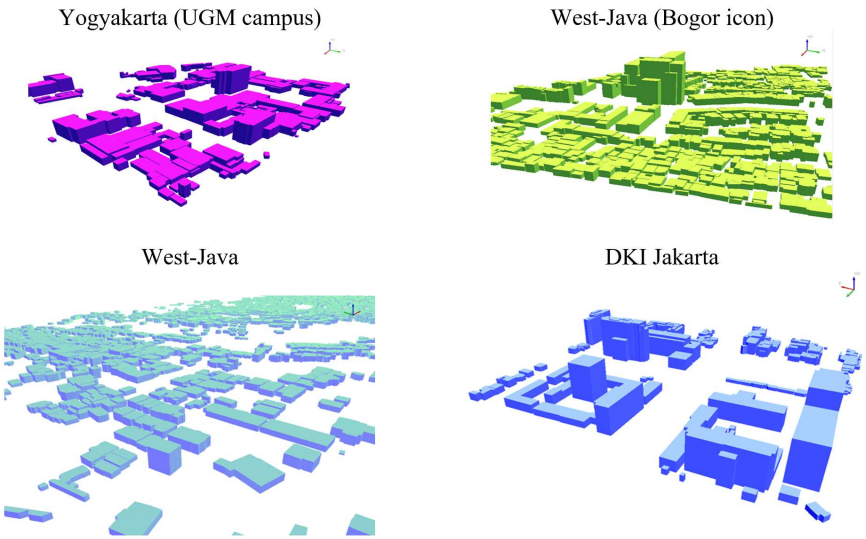
Automatic DTM and Building Footprint Extraction from Imageries and Point Clouds in Indonesia's Land Registration Drone Survey: A Roadmap Towards Reconstruction of LOD1 3D building model.

Ruli Andaru, Trias Aditya, Bambang Kun Cahyono, Purnama Budi Santosa, Yulaikhah

Dept of Geodetic Engineering, UGM, Indonesia

Septein Paramia Swantika

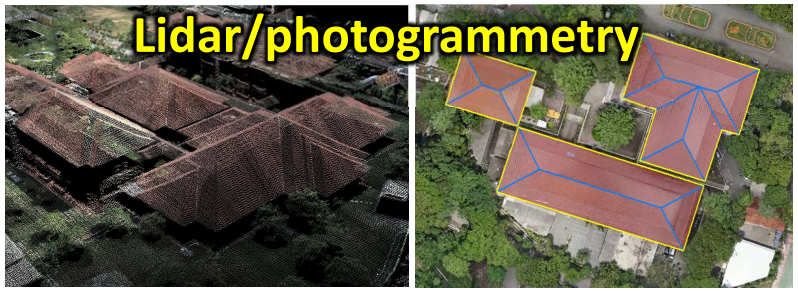
Ministry of Indonesian Agrarian Affairs and Spatial Planning

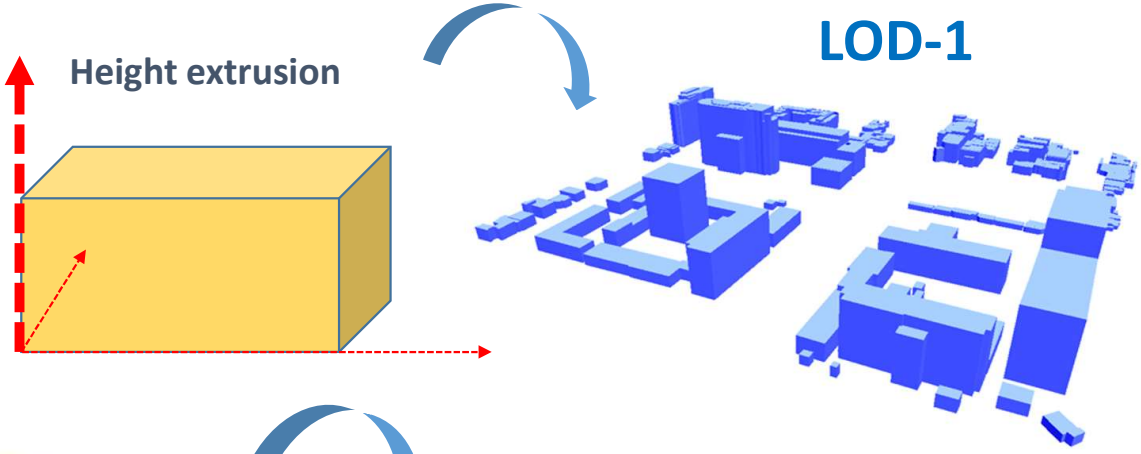


Motivation

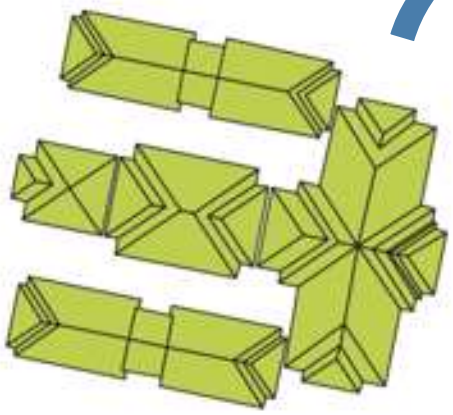
Keywords: building footprint, ground extraction, reconstruction 3D LOD1 model

Accurately and rapidly extracting building footprint information from remote sensing imagery is an essential step for reconstructing 3D building model.

