

Overview

Over the past two decades the need for up-to-date 3D data in urban scenarios has been motivating the geospatial community towards the development of advanced 3D reconstruction methods. Many solutions exist for 3D data capturing, semantic labelling and urban objects modelling, but still many challenges are evident, thus stimulating the adoption of benchmarking scientific initiatives aimed at boosting further research in these fields.

In this perspective, we are pleased to present the **3DOMcity photogrammetric contest**, a novel multi-purpose benchmark for assessing the performance of the entire image-based pipeline for 3D urban reconstruction and 3D data classification. The innovative aspects introduced by 3DOMcity are threefold:

1. MODULAR & MULTI-PURPOSE CONCEPT

it involves multiple tasks throughout the entire 3D reconstruction pipeline, that can be either performed independently from each other, or grouped together.

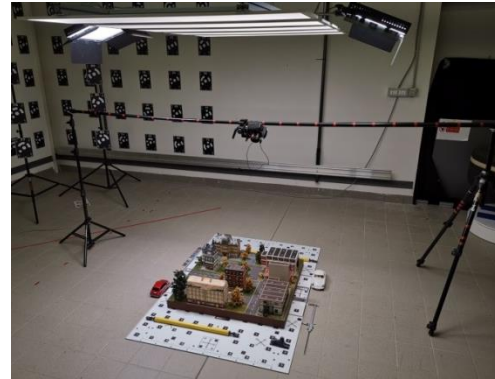
2. METROLOGICAL CONTEXT

the performance assessment is carried out within a controlled laboratory environment, that offers a privileged context for traceable measurements.

3. VERY HIGH SPATIAL RESOLUTION

the publicly available datasets feature very detailed GSD (imagery) and high density (point clouds), that enable the assessment of the algorithms' performance to provide for a detailed 3D reconstruction.

Benchmark dataset



The benchmark is realized within the FBK-3DOM metrological laboratory, where a 3D scene is captured under controlled environment conditions. The scene includes:

- a test-object, that simulates a typical urban scenario by means of a mock 3D city model (ca. 0.8 x 0.8 m) with the most typical elements of a urban scenario, i.e. buildings of varying shapes and heights, streets, gardens and trees;
- different kinds of references, i.e. coded/circular targets, resolution charts and scale bars laser printed on a semi-rigid and multi-layer surface, two calibrated invar rods, a caliper and a rigid measuring tape.

A set of 420 images are acquired with a Nikon D750 digital camera equipped with a fixed 50 mm focal length lens, simulating a classical airborne flight. Details on the imagery dataset are given in the table below.

Nadir Images			Oblique Images		
Number	Mean GSD	Overlap (along/across-track)	Number	Mean GSD	Overlap (along/across-track)
144 (tot.) 2 (per each camera station)	0.124 mm	80/65%	276 (tot.) 4 (per each camera station)	From 0.128 mm to 0.273 mm	85/70%

Reference dataset

The evaluation tests are performed using the following reference data:



1. CODED/CIRCULAR TARGETS (tot. 115)

- used to evaluate the precision of the adjustment in image space (the localization errors can be expected to originate only from the adjustment process)

2. CONTROL SCALE BARS (tot. 3)

- two calibrated scale bars (CO 1 and CO 3), $u_L = 0.0072$ mm;
- distance between the circular targets of the rigid measuring tape (CO 2), $u_L = 0.012$ mm.

3. CHECK SCALE BARS (tot. 3)

- distance between the circular targets on the two printed scale bars (CH 1 and CH 3) – no calibration provided;
- distance between the circular targets on the caliper (CH 2) – no calibration provided.

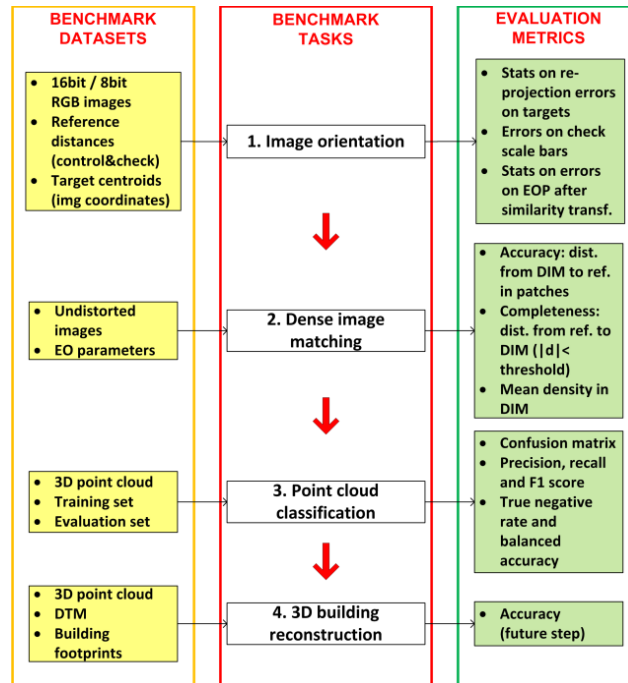
4. 3D POINT CLOUDS

- multi-stripe triangulation-based laser scanner, NextEngine 3D Scanner, used to acquire a 3D model of two buildings of interest (“border building” and “center building”);
- assessment under varying (i) redundancy and geometric configuration of image rays and (ii) occlusion levels;
- lateral resolution = 0.120 mm (single scan value);
- $u_R = 0.124$ mm (single-pair alignment error, 1σ value);
- incremental registration error = 0.218 mm – border building (incremental ICP-based registration – mean value);
- incremental registration error = 0.263 mm – center building (incremental ICP-based registration – mean value).

