RÉPUBLIQUE
FRANÇAISE
Liberté
Égalité
Fraternité

IGN
INSTITUT NATIONAL
DE L'INFORMATION
GÉOGRAPHIQUE
ET FORESTIÈRE

CHANGER
D'ÉCHELLE

3D BUILDING RECONSTRUCTION BENCHMARK

Emmanuel Séguin - Innovation project manager

IGN*fab* 2023

Context

- Numerous works at IGNF in the past, either in research or for data production (BATI3D, REFD3NAT, PROD 3D)
- Lots of projects requiring building models (renewable energy, energy retrofit, …) at IGNF project accelerator (IGN*fab)*
- Ongoing acquisition of LIDAR data by IGNF (10 pulses/m²)
  - Raw and classified IGNF LIDAR HD datasets available as open data
  - Likely to have impact on other IGNF datasets (reference vector database, …)
- Possibly a large national digital twin project in the years to come
- New research projects regarding 3D reconstruction, mesh semantization at IGNF research units

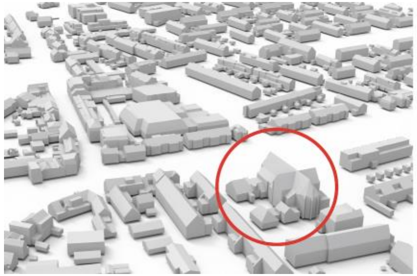
Benchmark framework

- Principles
  - Produce semantized 3D building models (at least LOD2) using classified LIDAR HD data, as automatically as possible, with open source or proprietary solutions
  - Produce building models on different urban configurations
  - Produce results in CityJSON or at least CityGML
  - Compare obtained results with a **ground truth** dataset as automatically as possible and produce metrics
- From January to July 2023. Follow up work still going on.

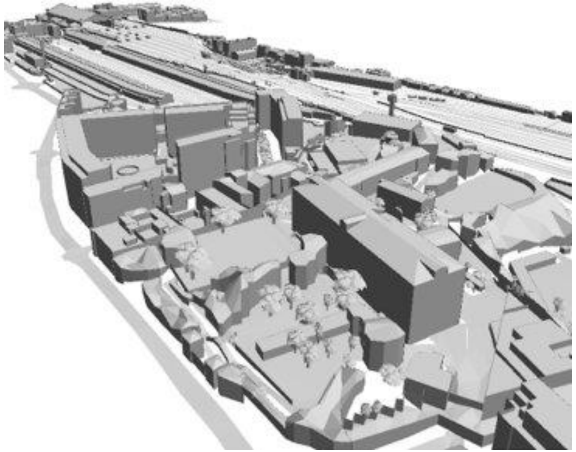
Identified solutions

- Considered solutions
  - Proprietary solutions
    - TerraScan
    - ESRI
  - Open-source solutions
    - City3D
    - Geoflow
    - Points2poly
    - KSR (soon to be published as open source in CGAL)
  - Other companies

- Not considered solutions
  - Proprietary solutions
    - FME
    - Global Mapper