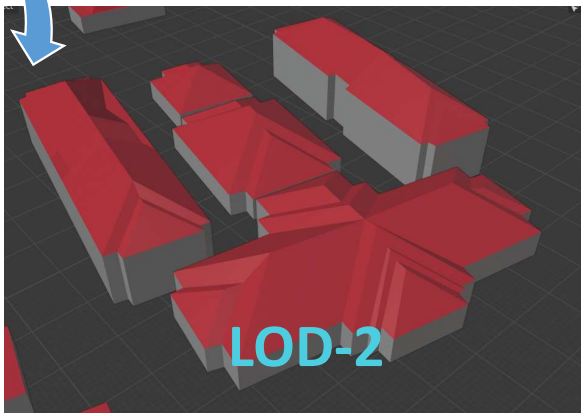




2D building footprint

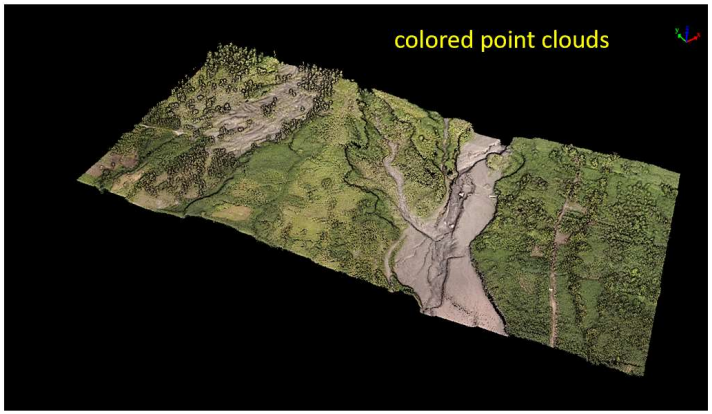


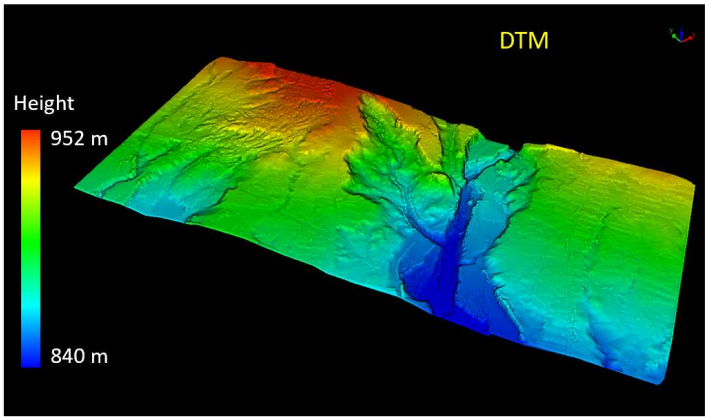
Roof Structure

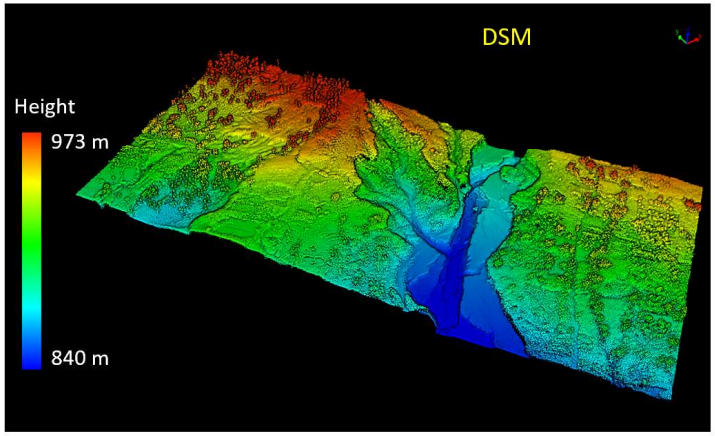


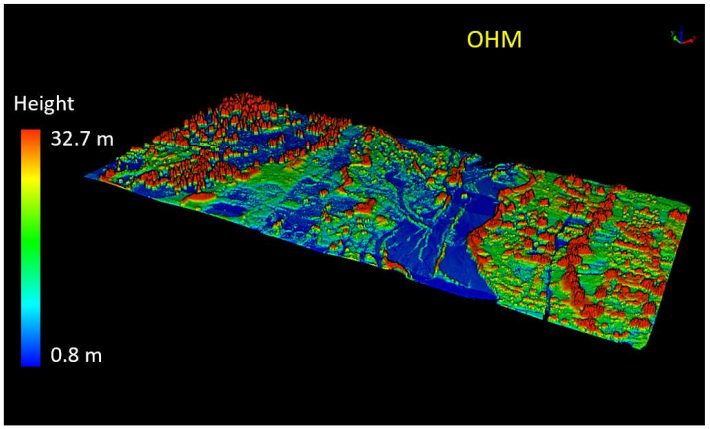
Motivation

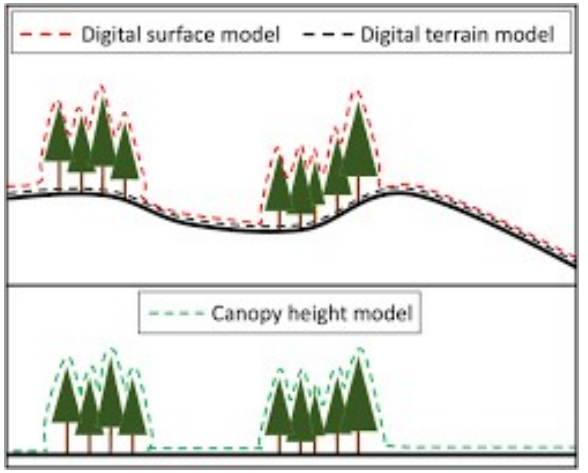
DSM and DTM are required to reconstruct 3D building model.
Object height model (OHM) : subtracting the DTM from the DSM











OHM: raster layer that maps the object height as a continuous surface

The methods to extract building footprint and ground points

Building footprint

Image segmentation:

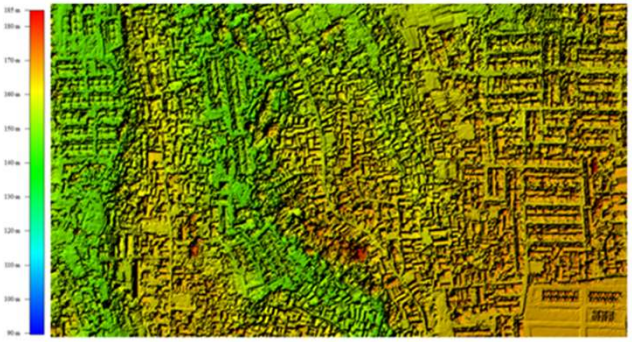
- OBIA method
- AI/deep learning

Point clouds segmentation:

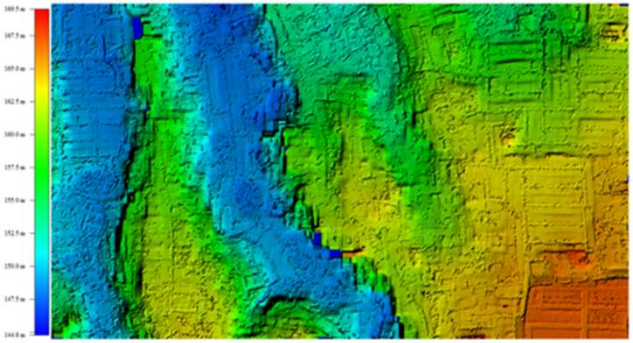
AI/deep learning+DBSCAN

Ground extraction

DSM



DTM



- Cloth Simulation Filter
- Progressive TIN Densification,
- ML/DL Random Forest , and PointNet/ PointNet++

Experimental study utilizing AI : ***Building footprint →YOLO-v8*** *Deep learning with custom trained data.*
Ground extraction → CNN *with dynamic graph convolution (DG-CNN)*

