DIGITAL TRANSFORMATION FOR RESPONSIBLE LAND ADMINISTRATION

FIG Commission 7 & 2 Annual Meeting 2023

2-4 October 2023, Deventer

AUTOMATIC GEOREFERENCING OF LAND CONSOLIDATION MAPS WITH AI

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Motivation:

- Imagine a cadaster with a lack of coordinate information:
  - boundaries with unknown coordinates, fictive properties,
  - lack of coordinate information and boundary marks.

- This is the case in many parts of Norway, little or no view into the historical development of land, leading to legal issues and problems between landowners.

- How to find and correct these mistakes from already available historical data?
  - including historical maps, land consolidation maps, historical measurements and records.

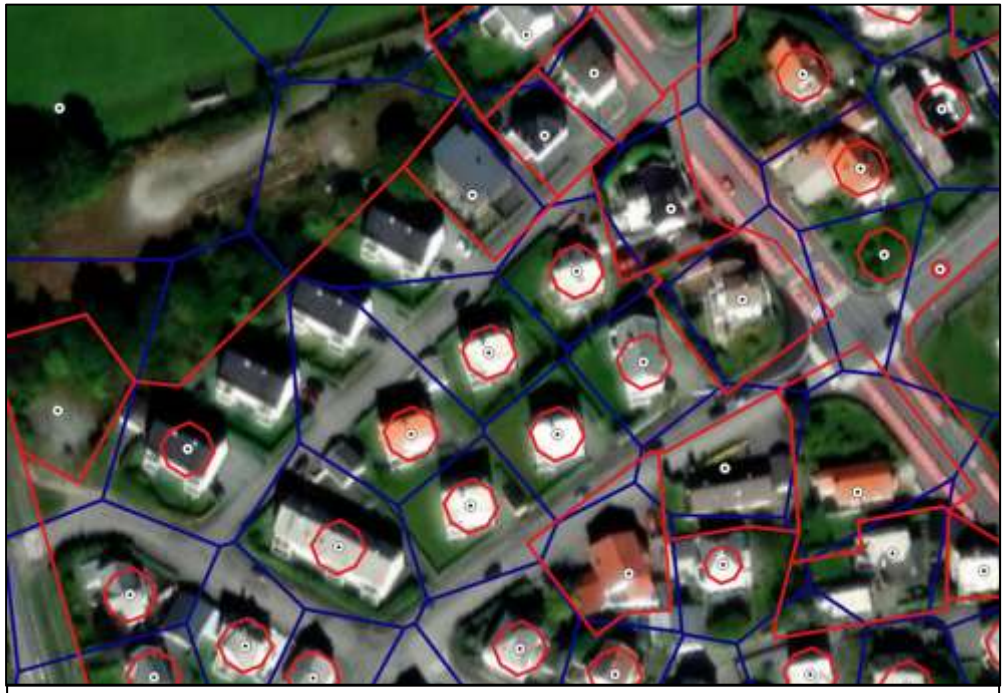
- **Aim:**
  - Add some coordinate information to maps, that do not have this information yet.
  - Automate cadastral mapping.

RESEARCH PROJECT (2022 – 2026):

How can we use AI to improve the Norwegian cadastre?

- Automatic error detection and error correction with AI,
- developing automated methods to improve the cadastre.

- Research areas:
  - circle properties (sirkeleiendommer) → unknown boundary,
  - computer vision, AI, NLP,
  - cadastral document detection system,
  - automatic georeferencing with AI,
  - Voronoi polygons,
  - cost surfaces,

