FIG WORKING WEEK 2023

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Protecting Our World, Conquering New Frontiers

The possibility of using AI tools to the inventory of technical and transportation infrastructure using UAV data

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Motivation

The main areas for improvement are:

- Improving the **accuracy of** project **data**
- better **access** to project data
- streamlining the field **productivity**

There are **3 big trends** that help achieve those goals

Our goal in our R&D project was

- To develop a methodology for using AI in the automatic inventory of construction elements in railway, street, and power network infrastructure

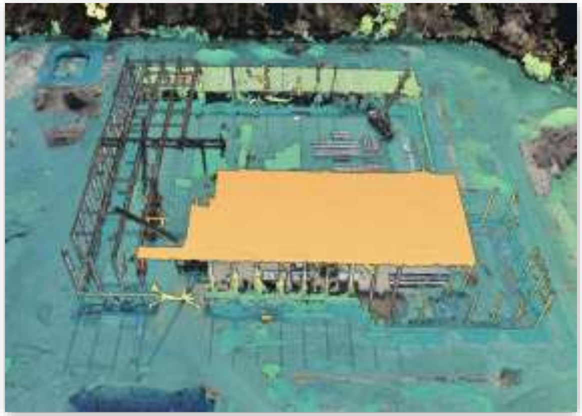
Trend #1 – Drones' market development

- It's a tool for collecting data
  - accurate
  - fast
  - safe
  - autonomous (near future)
- Already about 2.5 mln drones
- Becoming better and cheaper every year -> accelerating growth

Trend #2 – Photogrammetry and geoportals

More processing -> more information

Data

Photos / Videos	Orthomosaic (2D)	Terrain Models (3D)	Cyclical models / Management system
			

Goal

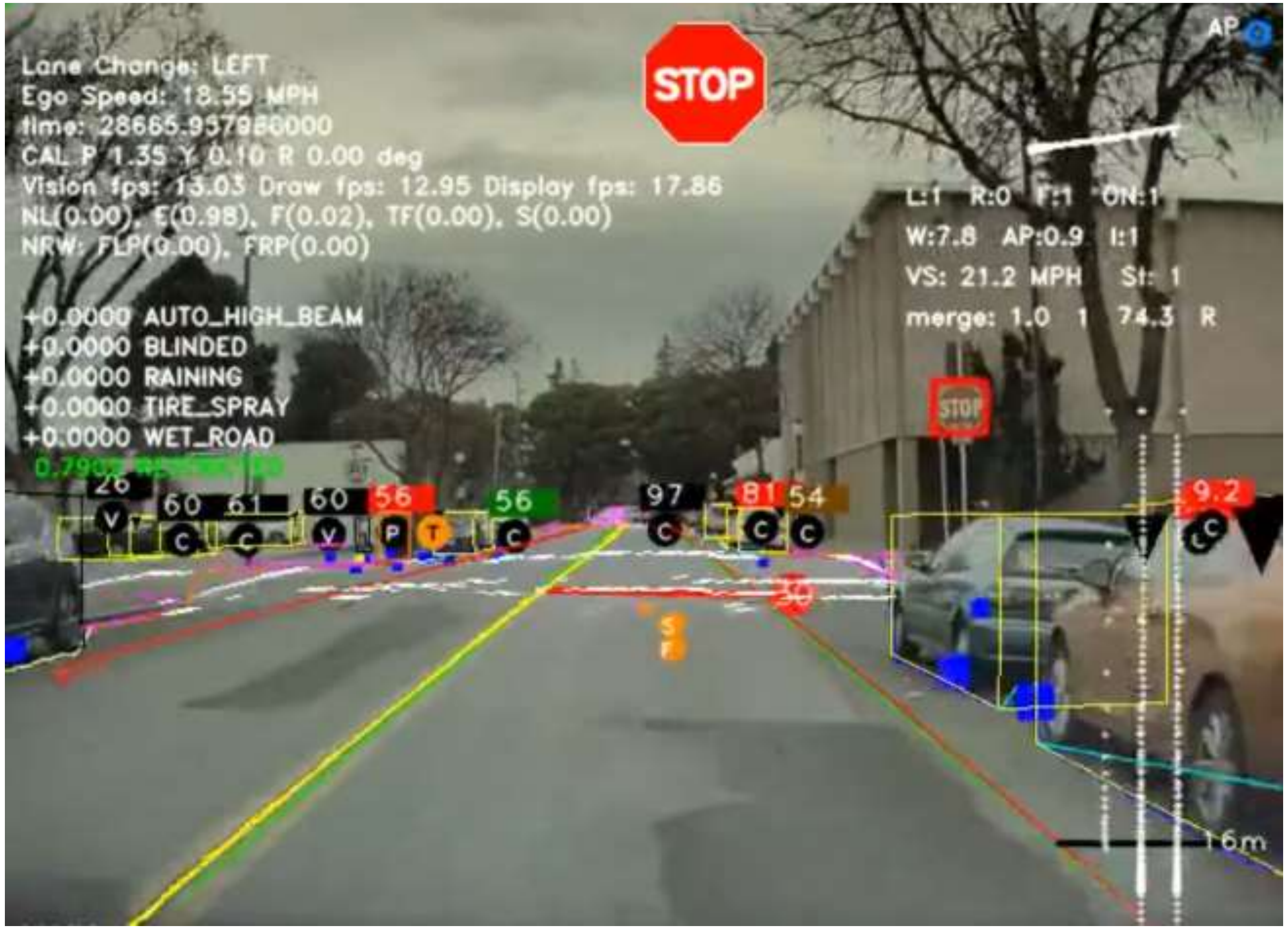
Photos / Videos
- Overall assessment and visualization

Orthomosaic (2D)
- 2D representation of terrain
- 1-5 cm accuracy
- 2D (X, Y) measurements
- 2D As-Built vs As-Designed

Terrain Models (3D)
- 3D representation of terrain
- 3-10 cm accuracy
- 3D (X, Y , Z) measurements
- 3D As-Built vs As-Designed

Cyclical models / Management system
- Progress tracking
- BIM 4D
- Asset management

Trend #3 - Machine Learning including artificial intelligence



- ML and AI can make geospatial data processing more automated replacing manual work in:
  - Detecting and recognizing infrastructure objects
  - Modelling Surface
  - Measuring in 3D

