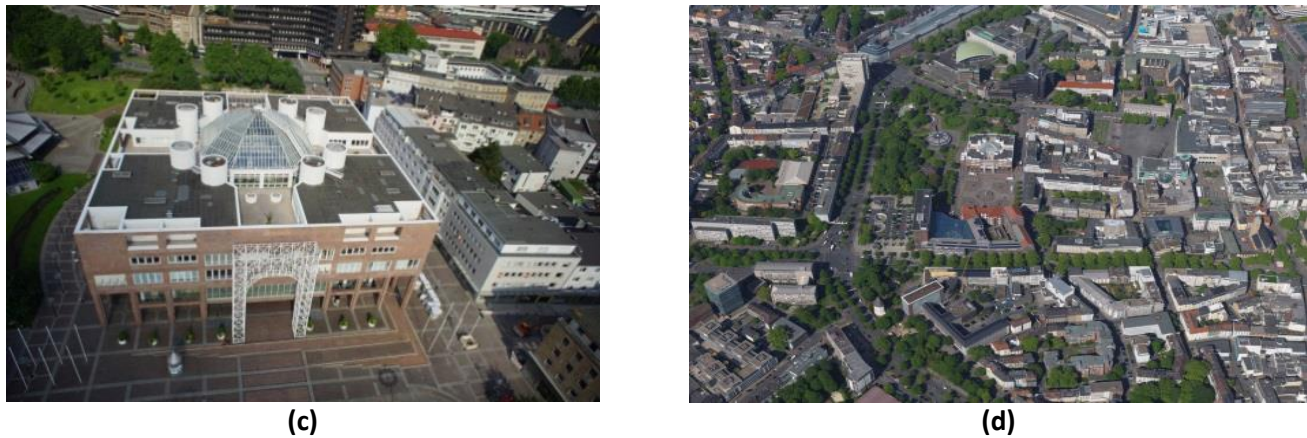

(a)   (b)

(c)

(d)

Figure 3: Example of the acquired terrestrial (a), zoom to show the targets (b) UAV (c) and airborne oblique images (d).

A total amount of about 2TerraByte was collected in the data acquisition. Figure 3 shows some sample images.

DATA PROCESSING

The captured **images** are too many to be directly delivered to the participants. Some of them are redundant (as from the same position) or they have poor quality (i.e. blurred, occlusions by moving objects/persons, etc.). A subset for each dataset was therefore manually selected, reducing the number of images without losing in data completeness. Some preliminary tests have been performed considering these datasets (Figure 4).
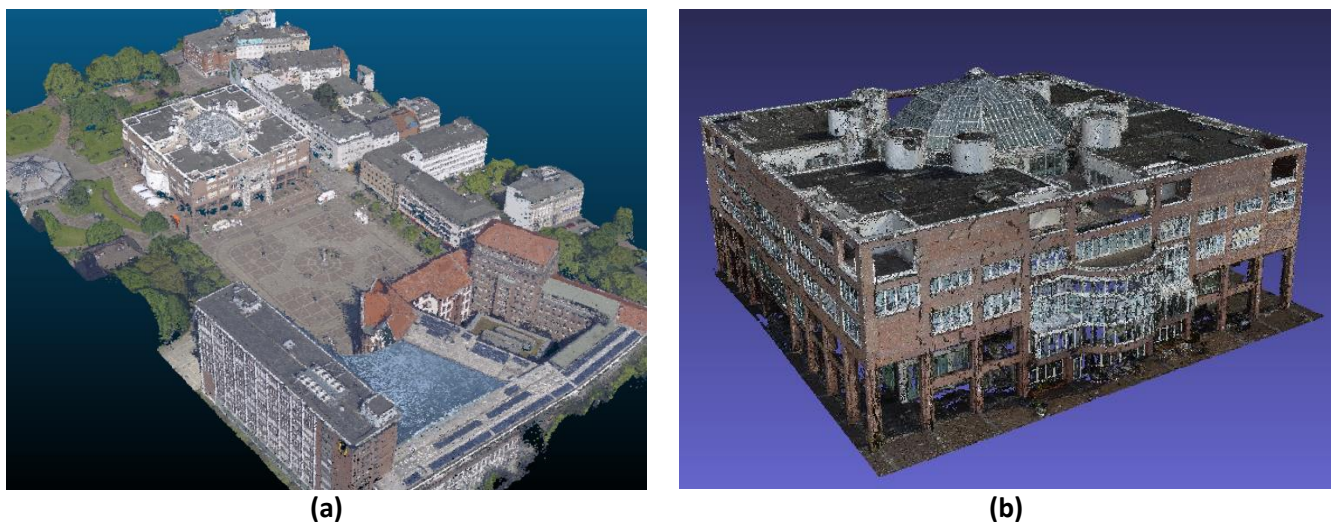