Datasets used



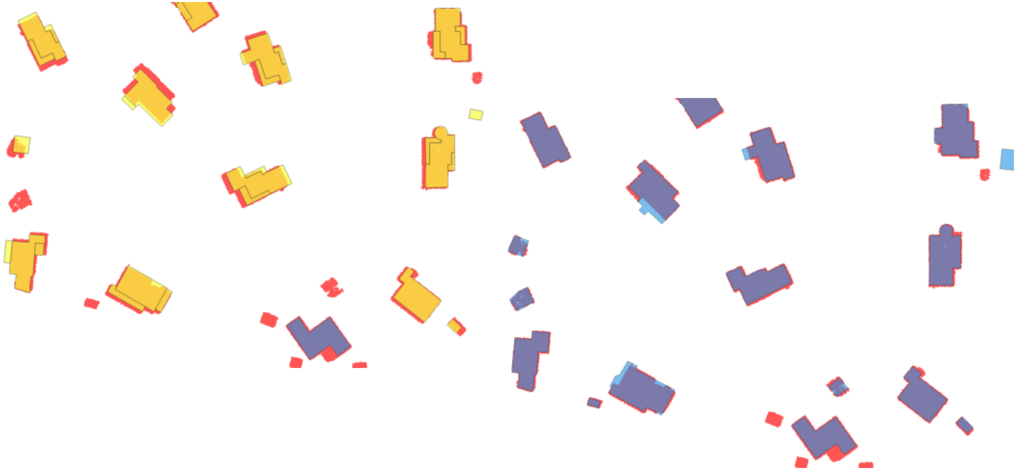
- Ground truth dataset : IGNF PROD 3D
  - Manually acquired LOD3 CityGML dataset based on aerial imagery
- IGNF classified LIDAR HD
  - Automatically classified (partly with Myria3D)
  - No manual correction
- Building footprints
  - Using IGNF reference vector database (BDTOPO) => first tests showed gaps between footprints and LIDAR (mainly due to the use of an external source for the building layer) and lacks (mainly due to timeliness of the data)
  - Decision to use building footprints extracted from the ground truth dataset. Probably the bestidea, in the end, to compare the quality of 3D reconstruction.

Focus on building footprints

- Missing footprints
  - Tests using an improved version of https://github.com/Geodan/building-boundary and Terrascan
    - Similar types of results. Geodan probably a bit better.
  - At the end of the day, the main idea is **clustering + alpha shapes + regularization**
  - Only blocks of buildings. Lack of details. Noise.

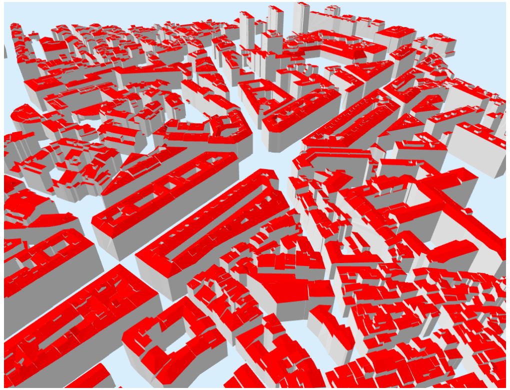
- Misaligned footprints
  - No time spent on this task at first
  - Only Terrascan was tested
  - Currently trying to work out a piece of code to do so

- Other things that could have been tested
  - Automatic footprints extraction from true aerial orthophotography (Frame Field Learning, Polyworld, …)

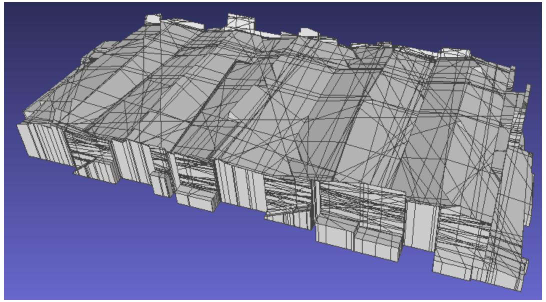


Results of our tests

- **TerraScan**
  - “Black box” solution + no logs or progress status
  - Able to work with and without footprints
  - Requires an intermediate step via 3DCityDB to export results in CityGML or CityJSON
  - Not very good at reconstructing complex buildings or curved surfaces
  - Not the fastest contender