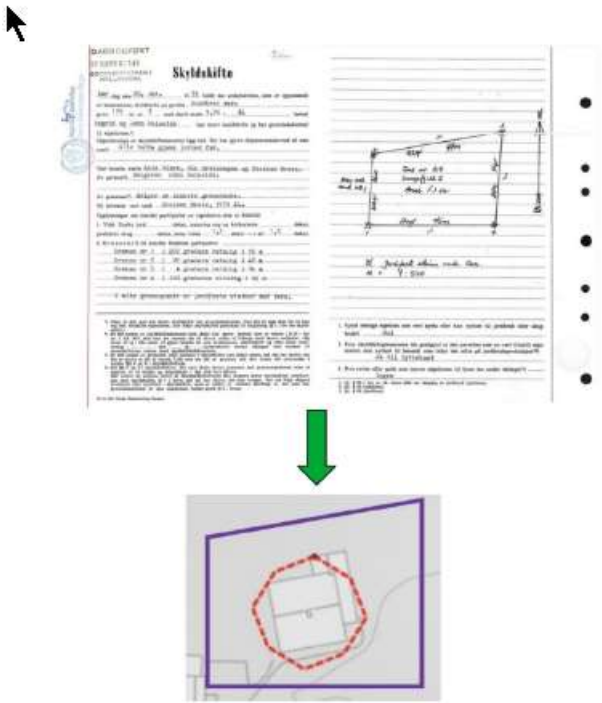


Red – correct/known coordinates
Blue – proposed/Voronoi diagrams

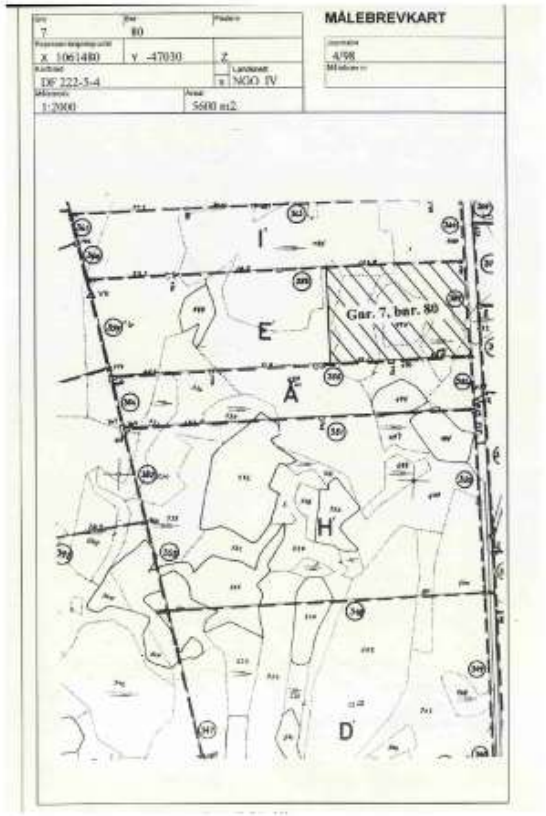
- Open-source software used: QGIS, GRASS, Postgres and PostGIS, Python, R, PyTorch, ...

THINGS I AM TRYING AND FAILING TO DO:

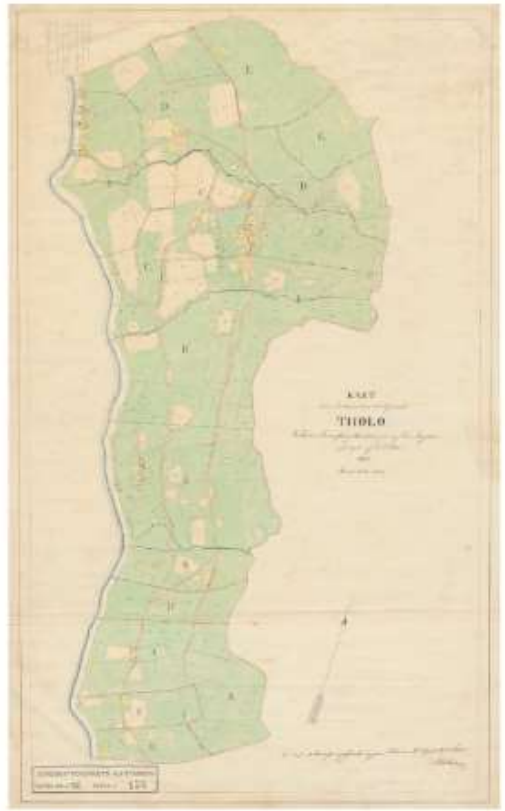
Cadastral document detection system



AI-based cadastral mapping



AI-based georeferencing



AI-based GEOREFERENCING - what/why/possible?

