Detection of Bicycle Racks from Geodata Using Deep Learning

Landeshauptstadt München

Motivation & Goal

City of Munich:

- > 350 bike parking sites
- > 2.000 bicycle parking facilities
- > 34.000 bike racks

goal: automatic detection for inventory & maintenance purposes

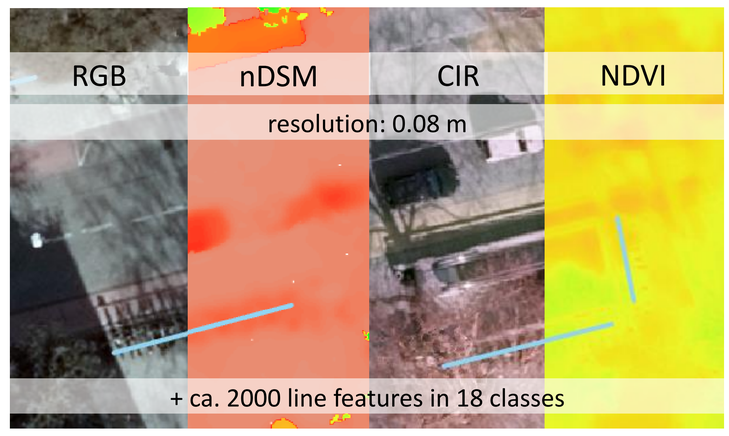
detection of bicycle parking facilities **in aerial images + additional raster data**: RGB, nDSM, CIR, NDVI

with the **Deep Learning** functionality of **ArcGIS Pro**

classification of different rack types / classes

evaluate influence of shadows & number of bicycles in parking facilities

Data



Used raster data from winter 2019 (RGB, nDSM*, CIR, NDVI) & line features indicating bike rack positions
*normalized Digital Surface Model, difference between DTM and DOM

Methodology

ArcGIS Pro | Windows 10 Desktop PC

Label Objects for Deep Learning

- a polygon is drawn manually around each bike parking facility visible in the aerial image
- coded according to rack type

→ 1839 labeled objects in the training dataset

Bike rack labels for two different rack types

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Export Training Data

- 256 px x 256 px image tiles
- 50 % overlap – to enlarge training dataset artificially

→ 7500 image tiles per raster combination

RGB
CIR
RGB+nDSM
RGB+NDVI
RGB+nDSM+NDVI

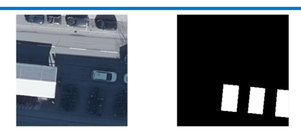

Image tile & corresponding mask with three objects

ArcGIS API for Python (arcgis.learn module) | NVIDIA DGX-P100/V100

Training

Mask R-CNN - object instance segmentation

pretrained backbone: ResNet-50
epochs: 100, batch size: 8

20% of training data as validation set
4 test areas with 128 bike parking facilities excluded from training

+ data augmentation:
random cropping, zooming, brightness and contrast changes, flipping and rotations to prevent overfitting

→ for each raster combination: a Mask R-CNN Deep Learning network is trained

Iterative Improvement

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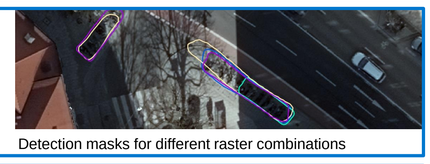
Detect Objects Using Deep Learning

- analysis of detected objects
- analysis of undetected bike parking facilities
- comparision of raster combinations
- analysis of classification

→ Evaluation



Detection masks for different raster combinations

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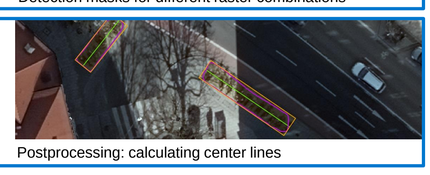
Postprocessing

- filtering out private racks (with mask indicating public areas)
- calculating centerlines of detected bike racks
- postprocessing steps aggregated in ArcGIS Toolbox



Postprocessing: calculating center lines

Results

For all test areas:
evaluation of correctly and wrongly detected objects for all of the five raster combinations

>80% correctly detected (true positive, TP)
this also includes
- private parking facilities not in the dataset
- single bicycles locked to e.g. street signs

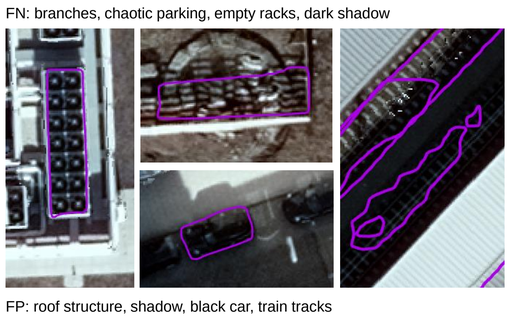
reasons for racks not detected (false negative, FN)
- trees / branches covering racks
- dark shadows
- empty bike racks
- chaotic parking

reasons for misdetections (false positive, FP)
- cluttered background (e.g. shadows)
- dark cars, train tracks

Classification: possible when similar types are grouped

TP: public racks, private racks, single bikes

FN: branches, chaotic parking, empty racks, dark shadow



FP: roof structure, shadow, black car, train tracks

Conclusion

RGB+nDSM gives best results:
recall 77.3%, precision 83.2%
→ **height** of objects supports training

ArcGIS Pro: valuable tool to view, process and analyze the data

classification not for all subtypes but sufficient for a first categorization

training data is an important factor: in this training dataset many bike racks are in **shade** & **many bicycles** are parked in the parking facilities, which affects the result

Sources:
CITY OF MUNICH / LANDESHAUPTSTADT MÜNCHEN – KOMMUNALREFERAT - GEODATENSERVICE, 2020: RGB, CIR, nDOM, DOM, DGM, NDVI 2019. (all images)
ESRI, 2022: Deep learning in ArcGIS Pro. https://pro.arcgis.com/en/pro-app/2.7/help/analysis/image-analyst/deep-learning-in-arcgis-pro.htm (last access: 09.04.2022)
HE, K., GKIOXARI, G., DOLLÁR, P. & GIRSHICK, R., 2017: Mask R-CNN. 2017 IEEE International Conference on Computer Vision (ICCV), 2980-2988, https://doi.org/10.1109/iccv.2017.322.

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link to thesis