Scope of analysis in R&D project

Using AI we worked with geodata to detect

- Rail sleepers
- Rails
- Rail gates
- Rail traction poles
- Traction power cables
- Traction network power poles
- Street lights
- Road Stockpiles
- Road construction layers

For each category, photogrammetric products were considered as available source data for detection and recognition

- Nadir images
- Oblique images
- Orthomosaics
- Ortho images
- Dense Image Matching point cloud
- Lidar point cloud

See also: Zachar, P., Ostrowski, W., Bakuła, K., Buda, M., Foltyn, M., Palak, R., & Sosnowicz, K. Application of AI tools to the inventory of technical and transportation infrastructure based on UAV data, FIG Congree 2022


Street lamps
detection

Datasets

Errors in recognition for street lamps with image-based orthogonalized products in UAV-dedicated software

Caused by image adjustment in the orthorectification process involving many images – visible few lamps instead of one

Caused by unstandard orthorectification proces involving mesh models instead separated images directly – visible parts of a lamp coming from different images

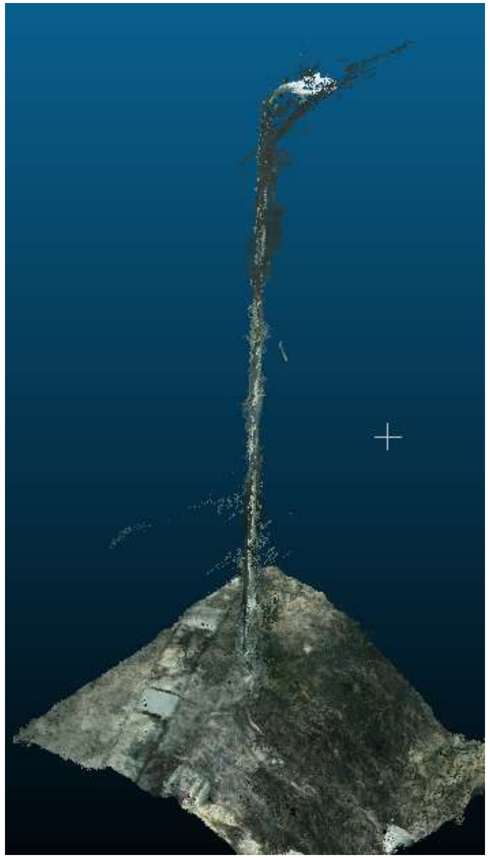
Caused by using only nadir images for lamp located in central part of images – the visible lamp is in orthogonal projection and only the top of the lamp can not be recognized

Automatic seem lines in orthorectification can cause a problem in recognizing one element in a few locations

Datasets

Errors in recognition for street lamps with image-based point cloud generated in UAV-dedicated software

DIM in case of nadir images does not bring the point cloud for whole lamp, providing points mostly for lamp head what makes automatic detection difficult cause data for training and for prediction are diverse



DIM of oblique images brings a point cloud showing the whole lamp shape, but sometimes it is much noised due to the high number of overlaps

Datasets

The final decision for type of datasets lamp detection

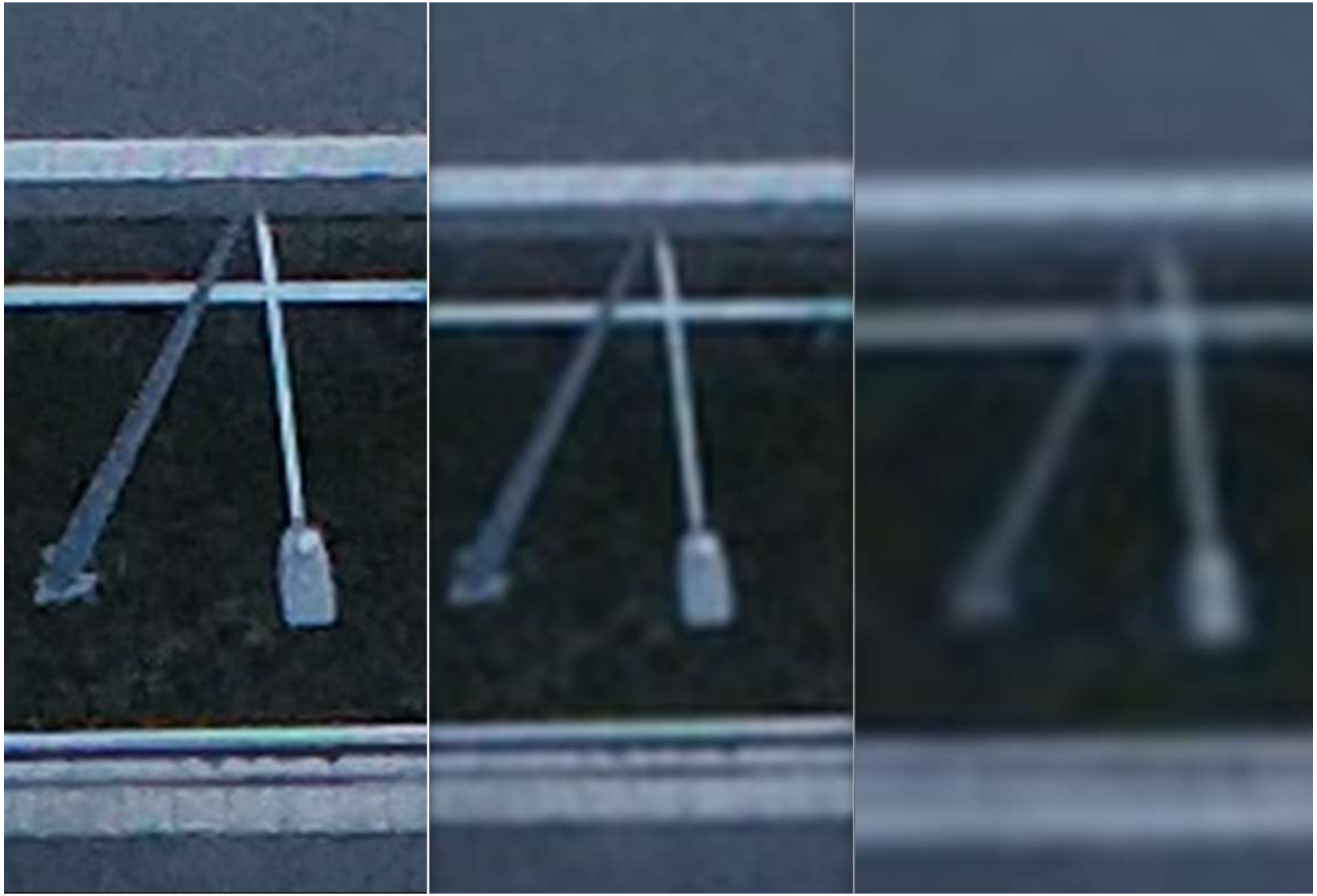
- Whole shape of the object is visible if the flight is over the road axis or two flight lines with the camera oriented ahead
- Using oblique images with georeference and the results of calibration with mitigation of center projection and camera parameters' influence
- This solution brings the redundancy in one item detection on dozen images that allows for excluding single wrong detections and quality control.