1) **Georeferencing** is a process that takes known ground control points and connects them to the raster in order to apply a coordinate system and projection to the image.
2) With **artificial intelligence (AI)** we can teach algorithms to make human decisions. This enables the automation of tasks, including the detection of ground control / tie points for georeferencing.
3) This is what we mean by **AI-based georeferencing**.

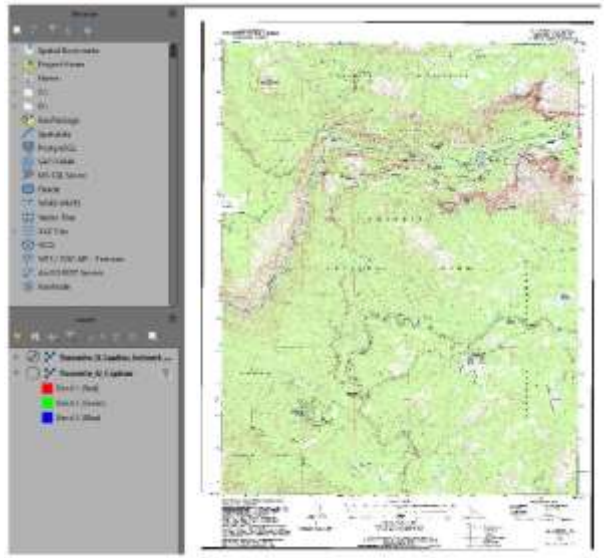
- **Why?** Automation, improved decision-making, cost reduction in the cadastre.
- **Possible?** Yes, because:
  - We can detect objects on images/videos with computer vision.
  - We can analyze text, sound and time-series with AI.

- **AIM: Use AI to automate georeferencing, moslty focusing on the detection of tie-points, that transform the map without coordinate information into a map with defined coordinate information.**

THE PROCESS OF GEOREFERENCING MAPS – what can be automated with AI?

1) Import image to be georeferenced
2) Identify a series of tie-points either from coordinates (if the map has a coordinate grid) or following natural phenomena on the map.
1) Use the tie-points to permanently transform the map from its existing location to the spatially correct location.
2) The connection between one control point on the source map and the target map is a link.

3) Export the georeferenced image.



GDAL to the rescue!

Geospatial Data Abstraction Library

- https://gdal.org/index.html

Pefect combo: Like bread and Hagelslag.

georeference.py

```python
from osgeo import gdal, ogr, osr

# Input map image and its four reference points (pixels) corresponding to real-world coordinates
input_map_image = 'input_map_scandinavia.jpg'
reference_points = [
    {'pixel_x': 100, 'pixel_y': 100, 'lon':  65.4194, 'lat':  5.7749},
    {'pixel_x': 100, 'pixel_y': 100, 'lon':  65.5294, 'lat':  5.5549},
    {'pixel_x': 100, 'pixel_y': 100, 'lon':  65.3694, 'lat':  5.1255},
    {'pixel_x': 100, 'pixel_y': 100, 'lon':  65.1294, 'lat':  5.5412},
    {'pixel_x': 100, 'pixel_y': 100, 'lon':  65.1194, 'lat':  5.4249},
]

# Create a new GDAL dataset for the output georeferenced image
output_georeferenced_image = 'output_map_georef_scandinavia.tif'
ds = gdal.GetDriverByName('GTiff').Create(output_georeferenced_image, 400, 400, 3)

# Load the input map image
input_ds = gdal.Open(input_map_image)
ds.GetRasterBand(1).WriteArray(input_ds.GetRasterBand(1).ReadAsArray())
ds.GetRasterBand(2).WriteArray(input_ds.GetRasterBand(2).ReadAsArray())
ds.GetRasterBand(3).WriteArray(input_ds.GetRasterBand(3).ReadAsArray())

# Set the geotransformation matrix to map the reference points
gt = [reference_points[0]['lon'], (reference_points[1]['lon'] - reference_points[0]['lon']) / 400, 0,
      reference_points[0]['lat'], 0, (reference_points[2]['lat'] - reference_points[0]['lat']) / 400]
ds.SetGeoTransform(gt)

# Set the spatial reference information (WGS84)
srs = osr.SpatialReference()
srs.ImportFromEPSG(4326)
ds.SetProjection(srs.ExportToWkt())

# Clean up and close the datasets
ds = None
input_ds = None

print(f"Georeferenced map saved to {output_georeferenced_image}")
```