(a)

(b)

Figure 4: Example of dense point clouds generated from airborne oblique images (a) and co-registered UAV and terrestrial images, both showing the city hall (and square, in (a)).

- The **topographic network** was refined using LS adjustment process: residuals were not larger than 4mm. All the points were transformed to UTM projection (zone 32N), while the vertical coordinate reference system chosen is the official German according to the DHHN92 model (http://georepository.com/crs_5783/DHHN92-height.html).

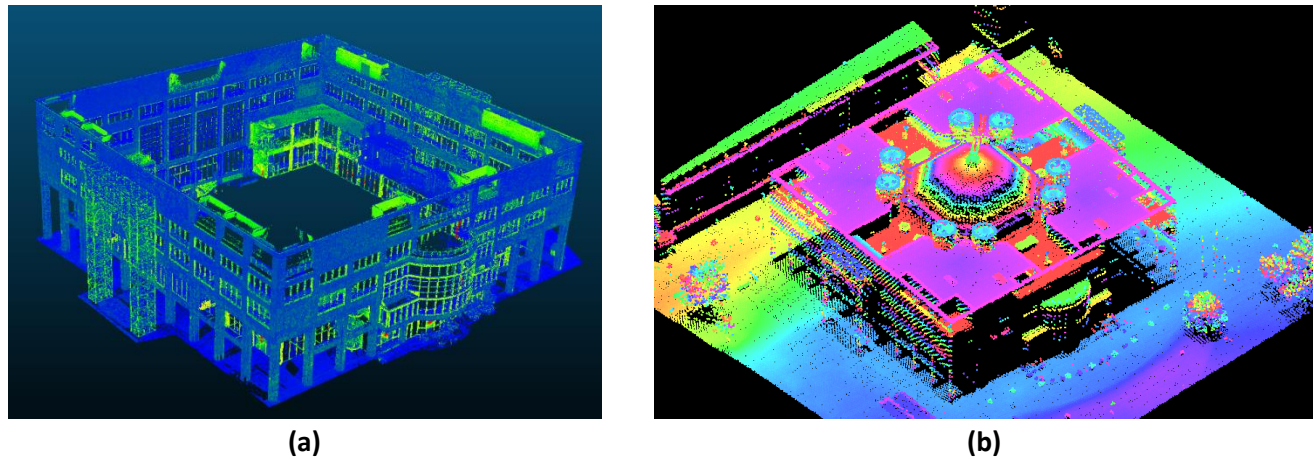**(a)**   **(b)**

Figure 5: Registered TLS (a) and ALS (b).

- The **Terrestrial Laser scans** were registered using targets glued on the building façades. Then, the results were further refined by means of an ICP-based algorithm. The Z+F software was adopted for this purpose (Figure 5). Since the TLS registration and the image orientation is performed using the created target and GCP network, all sensors will be registered in the same system – UTM/DHHN92. The ALS provided by the municipality is also registered to the same projection and height system.