The final decision for the type of datasets lamp detection

Bounding boxes with approoximated location (the closest point to the 2D location of image centre of projection – bottom of the lamp)

Datasets – Image collection

- Working on trained models to process the prediction of detection, we must be focused on collecting unified datasets comparable to those from which the model was trained
- Spatial resolution is a crucial factor in the prediction process.
- Most of the training data were captured with 3 cm resolution.
- The results of prediction with different resolutions were not successful
- Before prediction higher resolution should be downgraded to worse but still acceptable, lower resolution was not acceptable



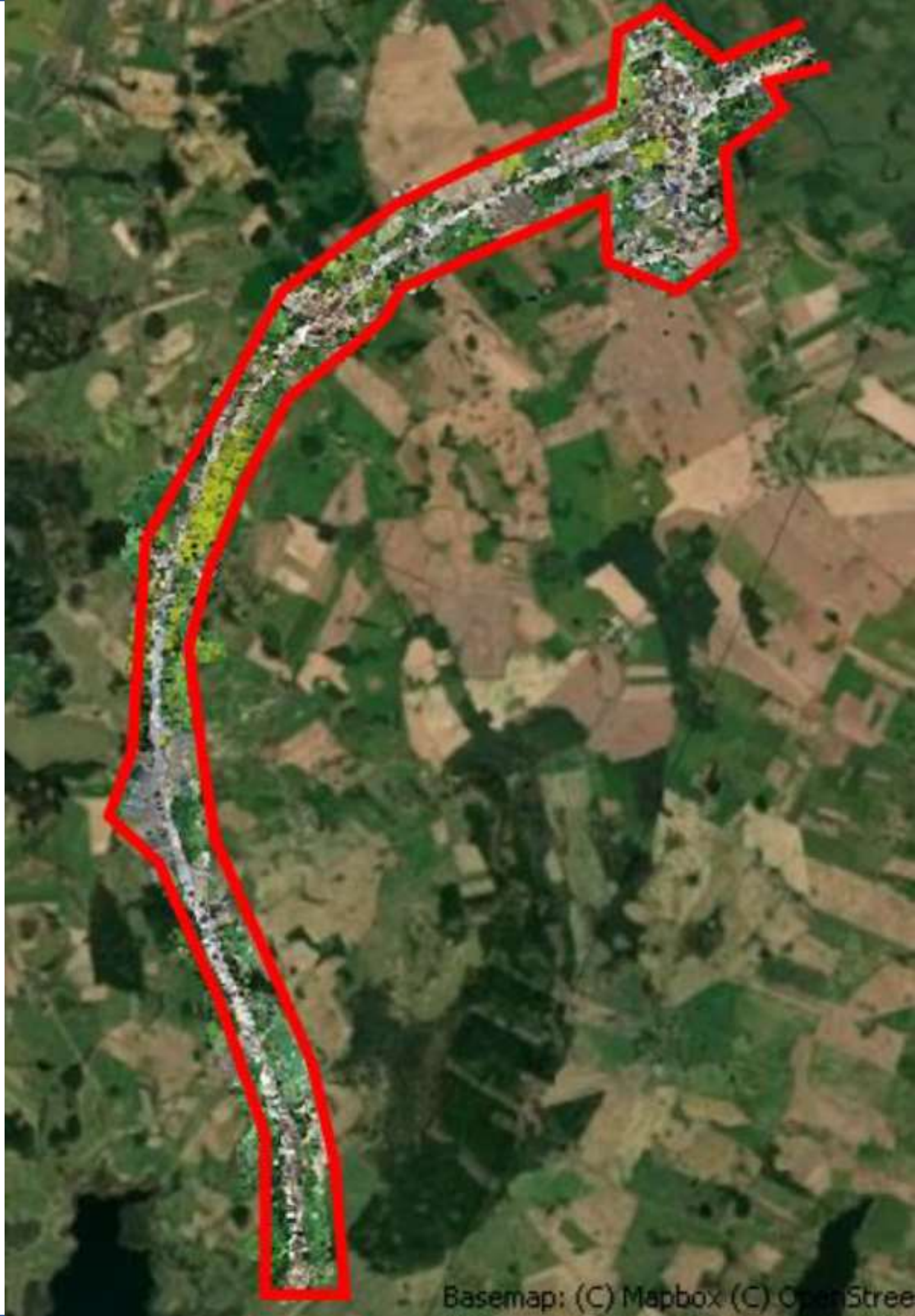
3 cm 5 cm 10 cm

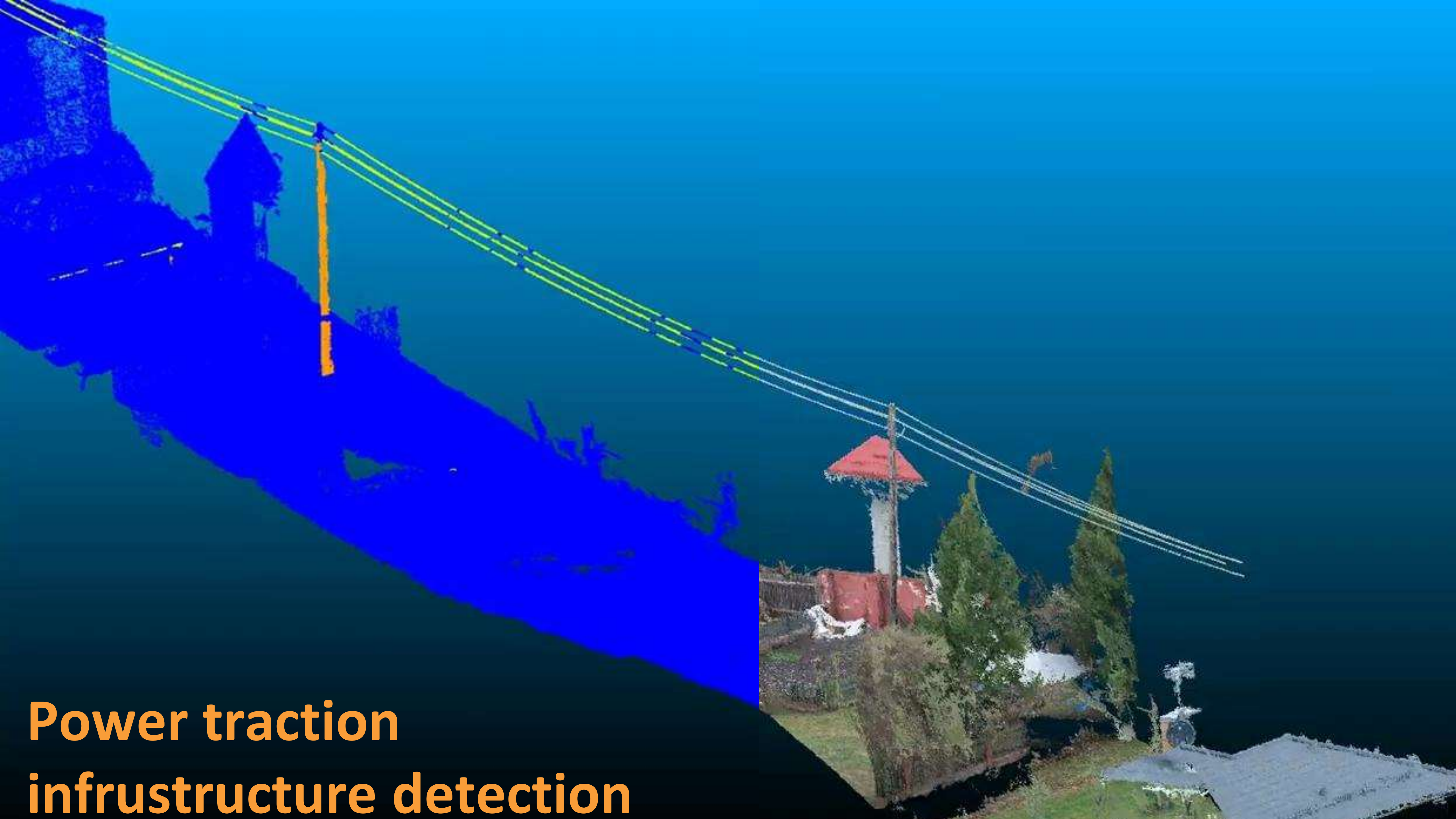
image resolution showing quality of dataset for the street lamp detection

Detection results

- Independent test area in Ełk of 10 km – Northern Poland (Mazury region), 6034 images
- Accuracy (recall), precision and F1 scores analysed (on independent dataset)
- RetinaNet with feature pyramid network (ResNet-50)