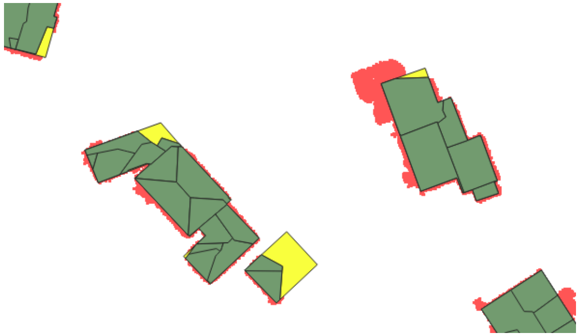


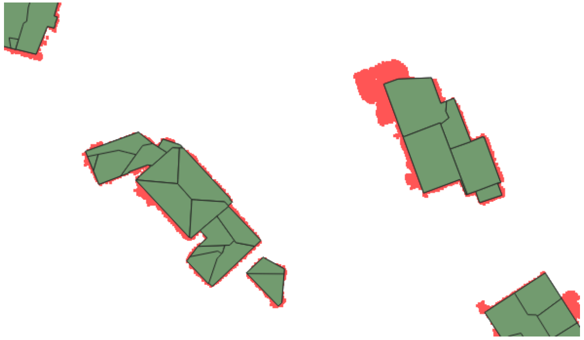
- **City3D** (our test pipeline is available at https://github.com/ignfab/City3D)
  - Tested with the Gurobi solver to speed up calculations
  - Unable to deal with large or complex buildings (similar issue than in Polyfit)
  - Way too many faces and edges in produced models : easy3d to improve results
  - Most of the produced models were invalid (missing vertices, self-intersection, …)



Results of our tests

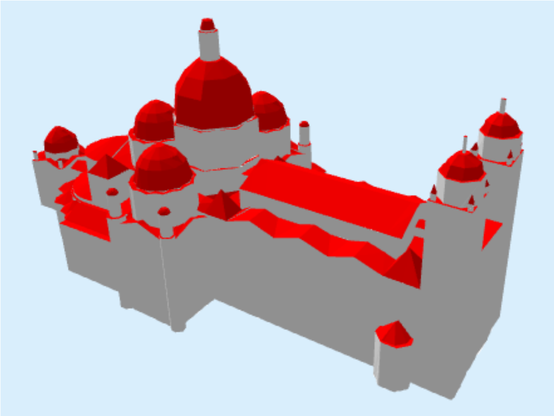
- **Geoflow**
  - Pros
    - Interesting ETL approach to audit the workflow
    - FOSS and modular
    - Visually pleasing results
    - Can reconstruct curves and complex buildings
    - Keep original attributes
    - Fast
  - Cons
    - Data preparation and usage took some time to figure out
    - Requires good programming skills
    - Very data dependent
    - Sensible to unclassified points clusters in the building points
    - Lack of regularization
    - Work on the parameters to be done to evaluate in depth their impact