Objective & research questions

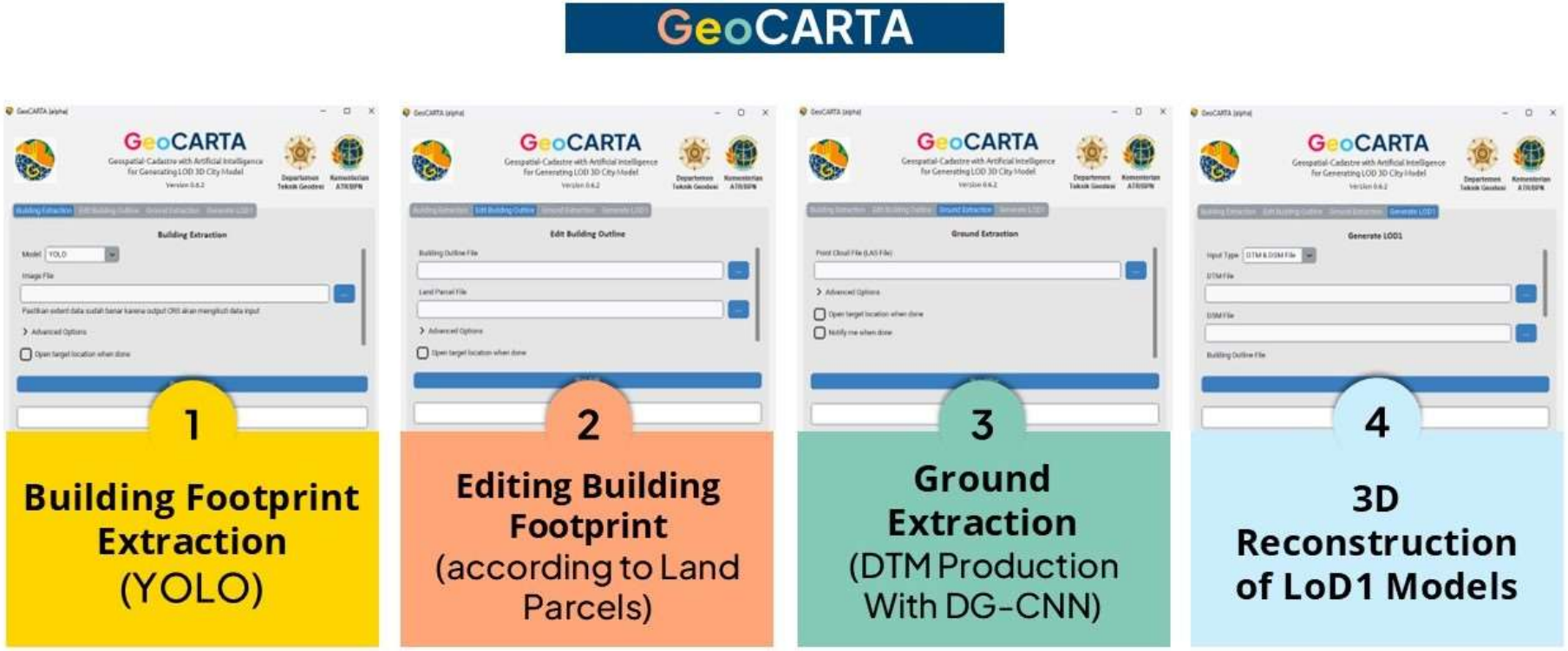
1. How to generate highly precise OHM in an automated manner.
2. Which specific AI algorithms are most appropriate for extracting building footprints within the context of Indonesia?

Ensuring the users can easily navigate and utilize those two algorithms (YOLO and CNN), we introduce **Geo-Carta App** (Geospatial-Cadastre with Artificial Intelligence for Generating LOD 3D City Model).

www.geocarta.id

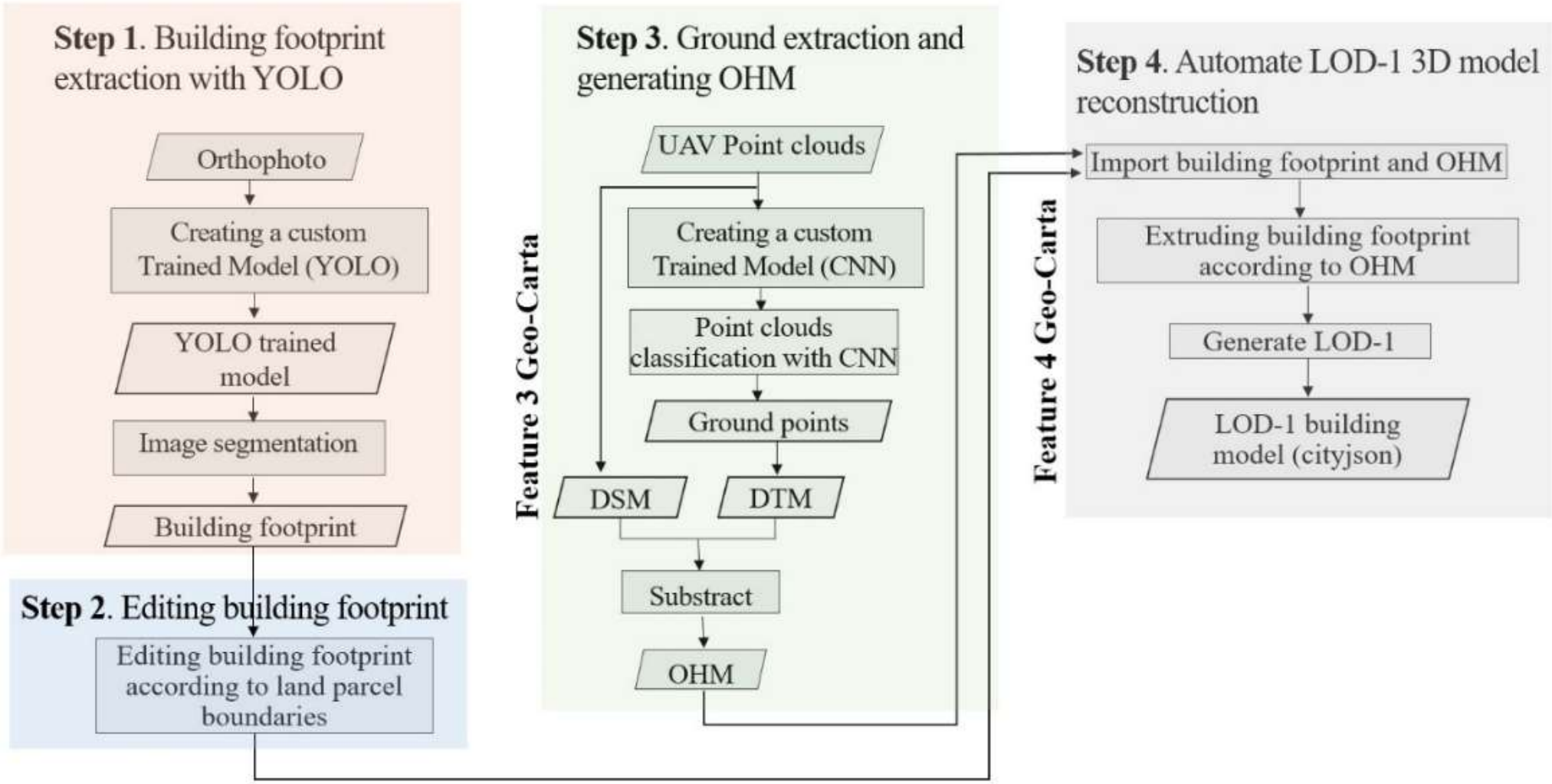
GeoCARTA App

It comprises four interconnected steps for generating LOD1-3D model automatically.