EVALUATION CRITERIA AND PROCEDURES

The benchmark focus is on two main goals: a) **dense image matching**, b) **image orientation and calibration**. Six 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. 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 initiative 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 will be 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 will be 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" will be used for dense matching evaluation. The 85 oblique images from this area and their exterior orientations, as well as camera calibration protocols, will be delivered to participants. The results evaluation will be performed using the TLS data of the administration building. For details on the evaluation method see (Cavegn et al., 2014).
Scenario B) *Dense image matching in a combined terrestrial and UAV image block*

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

The data will be made available for download through both ISPRS and EuroSDR websites. The results provided by participants will be presented on a shared webpage.

Task B)

Image Orientation evaluation. This task is focused on the image orientation assessment of different image block configurations. Both the available areas are considered, but different input data are delivered according to the goal of each conceived test. For this reason, different scenarios have been set up. For each scenario a set of images will be delivered together with GCPs coordinates; image coordinates of both GCPs and CPs will be provided, too. Participants will be requested to deliver CPs coordinates in object space and the sparse tie-points point cloud. 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.

All scenarios are still not active, due to the lack of a complete GNSS survey (as it will explained in the following sections).

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

The **whole oblique/nadir image block (1204 images, IGI Pentacam)** will be provided to participants together with a set of GCP (both image and ground coordinates) and CPs (only image coordinates). The approximate orientation achieved by direct sensor orientation solution[1], and the lab camera calibration will be disclosed, too. Participants will be requested to provide object coordinates of CPs and the sparse point cloud of orientation tie-points. In addition, the participants will be asked to provide the EO elements they computed for all images to enable us to ensure that all images got adjusted. For the delivered EO elements it will only be assessed whether they are close to our reference solution, i.e. no quantitative analysis is planned so far.

The sparse point cloud will be 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.
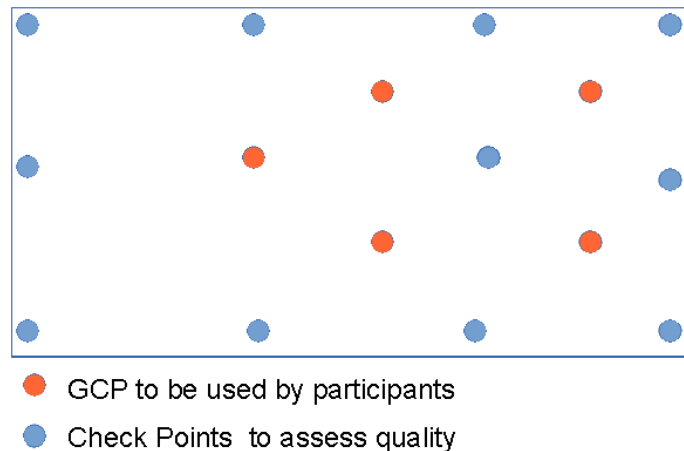

  ● GCP to be used by participants
  ● Check Points to assess quality

Figure 6: distribution of GCPs and CKs for the benchmark.

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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.

In order to test better for remaining systematic errors in the bundle solution we will NOT provide the participants with well distributed GCPs, but concentrate them in one side of the block, see Figure 6. In this way, the participants will need to extrapolate within the block and deformations will be better visible from the CPs residuals.

Scenario B) *Orientation of large airborne multi-view image blocks, including UAV images*

The Scenario A will be extended **adding the UAV** image block to the oblique dataset. Only the images captured on the "Stadthaus", obelisk and the square will be considered in this dataset (the data from the city hall will kept back for the next scenario). The approximate information provided by the onboard navigation devices will be disclosed. Again, CPs image coordinates will be delivered. The additional goal (compared to scenario A) will be to assess the capability to correctly orient UAV images just using the oblique images. It is likely that the absolute orientation of UAV images will not be in sub-pixel range since the airborne oblique have a 4-5 times larger resolution, but the interesting question is how good and reliable tie information can be retrieved. Through the check of EO elements of the UAV images we ensure that all of them actually contribute to the bundle block.