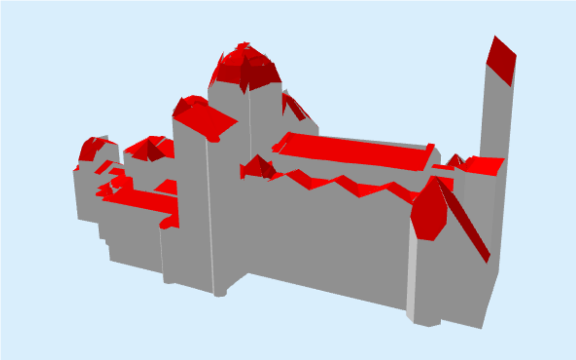


Examples

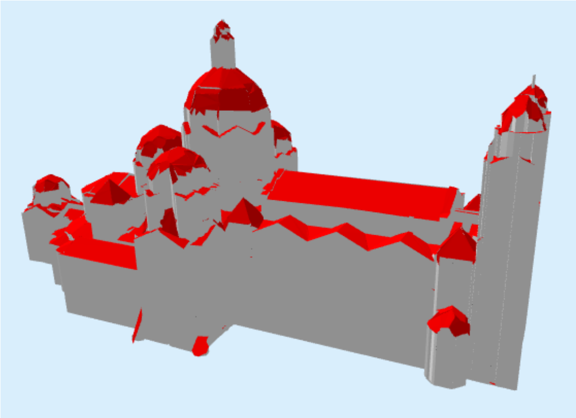
IGNF LIDAR HD



IGNF PROD 3D

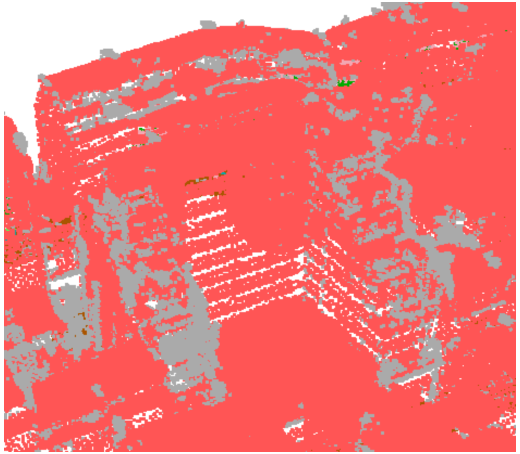


Terrascan

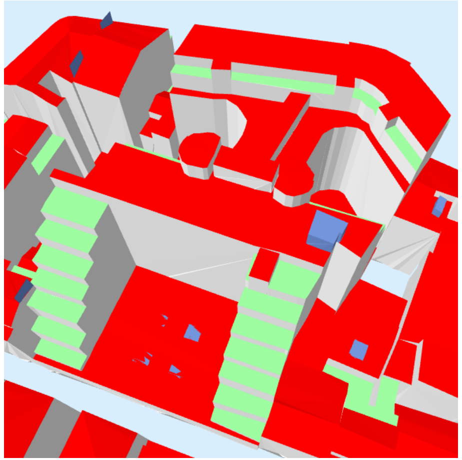


Geoflow

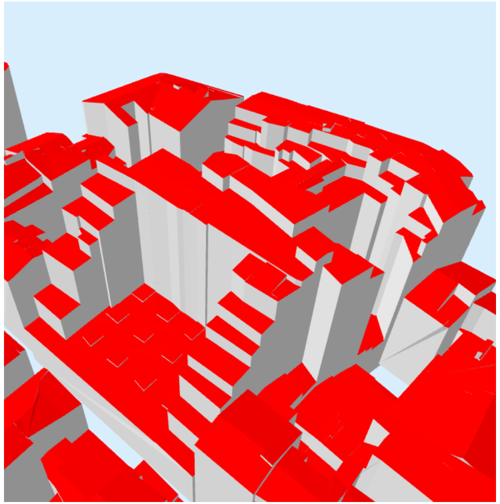
Examples



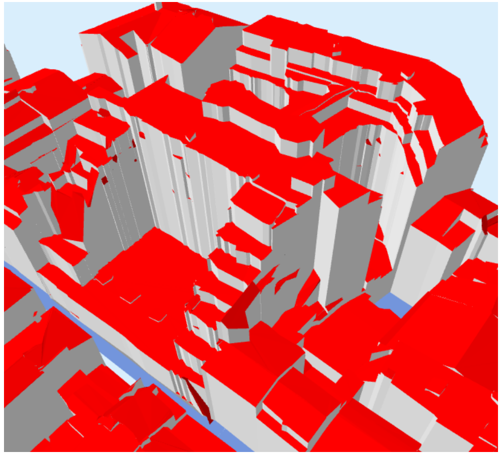
IGNF LIDAR HD



IGNF PROD 3D



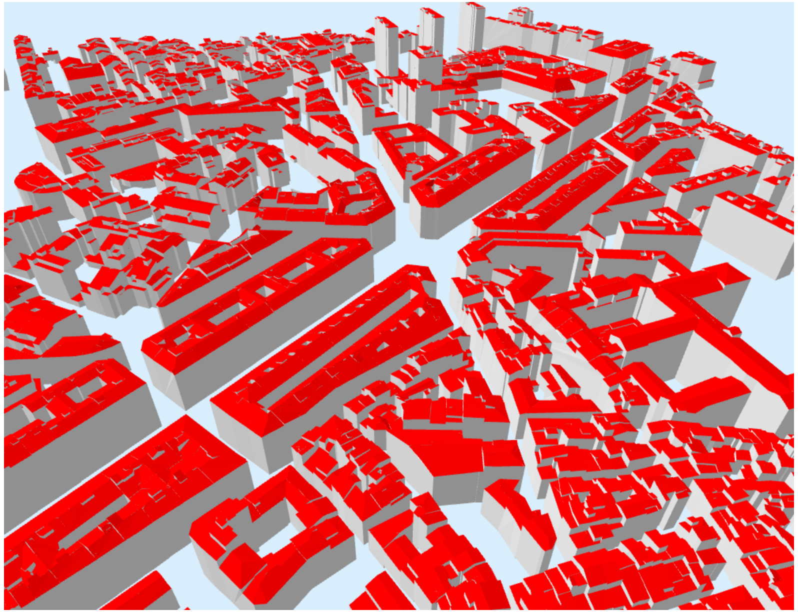
Terrascan



Geoflow

Quality assurance

- Complementary approaches
  - Identifying buildings than were not reconstructed
  - Visual inspection
  - Metrics production
    - Intrinsic metrics : Reconstructed models validity
    - Extrinsic metrics : Comparison with ground truth dataset



Metrics production

- Inspired by previous AI4GEO works and an ISPRS paper
- Written in Python for processing CityJSON building datasets using cjio
- Intrinsic metrics : Use of val3dity
- Extrinsic metrics
  - Tailor-made metrics to compare obtained results with ground truth dataset
- Should be released as FOSS in the coming months

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

IGN CHANGER D'ÉCHELLE

Topologic metrics