Parameter	Value
Accuracy (Recall)	94%
Precision	98%
F1 score	96%

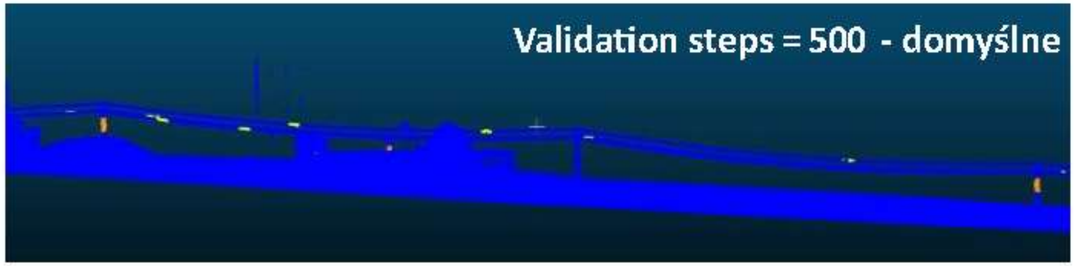


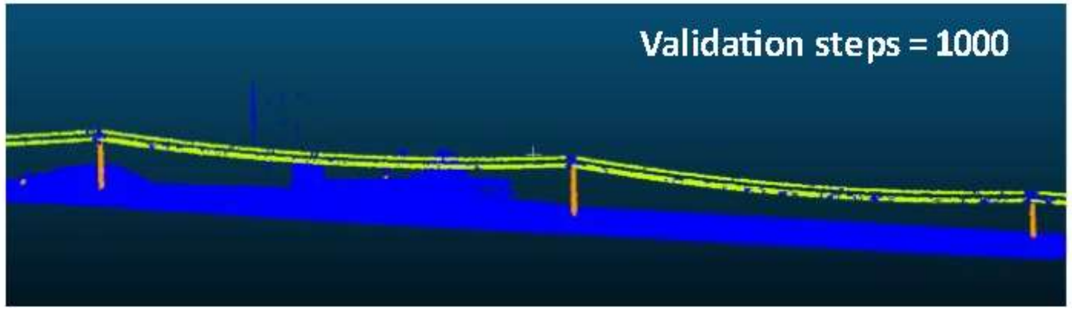


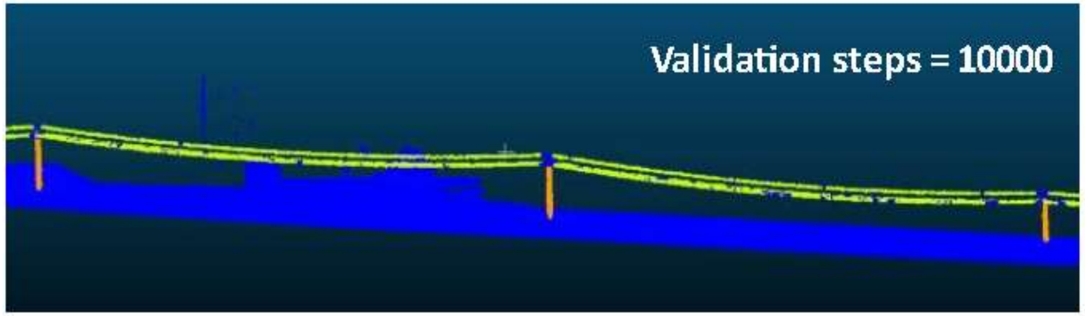
Power traction infrustructure detection

Datasets – why 3D approach

- Training models with 3D because there was a problem with labelling of great length of objects (cables) that are line-type infrastructure
- They are also overlaying very different land cover/use
- Poles are topographically integrated with cables so after unsatisfying results for cables they were detected with lidar or image-based point clouds too







Datasets – what lidar or RGB

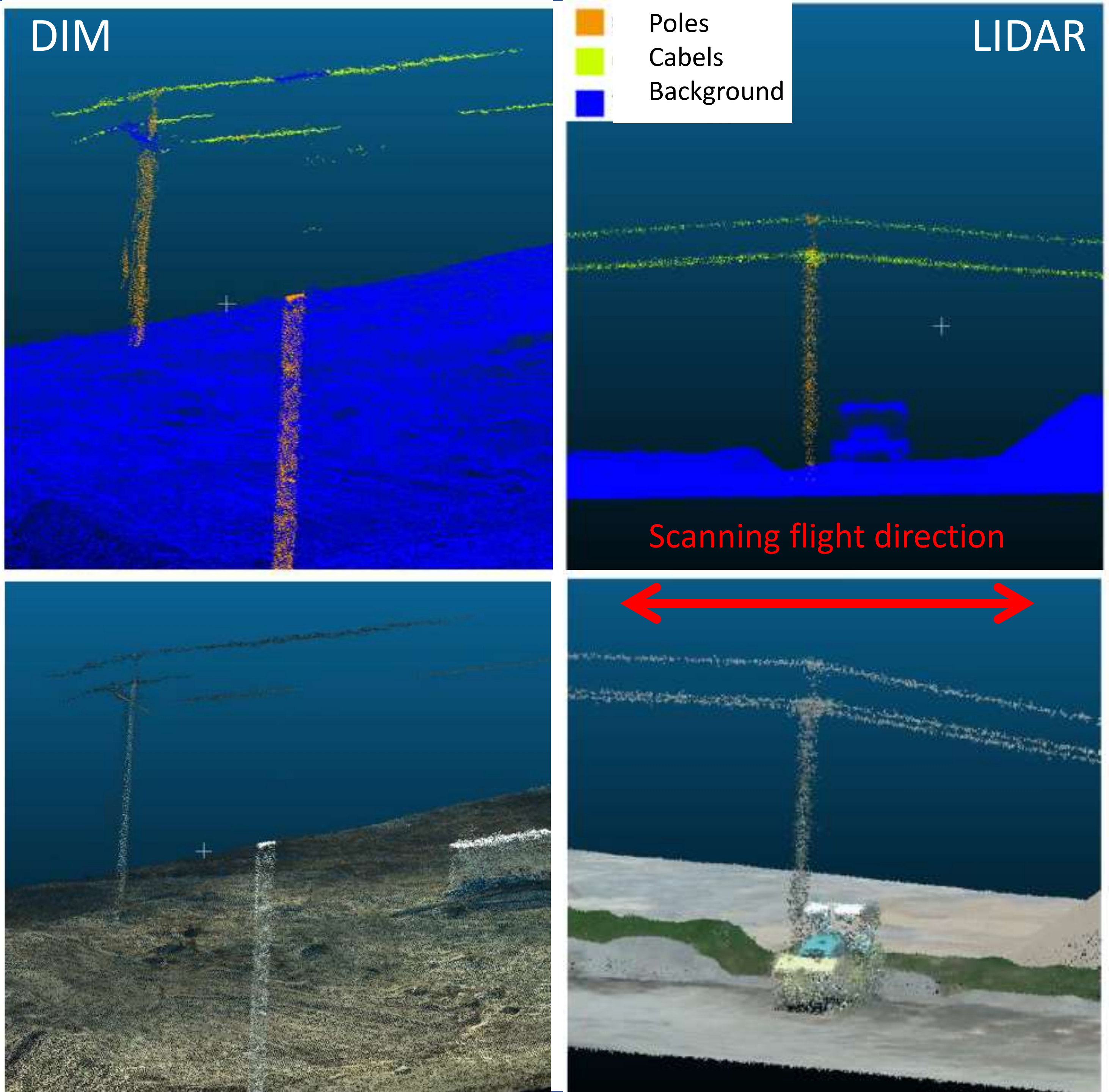
- For AI, point clouds from both sources are 3D products so they should present infrastructure in a reliable way