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HISTORICAL MAPS, CHALLENGES and LIMITATIONS

Georeferencing historical maps can be challenging due to many drawbacks, including:

a) Limited metadata – historical maps may lack detailed metadata or context regarding their creation, making it challenging to determine the map's source, date or purpose.

b) Map distortions and inaccuracies – historical maps may contain distortions, errors or inaccuracies introduces during their creation.

c) Lack of geographic reference points / coordinates – historical maps often lack clear and recognizable geographic reference point including coordinates or known landmarks.

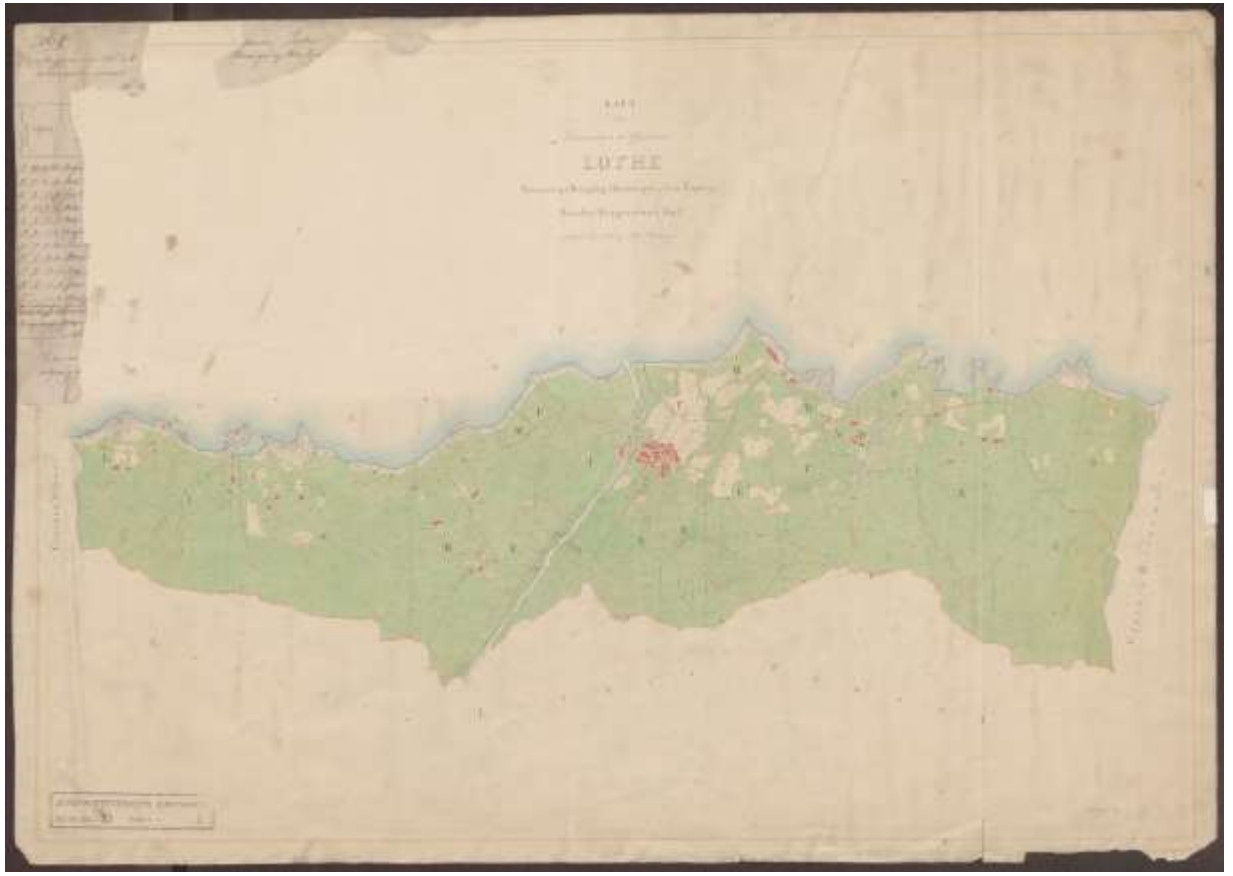
d) Changes of landscape over time – the physical landscape presented on historical maps may have undergone significant changes over time, including alterations in coastlines, rivers and urban development. Accounting these changes when georeferencing is crucial.

