

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





1





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.



Motivation



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



The methods to extract building footprint and ground points





Building footprint



Image segmentation:

- OBIA method
- Al/deep learning



Point clouds segmentation: Al/deep learning+DBSCAN



Ground extraction



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

Experimental study utilizing AI : Building footprint \rightarrow YOLO-v8 Deep learning with custom trained data. Ground extraction \rightarrow 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.

	GeoC	ARTA	
🖗 SexCATEA juganel - O X	🗣 sescatta lagnal — O X	\varTheta GenCATATAININA – D X	🗣 Genicanta Infinal — O X
GeoCARTA Gesputul-Cadatre seth Artificial totelligence fair Generating LOD 20 City Model Vendor 8.2	Constantial Cardination with Artificial Intelligence for Generating LCD 10 City Model Version 0.6.2	Cecopatial Cadatore with Artificial Intelligence Ar Generating LOO 30-City Model Version 16.2	Geo CARTA Gespatisi-Cadatte vetA Artificial Intelligence For Generating LOD 30 City Model Versike 0.6.2
Building (martish) and Building former (and see as 2001) Building Extraction	Series Lancenze Litt Building Solice Transit Schemen 2 (2001) Edit Building Outline	Rading Desires 201 Dates Sofer Desires Break Laboration Ground Extraction	Reining Devotion - Birl Reining Defen - Breune - Generate 1001 Generate 1001
Model VOLD	Balling Oxfore File	Point Claud File (ASFRe)	Next Type 07M KDSM/Te W
	Led Pereillie	> Advanced Optimes	
Advanced Options	> Advected Options	Open target location when done Notify me when done	DMTR
	Ciper target location when done	3	Authorite
Building Footprint Extraction (YOLO)	Editing Building Footprint (according to Land Parcels)	Ground Extraction (DTM Production With DG-CNN)	3D Reconstruction of LoD1 Models





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



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









Yogyakarta





Results: building footprint

8	Geospatial-Cadastre wit for Generating LO Version	ARIA h Artificial Intel D 3D City Mode 0.6.2	ligence	Departemen Teknik Geodesi	Kemente
Model YOLO	ulding Outline Cround Extrac Building	ton Generate L	001		
Image File Pastikan extent data suc	lah benar karena output CRS ak	an mengikuti dat	a input		
Refinement Iteration		Predefined YOL	О Туре		
3		Default	~		
Model Path		Default			
AND CONTRACTORS OF	iments\GeoCARTA\ai\building_	Rapid Medium		best-10000.pt	
C:\Users\LENOVO\Doci		A March 1 and			
C:\Users\LENOVO\Doci		Highest			
C:\Users\LENOVO\Doci Output Target Directory C:\Users\LENOVO\Doci	ments\GeoCARTA\output\buil	ding_extraction\y	olo		
C:\Users\LENOVO\Doci Output Target Directory C:\Users\LENOVO\Doci	iments\GeoCARTA\output\build	Hignest	olo		



GeoCARTA could extract most of building footprints.

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%.

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



Results: building footprint

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

GeoCARTA



GeoCARTA achieves obvious improvement over Mapflow.

Mapflow



fails to detect building with relatively complex.

Discrepancies in orientation accuracy.











Results: Generated DTM

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

		Point Cloud	Ground points	DSM	DTM
Ceospatial-Cadastre with Artificial Intelligence for Generating LOD 3D City Model Version 0.7.5 Building Extraction Edit Building Outline Ground Extraction Generate LOD1 Ground Extraction Metode Ekstraksi M-DGCNN Point Cloud File (LAS File)	- O X			115 m - 120 m - 100 m - 110 m <td< th=""><th>$149 \ 3 = -$ $147 \ 5 = -$ $145 \ 0 = -$ $145 \ 0 = -$ $150 \ 0 = -$ $157 \ 5 = -$ $155 \ 0 = -$ $152 \ 0 = -$ $152 \ 0 = -$ $152 \ 0 = -$</th></td<>	$149 \ 3 = -$ $147 \ 5 = -$ $145 \ 0 = -$ $145 \ 0 = -$ $150 \ 0 = -$ $157 \ 5 = -$ $155 \ 0 = -$ $152 \ 0 = -$ $152 \ 0 = -$ $152 \ 0 = -$
		Poi	int Cloud	Gro	ound points
 Advanced Options Open target location when done Notify me when done 					
Run Filter			DEM		DTM
Progress Intersection over union (IoU) score an overall accuracy of 0.906 and 0.969 , respectively	nd	<pre>Mail Sector Sector</pre>		100	

Results: Editing tool for refining building footprint according land parcels

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











The land parcel boundary





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

😵 GeoCARTA (alpha)	_	×
Ceospatial-Cadastre with Artificial Intelligence for Generating LOD 3D City Model Version 0.7.5 Building Extraction Edit Building Outline Ground Extraction Generate LOD1		
Generate LOD1		
Input Type DTM & DSM File		
DTM File		
DSM File		
Building Outline File		
> Advanced Options		
Open target location when done		
Notify me when done		
Generate		
Progress		



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





onclusions

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.

- 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/ lowtextured roofs, they are not properly segmented. Editing building footprint with land parcel should be performed.
- Updating the trained models with various textures/shapes/color are essential for enhancing the 3. resulted footprint.

Future works



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

3