Data and methods

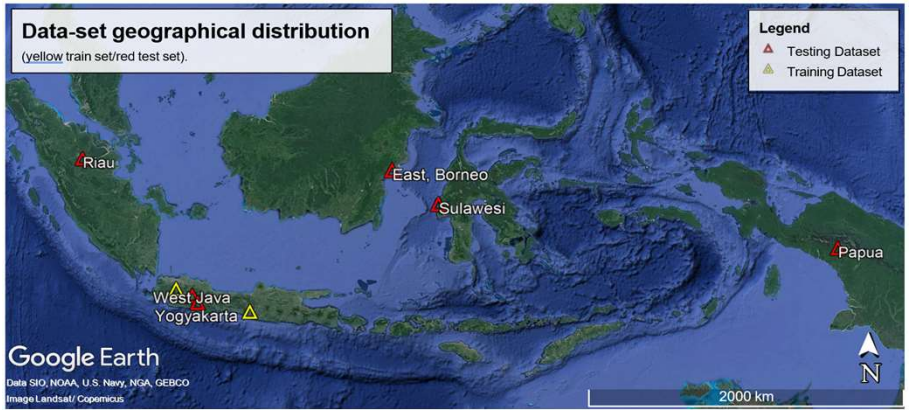
Interconnected steps for generating LOD1-3D in Geo-Carta App



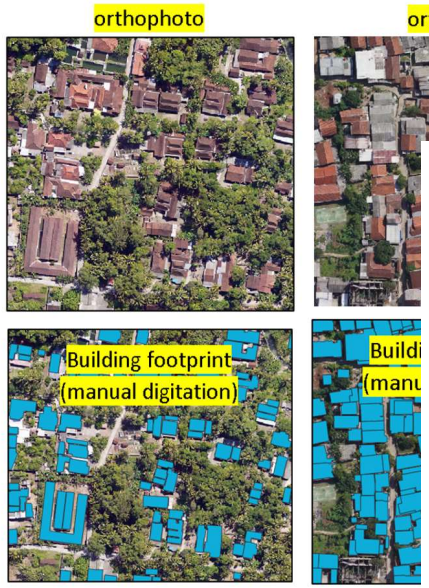
Data and method

Experimental research : six provinces in Indonesia (Papua, West Sulawesi, East Borneo, Riau, West Java, and Yogyakarta).

The entire images were captured by using UAV platform with the ground sampling distance of 10 cm.

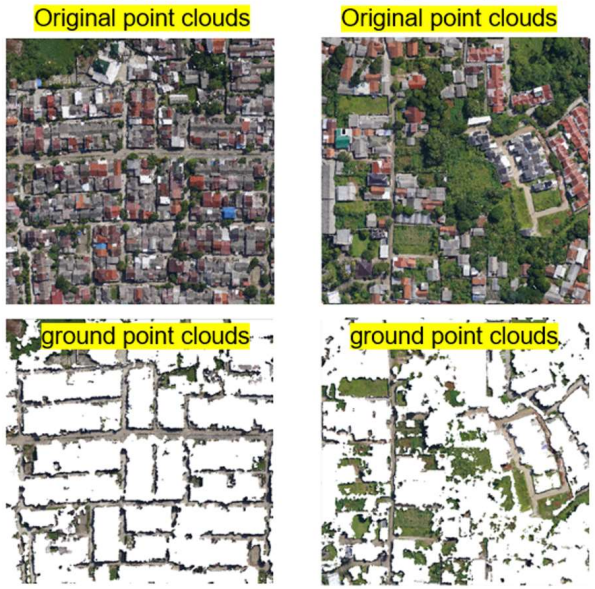


(a) YOLO training sample



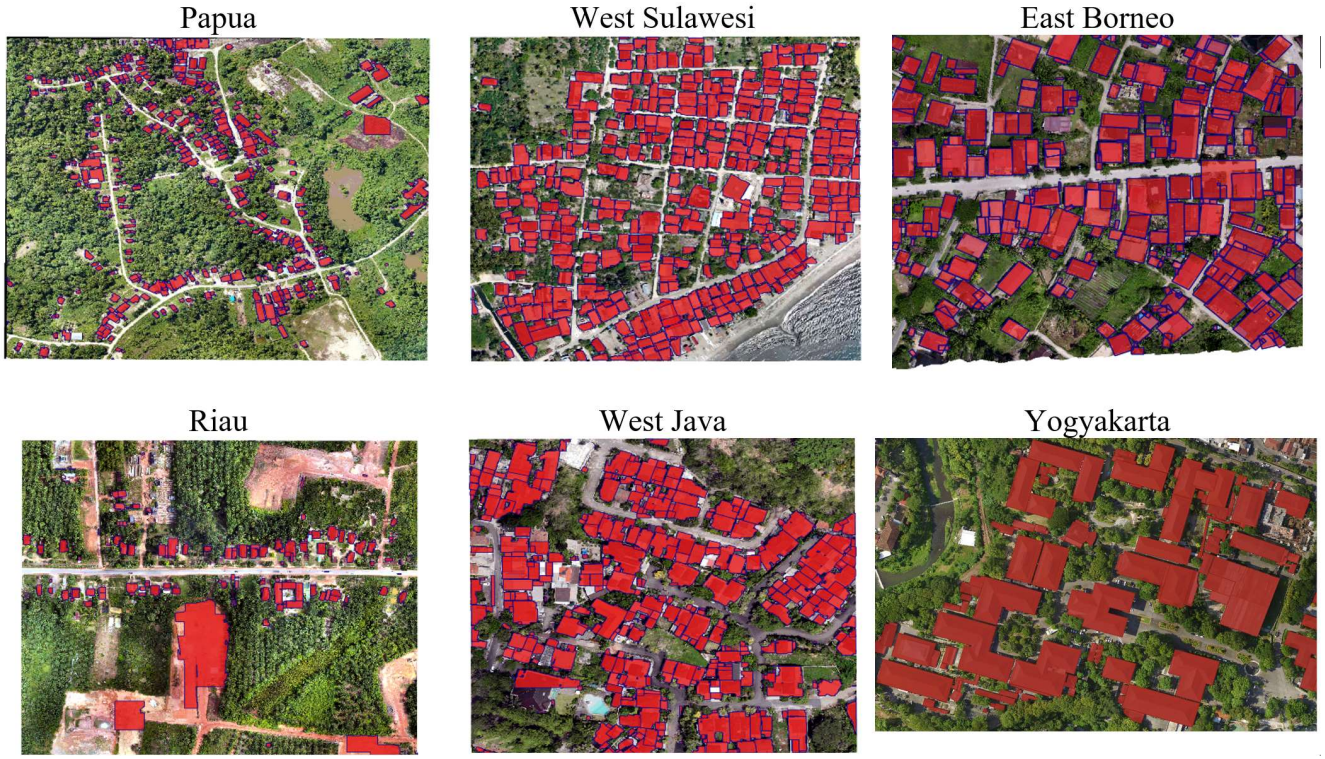
40 Ha in West Java

(b) DG-CNN training sample



55 Ha of urban and suburban areas in West Java and Yogyakarta

Results: building footprint



GeoCARTA could extract most of building footprints.