Dense Image Matching

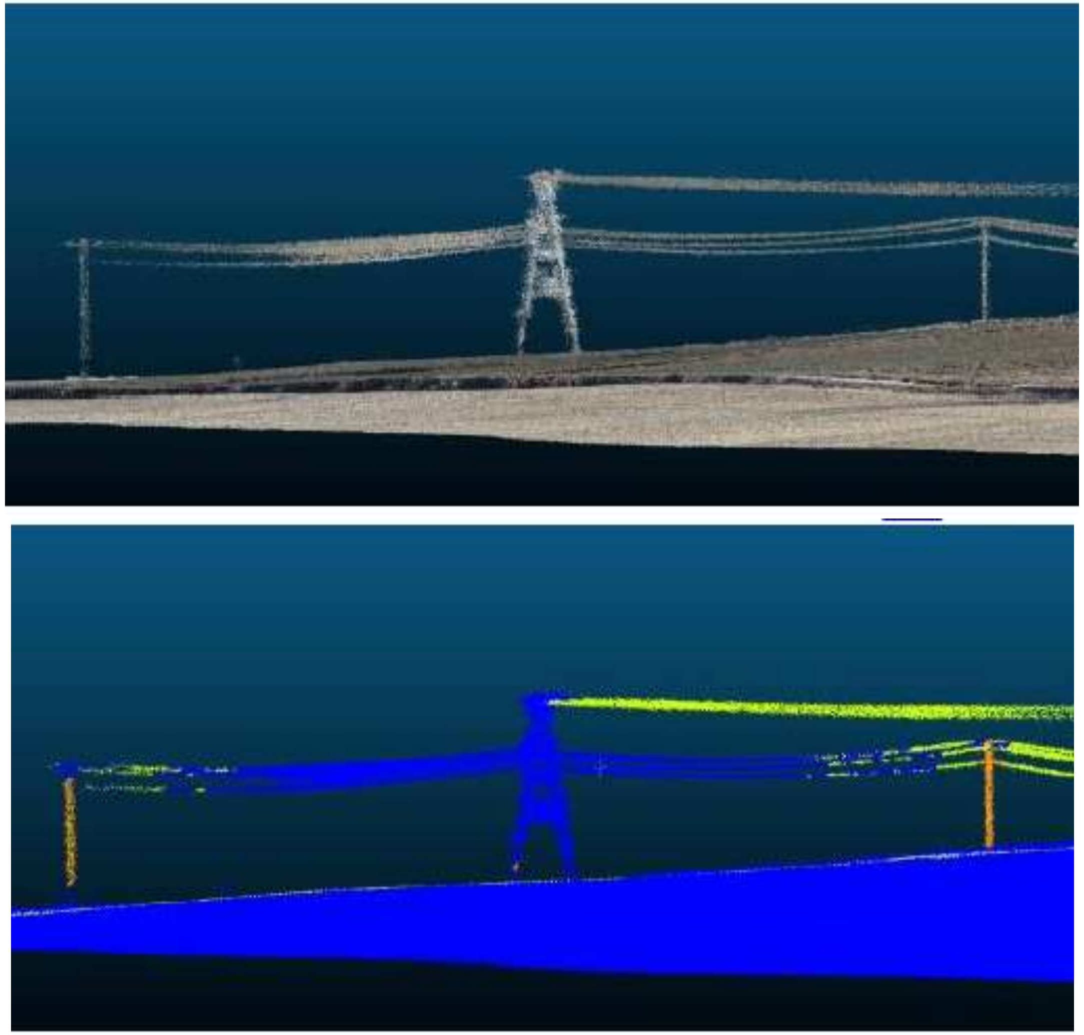
- DIM-based point clouds are the best with oblique images, but still gaps in points representing cables are visible
- relatively low pixel-sized is recommended with a low image footprint versus a safe flight height

Light Detection and Ranging

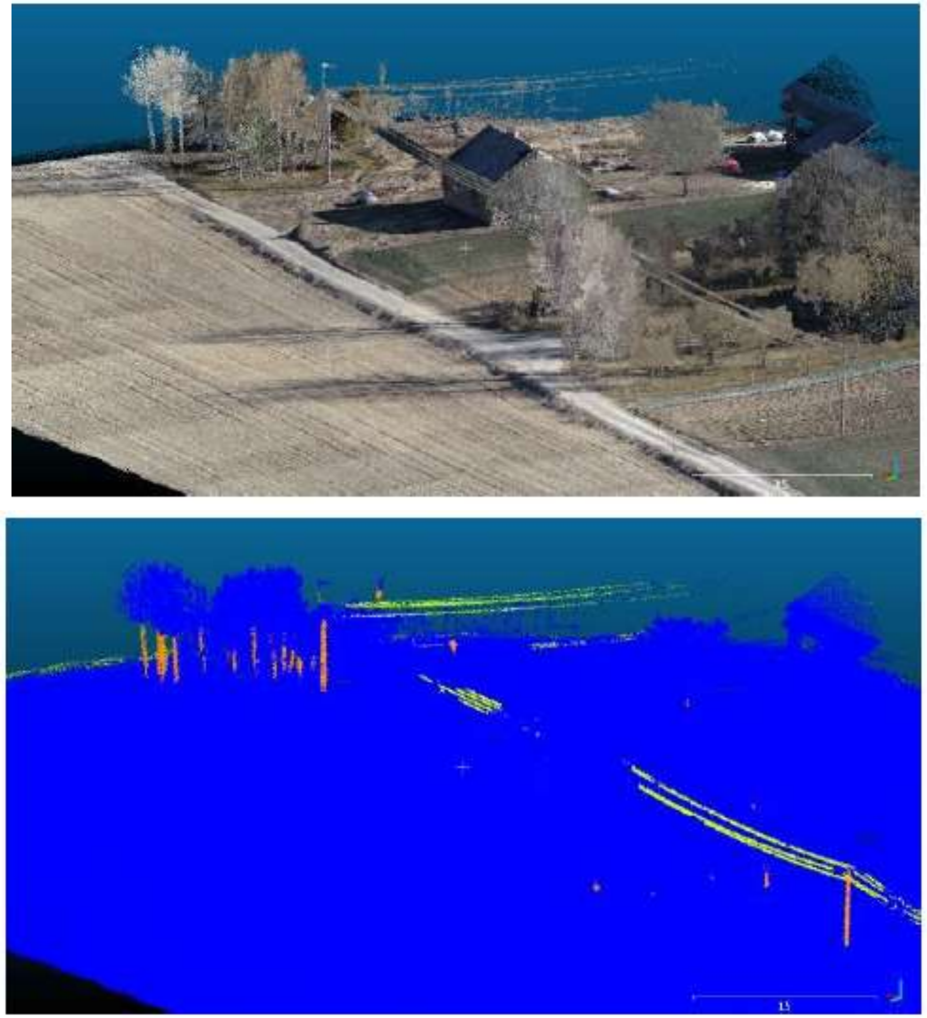
- LIDAR point clouds are more continuous having a regular distribution of points in line
- only corridor flight lines parallelly to infrastructure are recommended
- Flight height should be set considering a safe flight height and scanner range