Surfaces matching

The first step is to match the RoofSurface surfaces from predictions with the RoofSurface or OuterFloorSurface surfaces from the groundtruth dataset.

A prediction surface is matched with a ground truth surface if :

$$\frac{area(intersection(predictionSurface, groundtruthSurface))}{mininum(area(predictionSurface), area(groundtruthSurface))} >= 0.5$$

This criterion is refered to as `Intersection over minimal area`

In practice, the script builds a graph mapping the N-M interesctions between groundtruth and prediction surfaces

Topologic metrics

Oversegmentation, Undersegmentation, False positive, False negative

Based on the surface matching the following metrics are defined:

- Oversegmentation aka mean number of matched prediction surfaces per groundtruth surface

$$\frac{\sum_{g \in groundTruthSurfaces} |matchedPredictionSurfaces(g)|}{|groundTruthSurfaces|}$$

- Undersegmentation aka mean number of matched groundtruth surfaces per prediction surface

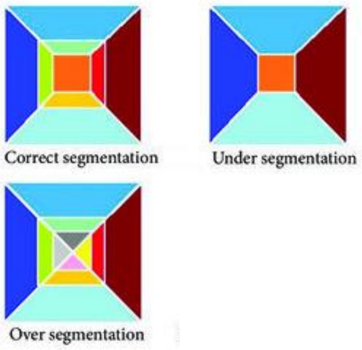
$$\frac{\sum_{p \in predictionSurfaces} |matchedGroundTruthSurfaces(p)|}{|predictionSurfaces|}$$