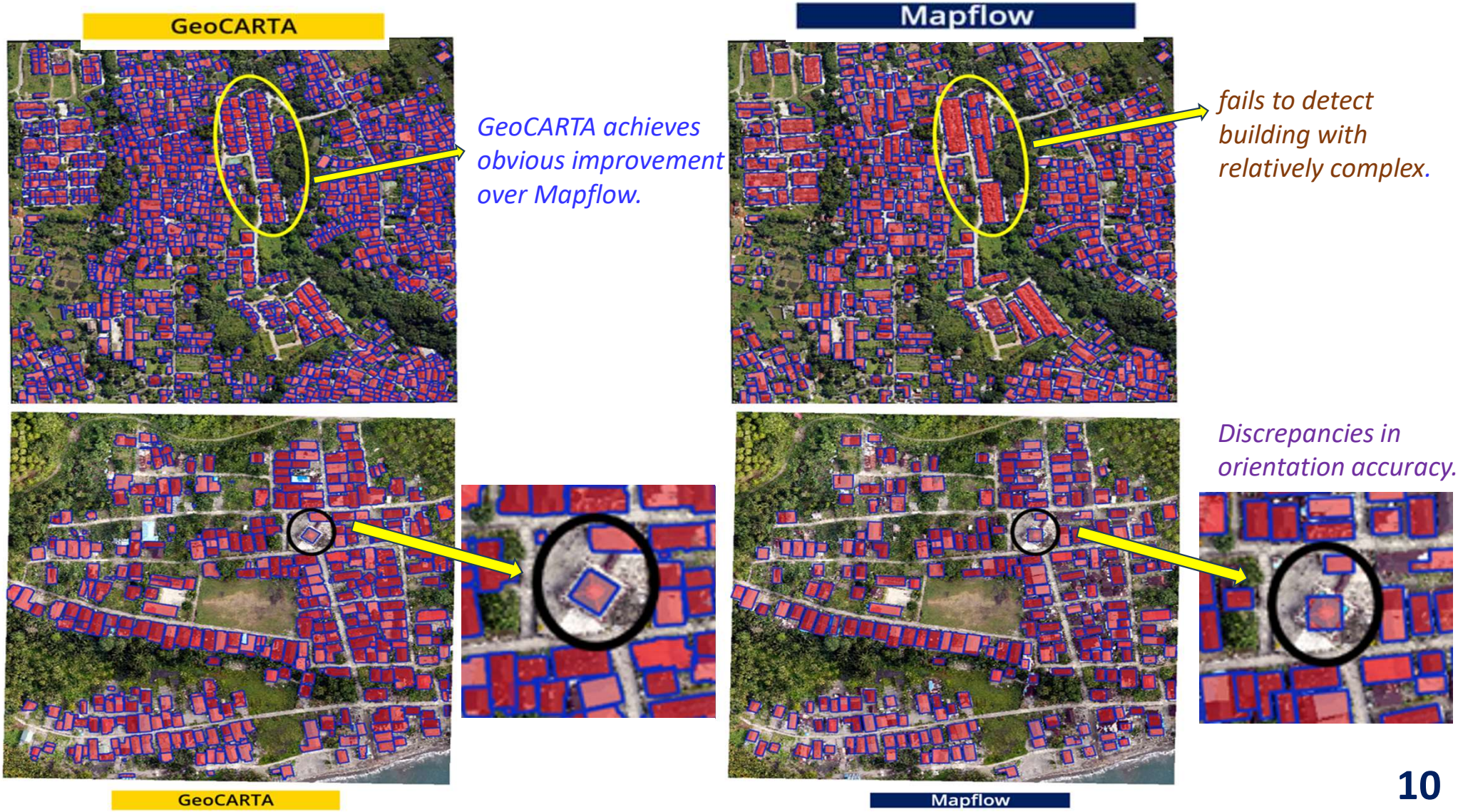
Still……. it fails to detect
building with relatively complex/connected buildings.

Evaluate the deep learning model

F1 score (measures a model's accuracy). It combines the precision and recall scores of a model = **93.88%.**
The **overall accuracy** as indicated that the predicted values match the actual values (ground truth) = **88.47%.**