Factors influencing on the classification results



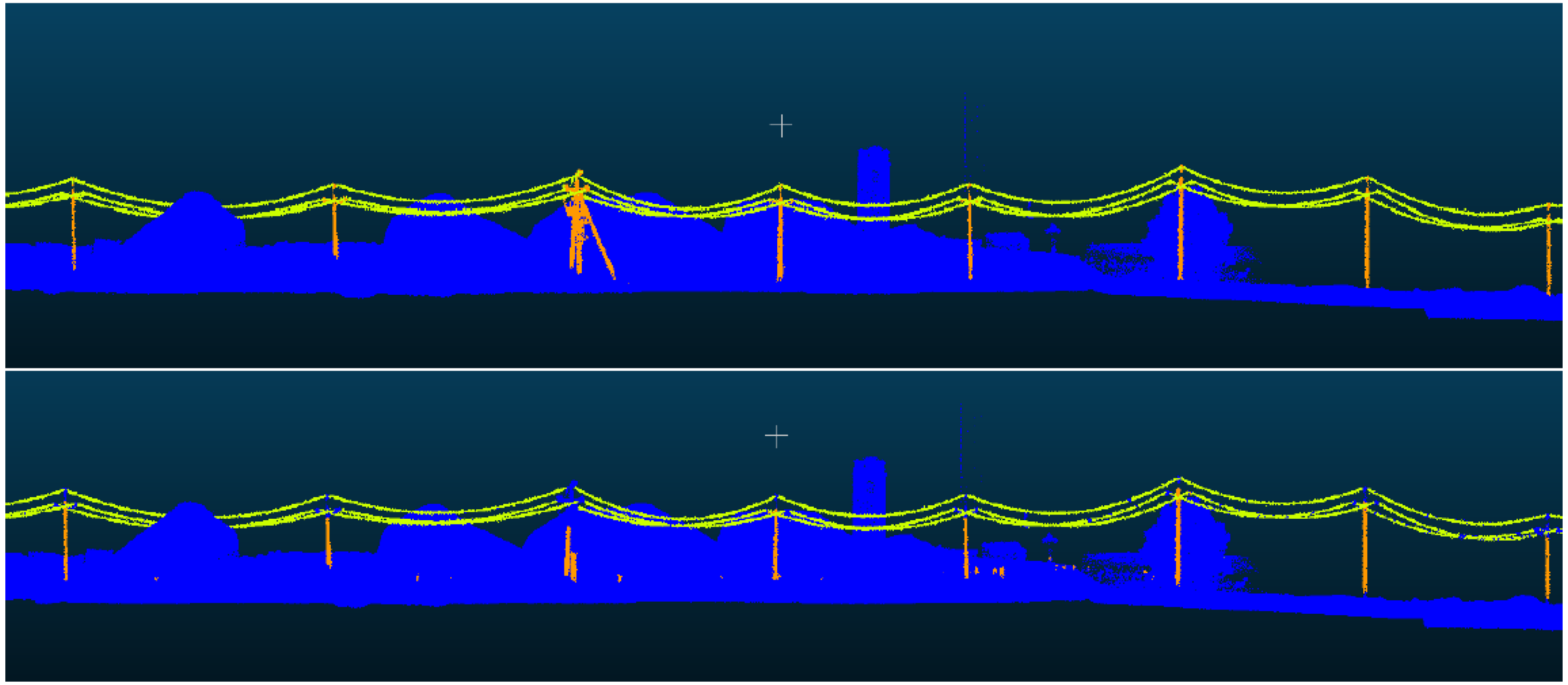
Despite the continuous representation of power cables in the point cloud, the results did not classify the whole line into proper classes – gaps can be filled



In the results of classification many trees were classified as poles – 2D approach or some GIS or BIM data could filter this result out

Detection results

- Independent test area in Mława – Northern Mazovia in Poland,
- DJI L1 point cloud collected with 50 m a.g.l
- RTK GNSS used with minimizing works in a field
- RetinaNet with feature pyramid network (ResNet-50)
- Accuracy (recall), precision and F1, score analysed (on independent dataset)