- False positive aka unmatched prediction surfaces rate

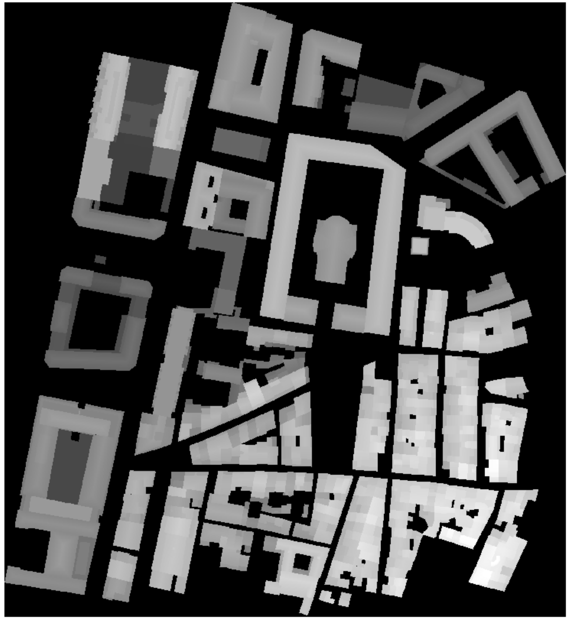
$$\frac{|predictionSurfaces| - \sum_{p \in predictionSurfaces} isMatched(p)}{|predictionSurfaces|}$$

- False negative aka unmatched groundtruth surfaces rate

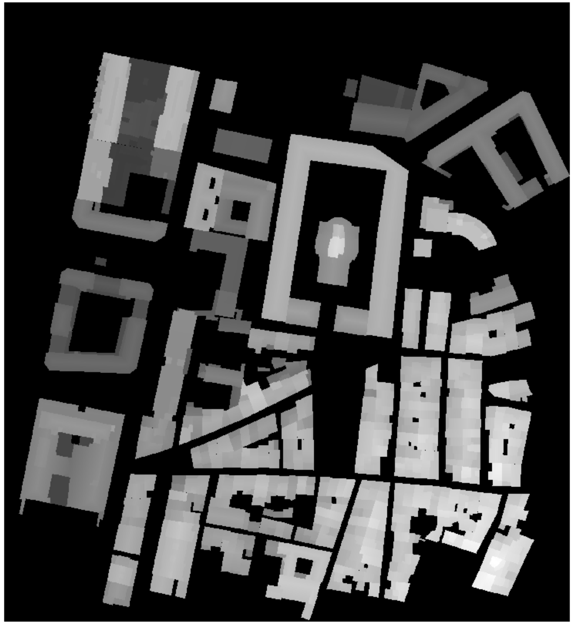
$$\frac{|groundTruthSurfaces| - \sum_{g \in groundTruthSurfaces} isMatched(g)}{|groundTruthSurfaces|}$$



Geometric metrics



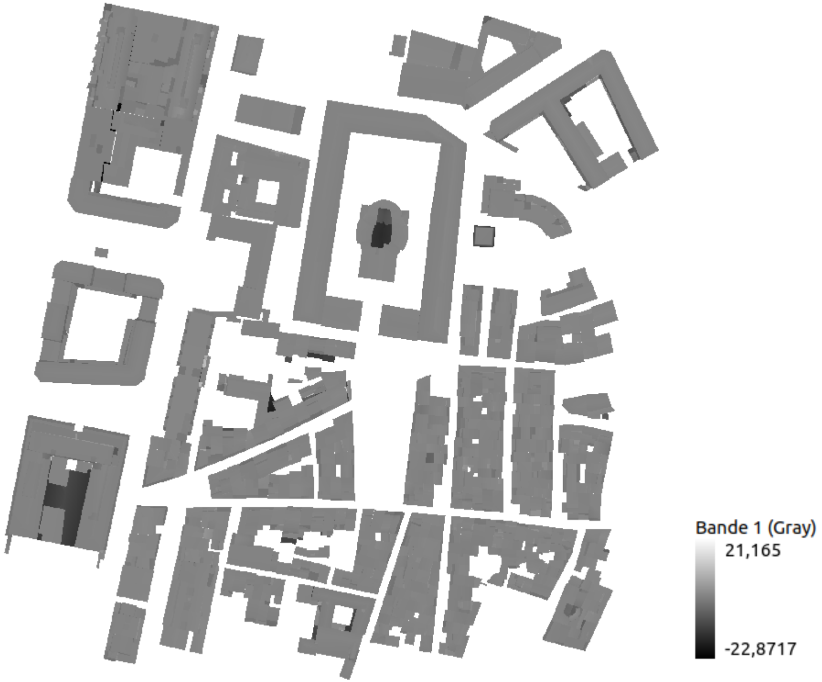
Ground truth roof Z as raster data



Reconstruction roof Z as raster data

Geometric metrics

Error Sum (m)	Squared Error Sum (m)	Under reconstruction (%)	Over reconstruction (%)
-0,5028325924	1,896250616	10,73327748	0,07204751587