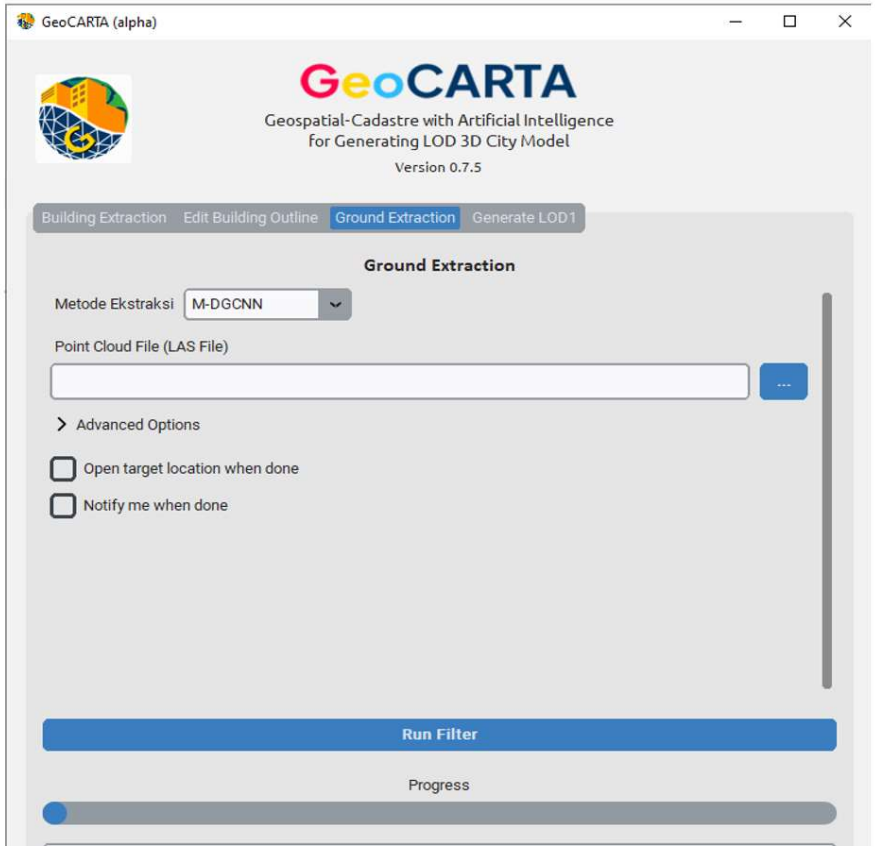
Results: building footprint

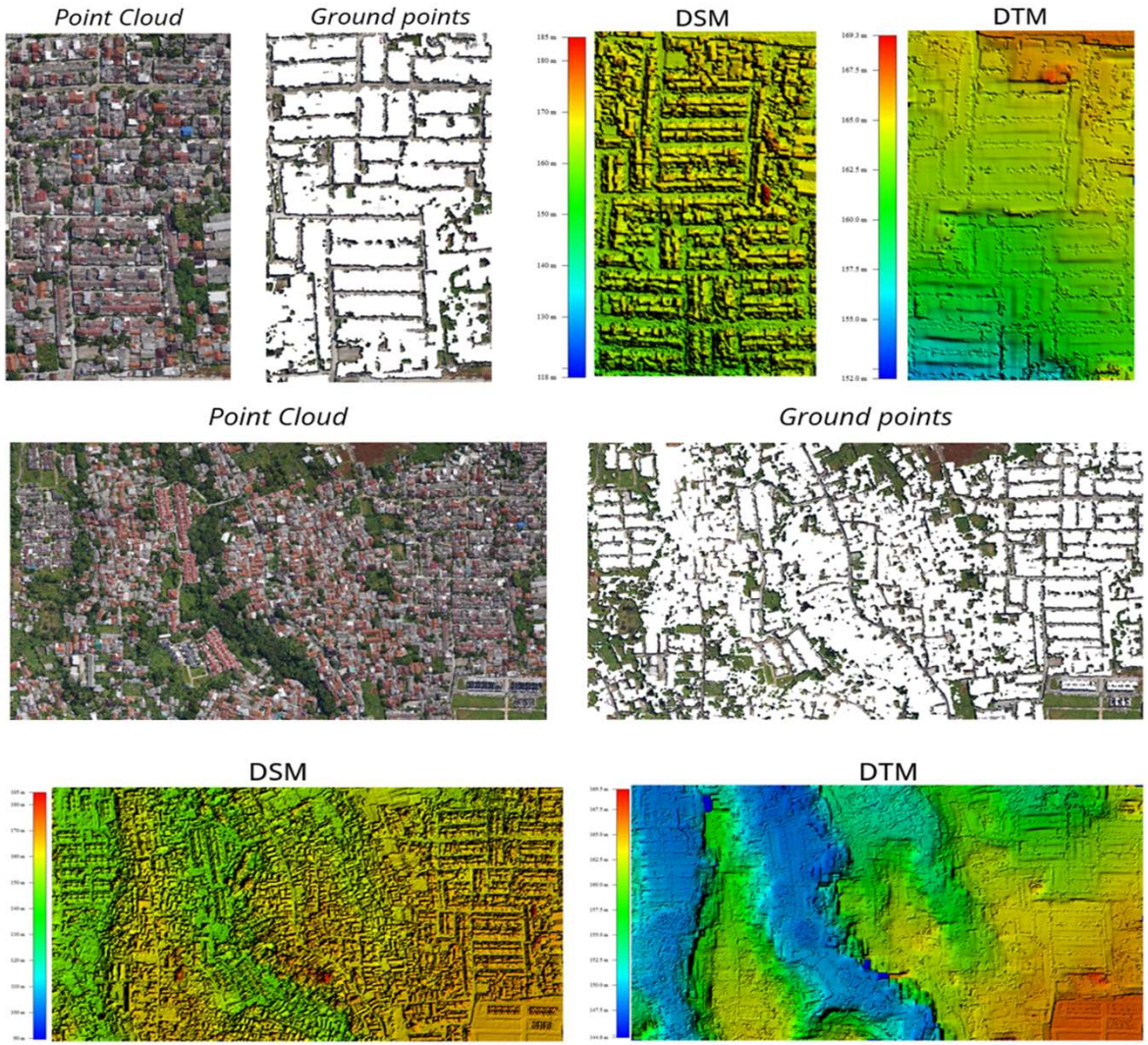
Comparative results between Geo-Carta and **Mapflow** (a *commercial* subscription plugin in QGIS)



Results: Generated DTM

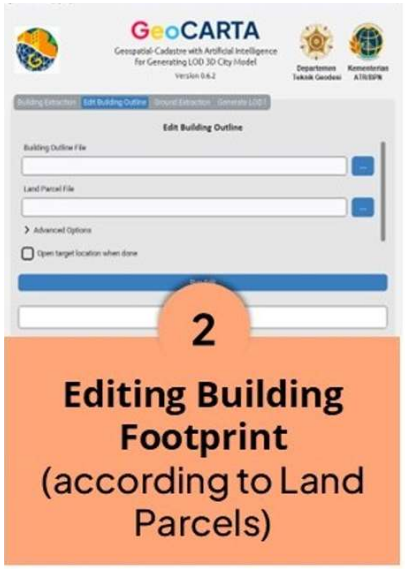
A custom DG-CNN trained model was developed for the Geo-carta App.





*Intersection over union (IoU) score and overall accuracy of **0.906** and **0.969**, respectively*

Results: Editing tool for refining building footprint according land parcels



GeoCARTA fails to detect footprints over closed buildings and low textures (Fig a).

(a)

(b)