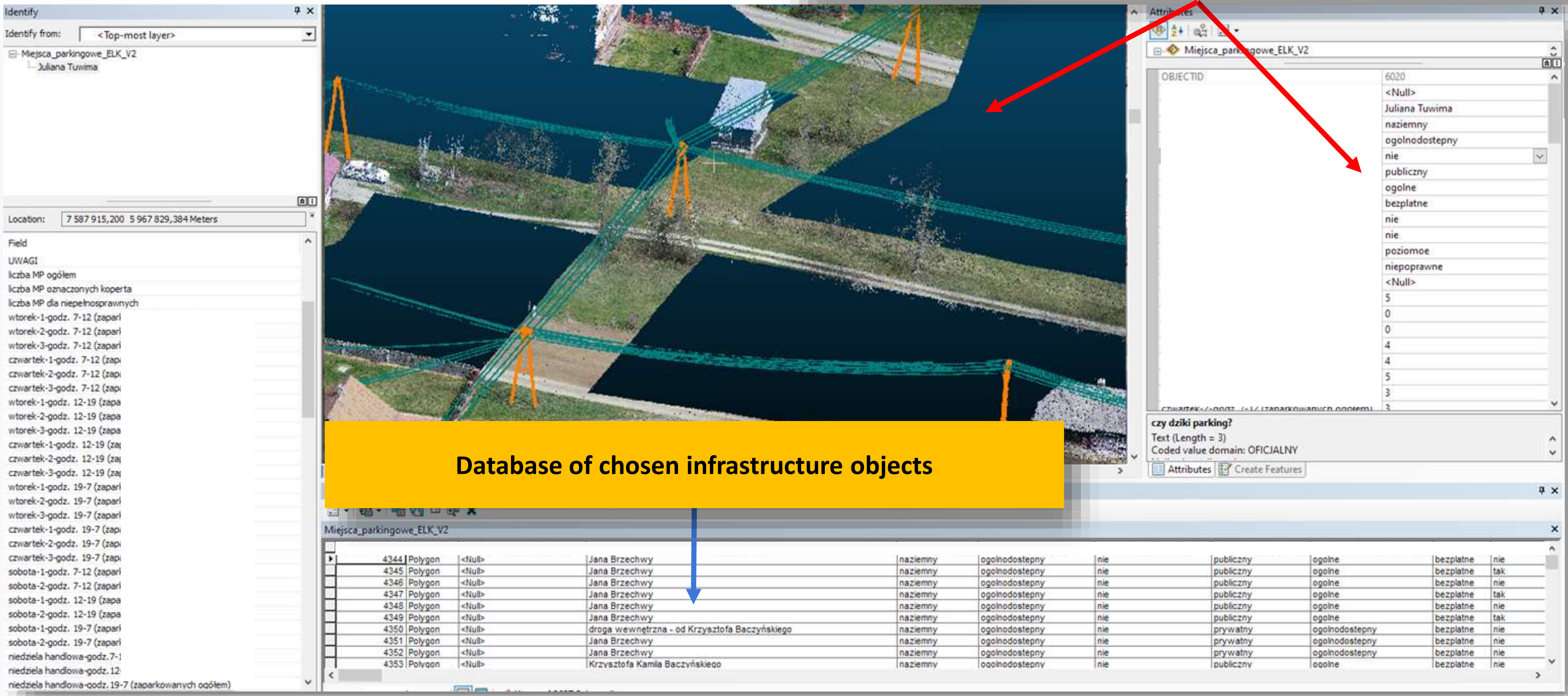


Parameter	Value for poles	Value for cabels
Accuracy (Recall)	98%	74%
Precision	80%	67%
F1 score	67%	67%

Final product
GIS database with objects and attributes

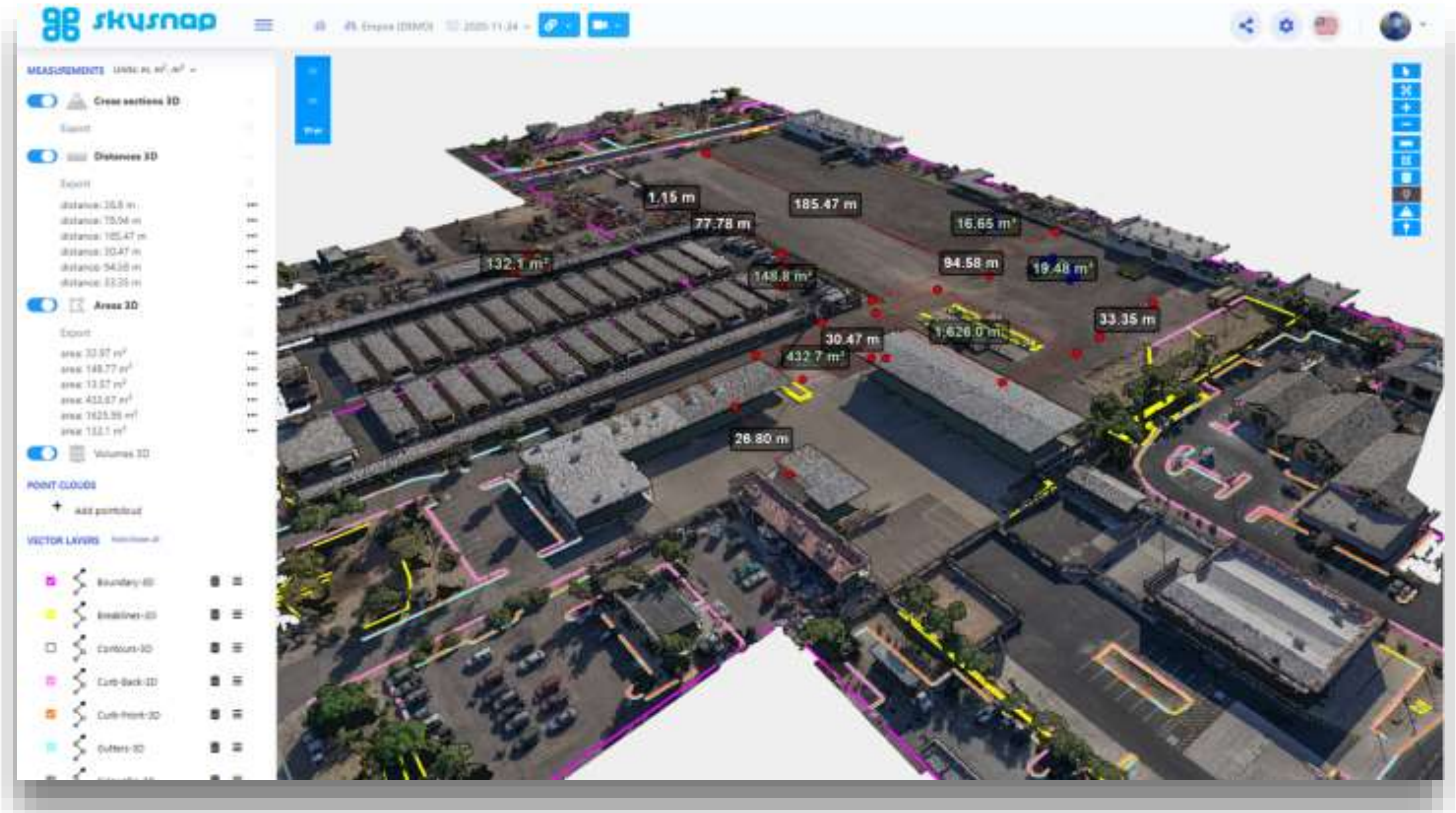
Attributes of a single object such as electric pole:

- Localisation x,y,z
- height
- type
- condition



Database of chosen infrastructure objects

Conclusion



- UAVs with sensing and georeferencing sensors provide us datasets ready for automatic processing with AI tools
- Photogrammetry delivers many opportunities to use products with AI-fueled tools
- Automation in photogrammetric dataset processing can deliver vector data for management of investment
- Results must be continuously assessed due to different factors influencing the images

- Up to **90% improved quality of data**
- **33% reduced cost** of infrastructure measurement
- At least **5 x faster** surveying than currently

NCBR
National Centre for Research and Development

The project is carried out by an interdisciplinary research team by SkySnap Sp. z o.o. company and Faculty of Geodesy and Cartography of Warsaw University of Technology within the project entitled, “R&D works in inventory and modelling of key technical and transport infrastructure objects in BIM technology using AI tools in the process of drone data processing", financed by the National Centre for Research and Development, grant no POIR.01.01.01-00-0980/20

Thank you for your attention ☺

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