Metrics production

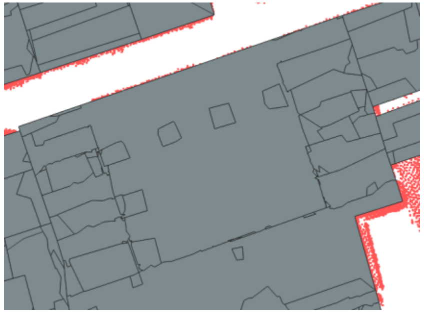
- Results available directly in a google sheet

A	B	C	F	G	H	I	J	K	L	M	N	O
			Métriques topologiques						Métriques géométriques			
Zone de travail	GT	Méthode testée	Nbr P w match	Nbr GT w match	TFP (%)	TFN (%)	T Sous Seg (moy	T Sur Seg (moy su	S-Err (m)	Ecart-Type (m)	Sous-reconstr. (%)	Sur-reconstr. (%)
P1	Maquette Prod3D	Terrascan	1101	3054	0,00	6,58	2,81	1,01	0,50	0,79	2,30	0,03
P2	Maquette Prod3D	Terrascan	2871	3391	1,31	8,03	1,64	1,39	0,15	0,70	0,79	0,33
U1	Maquette Prod3D	Terrascan	7017	13544	0,85	1,76	2,15	1,12	0,06	1,63	0,85	0,05
U2	Maquette Prod3D	Terrascan	7409	19966	1,29	2,25	2,96	1,10	0,85	3,55	1,90	0,30
P1	Maquette Prod3D	Geoflow	1093	2929	0,18	10,40	2,72	1,02	0,48	0,74	5,38	0,02
P2	Maquette Prod3D	Geoflow	2089	3165	0,76	14,16	1,83	1,21	0,14	0,66	2,33	0,12
U1	Maquette Prod3D	Geoflow	9211	13217	1,05	4,13	1,83	1,28	0,03	1,79	3,67	0,05
U2	Maquette Prod3D	Geoflow	10081	19632	1,91	3,88	2,40	1,23	0,65	3,04	4,73	0,31
P1	Maquette Prod3D	City3D	1952	3243	1,66	0,80	2,16	1,30	0,84	11,62	0,08	0,06
P2	Maquette Prod3D	City3D	0	0	100,00	100,00	100,00	100,00	100,00	100,00	10,00	100,00
U1	Maquette Prod3D	City3D	13672	13164	2,25	4,52	1,60	1,66	0,42	14,90	13,03	0,10
U2	Maquette Prod3D	City3D	10460	14186	4,02	30,55	1,98	1,46	0,58	2,43	39,22	0,18

- Geoflow and TerraScan are close
  - Geoflow is a bit better regarding squared errors sum
  - TerraScan is a bit better as in terms of over-segmentation

- Metrics that could be added
  - Metric for rectilinear edges vs « noisy » edges

Terrascan



Geoflow

Current status

- Still looking for the best solution to realign our footprints with our LIDAR dataset

- Still investigating KSR

- Still considering other approaches for 3D reconstruction (dictionary-based approaches, …)

- Continuing our tests with Geoflow
  - Exploring new flowcharts : batch and stream
  - Scaling up : Aiming for a French *department* to estimate production for the whole of France

- Open for collaboration

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

CHANGER D'ÉCHELLE

CONTACT US : IGNFAB@IGN.FR