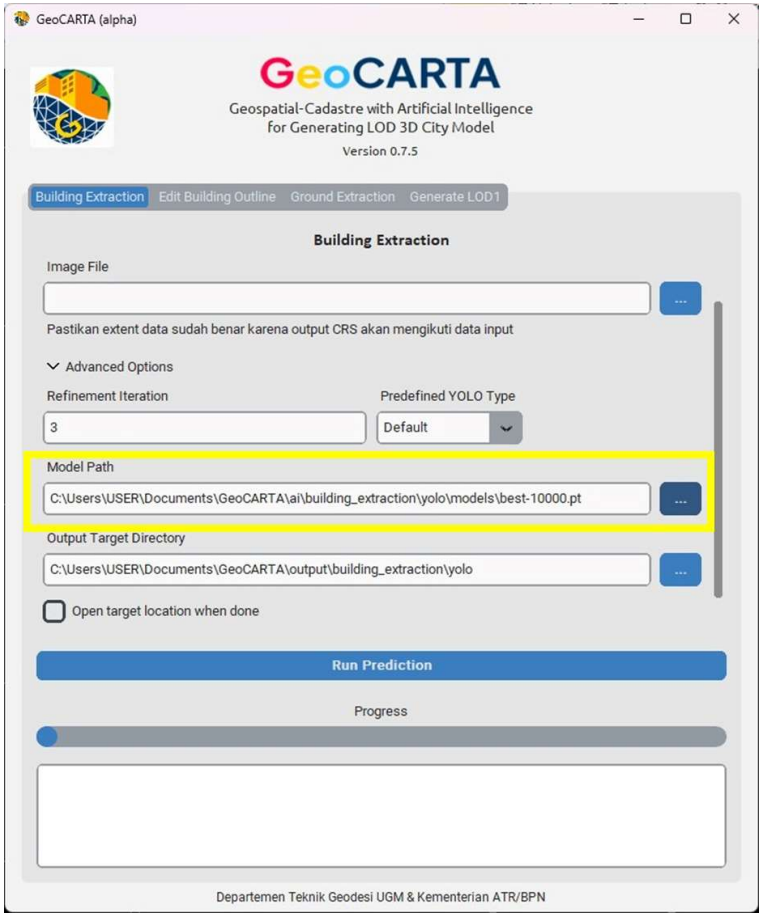
The land parcel boundary

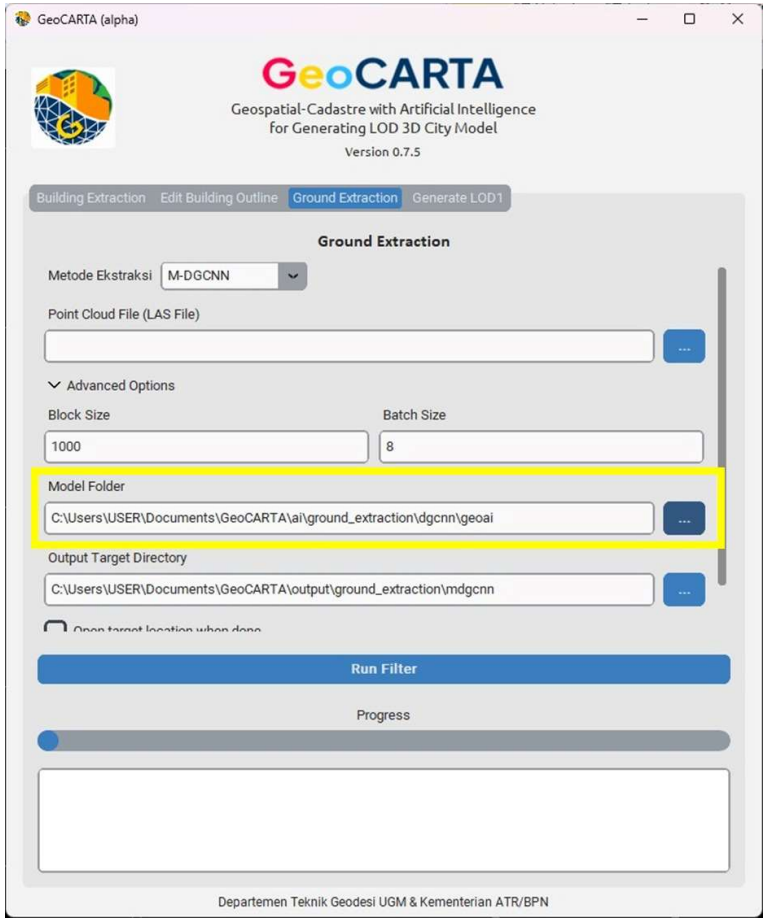
(c)

a refined footprint

Results: Geo-Carta facilitates updating the deep learning models

- **Trained model is very important**.
- It is advisable to revise and **enhance the trained model** in specific regions where it exhibits divergent characteristics relative to our model.



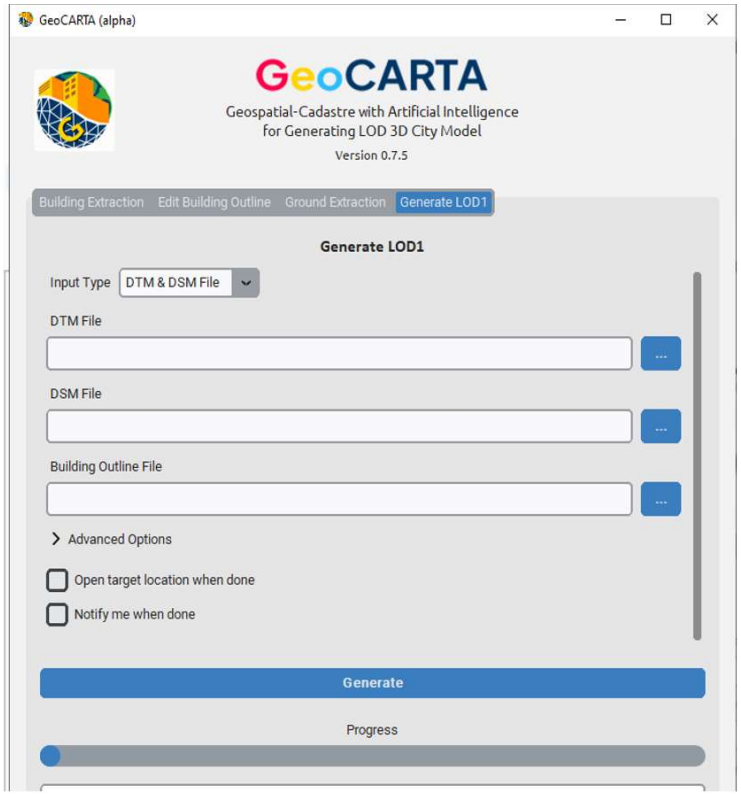


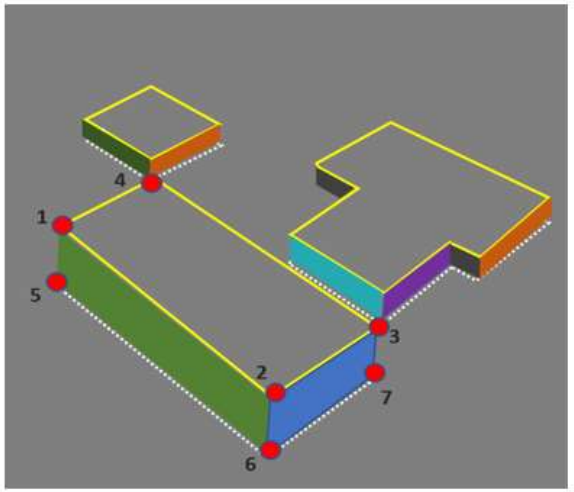
Input the new trained model file in Pytorch model format (.pt).