No GCPs are provided, in order to (i) avoid any external source of uncertainty that may introduce deformation effects within the image block, and (ii) make the participation/evaluation possible for software solutions that do not allow for GCP-supported bundle block adjustment.

Benchmark tasks

The benchmark tasks are described in the followings. Please, submit your results by sending an email to 3dom@fbk.eu.



1. Task 1: Image Orientation

The photogrammetric network adjustment is the first task of the contest. As input data, the users can download:

- RGB images, in 16bit tiff, 16bit NEF and 8bit jpg file format (FOLDER: Images);
- 2D image coordinates of target centroids (FOLDER: Reference-data)
- reference lengths for scaling the network (Control scale bars, FOLDER: Reference-data);
- reference lengths for accuracy estimation (Check scale bars, FOLDER: Reference-data).

Results submitted by users should include:

- adjusted EOP in txt file format (Image name X Y Z Omega Phi Kappa). Coordinates of the projection centers should be in mm, rotation angles should be in degrees.
- re-projection errors on 115 target centroids in txt file format, according to the following specs:
 - error values should be in pixels;
 - nan values should be written as -9999;
 - error values should be reported for x and y separately;
 - the general outline should be the same as the shared image measurement file, where each row stands for images (with given image names), and each column stands for the marker ids written twice for x,y error values.
- errors on 3 check scale bars in txt file format according to the following specs:
 - 3 rows and 2 columns in total;
 - first column for the check bar names;
 - second column for the errors in mm.

Evaluation metrics will be estimated by us and published in the form of:

- precision in image space → statistics on re-projection errors and corresponding plots;
- accuracy in object space → errors on check scale bars;
- relative EOP accuracy assessment → statistics on errors computed on EOP (see Özdemir et al., 2019^(*) for further details).

2. Task 2: Dense Image Matching (DIM)

The generation of a 3D point cloud is the second task of the contest. It can be addressed independently from Task 1. As input data, the users can download:

- undistorted images in 16bit tiff file format (FOLDER: Undistorted-images);
- adjusted EOP of the reference network (FOLDER: Ori-parameters).

or, the users can start from their adjusted EOP as results of Task 1, if they prefer to combine Task 1 and Task 2.

The DIM can be run on any image pyramid level and results submitted by users should include:

- DIM point cloud in ply file format (x, y, z, R, G, B); normals per each point are optional.

Evaluation metrics will be estimated by us and published in the form of:

- Accuracy \rightarrow Mean, σ , Median and $\sigma_{MAD} = 1.4826 * MAD$ of signed distances from submitted to reference cloud
- Completeness \rightarrow % $|distances_{Ref \rightarrow DIM}| < d_{threshold}$

Please, see Özdemir et al., 2019^(*) for further details.

3. Task 3: Point Cloud Classification

The classification of the 3D point cloud is the third task of the contest. As input data, the users can download:

- training set (FOLDER: Point-clouds);
- evaluation set (FOLDER: Point-clouds);
- reference point cloud (FOLDER: Point-clouds).

Training and evaluation point clouds are labelled for 6 classes: ground, grass, shrub, tree, facade, and roof. Number of labelled points per class for training and evaluation set are given in table below.

Class ID & Class Name/Point Cloud	Training	Evaluation
0 Ground	352,958	294,931
1 Grass	184,407	167,516
2 Shrub	129,205	196,163
3 Tree	562,220	535,417
4 Facade	938,932	861,154
5 Roof	157,485	153,055
Total	2,325,207	2,208,236

Results submitted by users should include:

- labelled evaluation set, as a text file including x, y, z, class id columns, in this order, and without any headers. The submissions are expected to keep the coordinate precision as much as possible, while the order of the points can be changed.

Evaluation metrics will be estimated by us and published in the form of:

- confusion matrix, precision, recall, F1 score, true negative rate and balanced accuracy. In case of missing points, those points will count as false negatives.

Conditions of Use

The data are distributed subject to the following conditions:

- 1) The data can be used for research purposes and research purposes only. Any other use is prohibited.
- 2) The data cannot be redistributed to third parties. Everyone, who are interested in the data, may obtain them through our webpage (<https://3dom.fbk.eu/3domcity-benchmark>).
- 3) Scientific papers whose results are based on the data must cite (Özdemir et al., 2019)^(*) and need to contain the following acknowledgement: “The 3DOMcity benchmark data set was provided by the 3D Optical Metrology unit of Bruno Kessler Foundation (Trento, Italy) [Özdemir et al., 2019]: <https://3dom.fbk.eu/3domcity-benchmark>”
- 4) 3D Optical Metrology unit of Bruno Kessler Foundation should be informed about published papers whose results are based on the data with an e-mail to 3dom@fbk.eu.
- 5) Obtained results should be sent by email to 3dom@fbk.eu.

(*) Reference paper

Özdemir, E., Toschi, I., and Remondino, F.: A MULTI-PURPOSE BENCHMARK FOR PHOTOGRAMMETRIC URBAN 3D RECONSTRUCTION IN A CONTROLLED ENVIRONMENT, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., Vol. XLII-1/W2, pp. 53–60, <https://doi.org/10.5194/isprs-archives-XLII-1-W2-53-2019>, 2019.

Submission Form

To access the benchmark data, please fill in the form available [here](#) and send it to 3dom@fbk.eu.