Scenario C) *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 will be provided together with a minimum number of GCPs placed just on one side building and the approximate position given by the onboard GPS devices. The image coordinates of GCPs and CPs will be provided to the users as well. As in the other scenarios, the output for the test evaluation will be the 3D coordinates of CPs as well as the sparse point cloud generated with tie-points, and the final EO elements.

Scenario D) *Absolute image orientation of UAV images using airborne nadir and oblique imagery and their known EO/IO elements*

The oblique images including full internal and external orientation of the Zollern Zoche test area will be provided to participants as input (i.e. the same information as used in Task A, Scenario A). UAV and terrestrial images captured on the "lohnhalle" and "verwaltung" buildings will be provided too: both nadir flight (acquired with the Mavinci platform) and the oblique images (multi-rotor platform) will be considered. As in the former scenarios, the approximate onboard navigation data will be provided with images. Only the image coordinates of some CPs will be given together with the approximate GPS information. The evaluation will be performed computing the residuals on the CPs and on some fitted planes (using the sparse point cloud of tie-points), so similar as described in the other scenarios.

DATA DELIVERY

A dedicated webpage have been set up on the ISPRS website (http://www2.isprs.org/commissions/comm1/icwg15b/benchmark.html). From this webpage any new participants give some information (name, institution, mail, etc.) and can directly download the available data. Only the data for the image matching evaluation will be available during this reporting period, i.e. till end of 2014. This part of the benchmark was developed in collaboration with EuroSDR. For this reason, every participant will receive the credential to download both our and the EuroSDR's dataset. The evaluation assessment is performed according to the Cavegn et al. (2014) methodology. As already mentioned above, the results provided by participants are shared on a dedicated webpage (still under improvement) that will be constantly updated in the following months/years.

The unexpected problems occurred during this year has forced to allocate some extra-budget for UAV acquisition, and as a consequence, to cut the initial budget for GNSS acquisition, hence the GCP coordinates in the large areas (yellow rectangles except area of red rectangles in Figs 1 and 2 above) still need to be captured by a surveying office. The great amount of data that was collected requested several days of work for data selection and preparation, aside the daily business of all people involved. Therefore, major parts have still to be implemented for the automatic residual assessment of the submitted results and to set up and maintain the overall evaluation workflows and websites.

For this reason, a new project proposal for the next year Scientific Initiative will be submitted.

DISSEMINATION

The Scientific Initiative has been already advertised during some events held in 2014 such as: the mid-term ISPRS Commission V Symposium in Riva del Garda, Italy, the PCV (Photogrammetric Computer Vision) Conference and the ECCV (European Conference of Computer Vision) in Zurich (Switzerland). In the following weeks it will be also advertised and presented at the ISPRS Commission I Symposium that is jointly held by ISPRS with the ASPRS and FIG conferences. In these conferences, the involved researchers got the opportunity to show the project aims during the opening or plenary sessions. Thanks to the partnership with EuroSDR, the Initiative has also been advertised in several meetings and conference held with NMCAs and private sector companies.

In 2015, it is already planned to advertise the initiative at the PIA Conference (Munich, Germany), Phowo '15 (Stuttgart, Germany), EuroSDR BoD (Southampton, UK) and the Geospatial Week (Montpellier, France) with dedicated papers, presentations and sessions.

Through the ISPRS website, a mailing list has been set up (http://www2.isprs.org/newsletter.html) in order to promote and quickly disseminate the news about the future progress and delivery of the Scientific Initiative. A new webpage has been implemented in the ISPRS WG I/Vb website.

References

Cavegn, S., Haala, N., Nebiker, S., Rothermel, M. & Tutzauer, P., 2014. Benchmarking High Density Image Matching for Oblique Airborne Imagery. In: Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., Zürich, Switzerland, Vol. XL-3, pp. 45-52.