Results: 3D LOD1 model

Three input data for generating 3D LOD1 model:

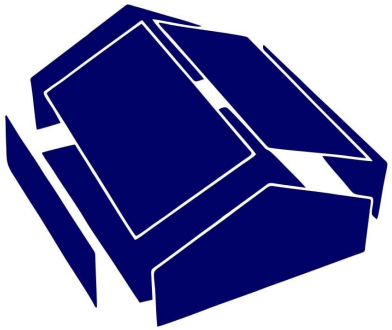
- Building footprint
- DSM
- DTM





Boundary Representation

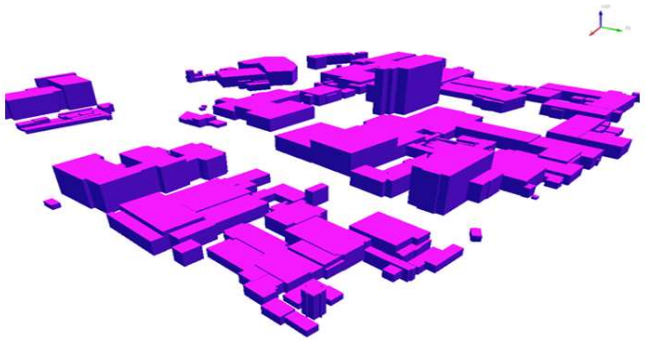
Aggregation of boundary surfaces,
which enclose
the body completely



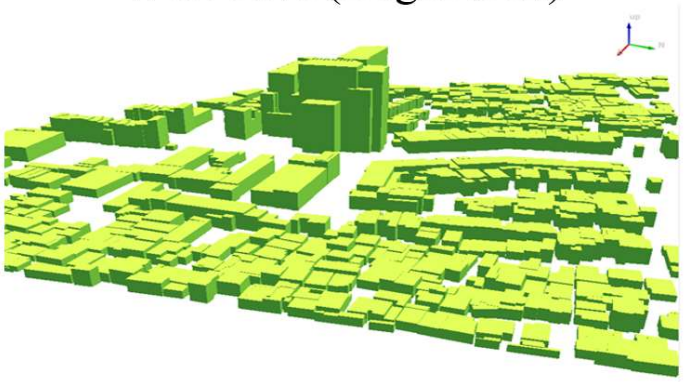
We have tested the 3D model reconstruction over four locations: Yogyakarta (UGM campus), West Java (Bogor icon building), and DKI Jakarta (Trunojoyo).

Results: 3D LOD1 model

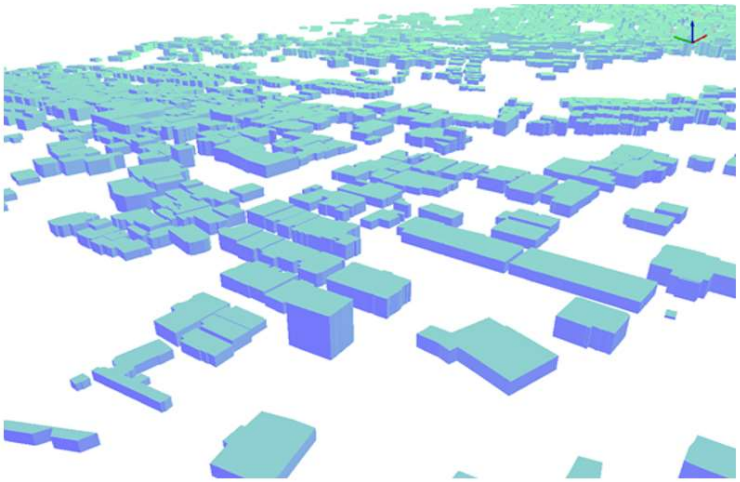
Yogyakarta (UGM campus)



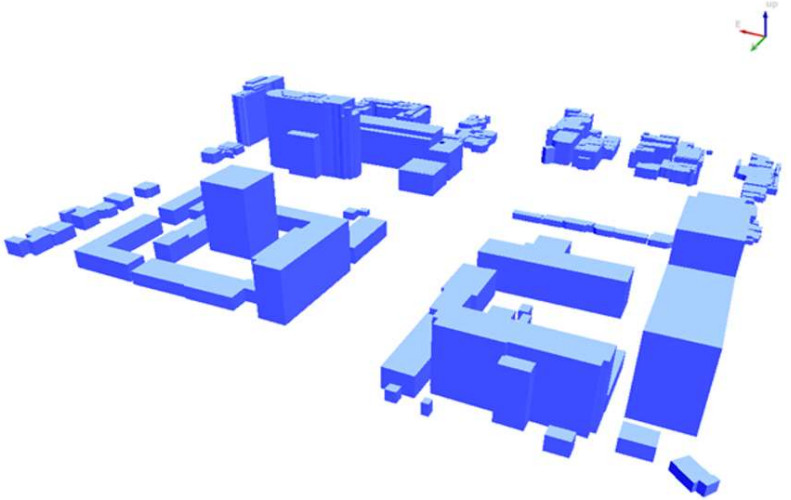
West-Java (Bogor icon)



West-Java



DKI Jakarta

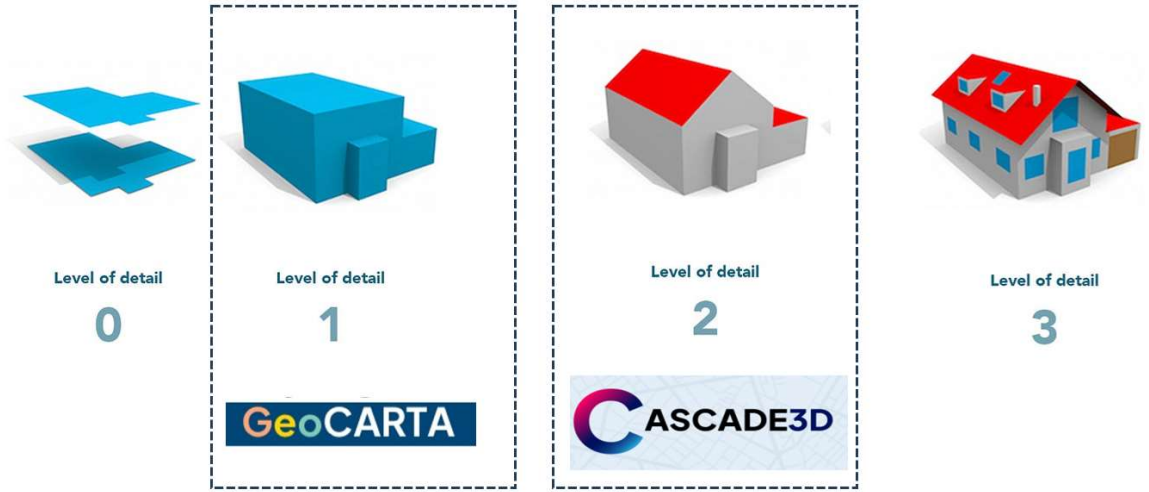


Conclusions

This paper presents an automatic method for detecting building footprint, ground point extraction and 3D model in LOD-1 based on UAV orthophoto and point clouds.

1. Those steps successfully integrated into a single interface application, namely Geo-Carta through YOLO deep learning and DG-CNN algorithm.
2. The building footprint can be well recognized, however, in the dense/connected buildings/ low-textured roofs, they are not properly segmented. **Editing building footprint** with land parcel should be performed.
3. Updating the trained models with various textures/shapes/color are essential for enhancing the resulted footprint.

Future works



*CAdastre and Spatial map adjustment with spatial Computation for Automatic builDing dEtection and 3D generation