e) High diversity of maps – historical maps do not follow standardized design practices. Especially older maps use various design principles.

f) Different measurements units – different units to measure lengths, including walking, steps, sometimes with measuring tape.

MAPS TO BE USED:

- https://media.digitalarkivet.no/view/58619/1?indexing
- around 45000 scanned maps as .JPG or .PDF



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WHAT CAN BE USED AS A TIE-POINT?

- water/lakes/coastline/streams
- buildings/churches
- mountains

- Automate the detection of tie-points with AI.

- Semantic segmentation.

- Perform the georeferencing with GDAL and Python.

COMPUTER VISION – ability to recognize images

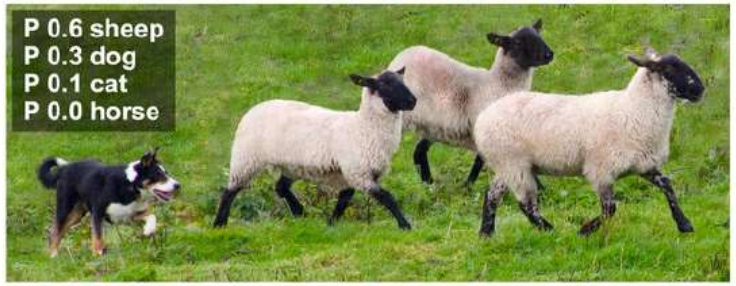
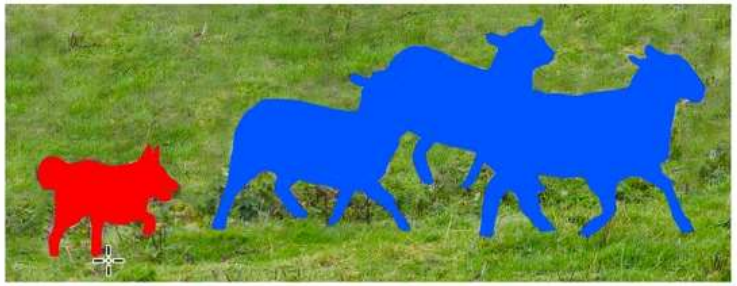
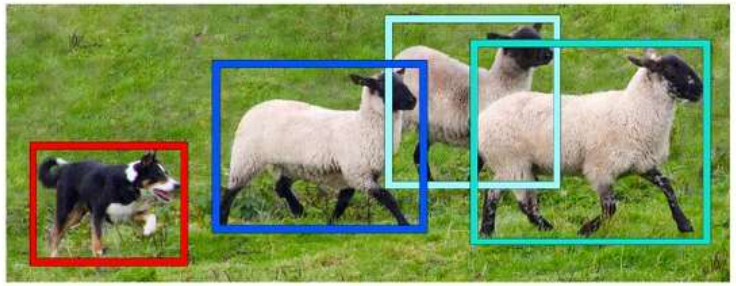


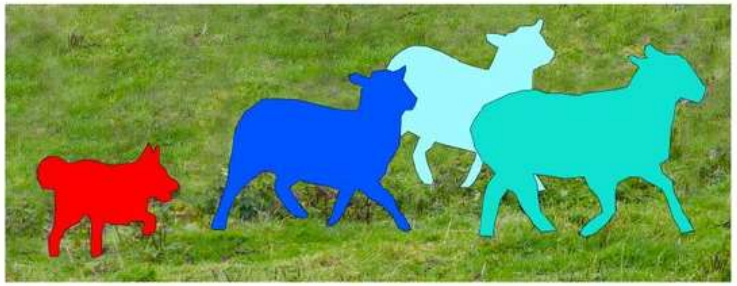
Image Recognition



Semantic Segmentation



Object Detection

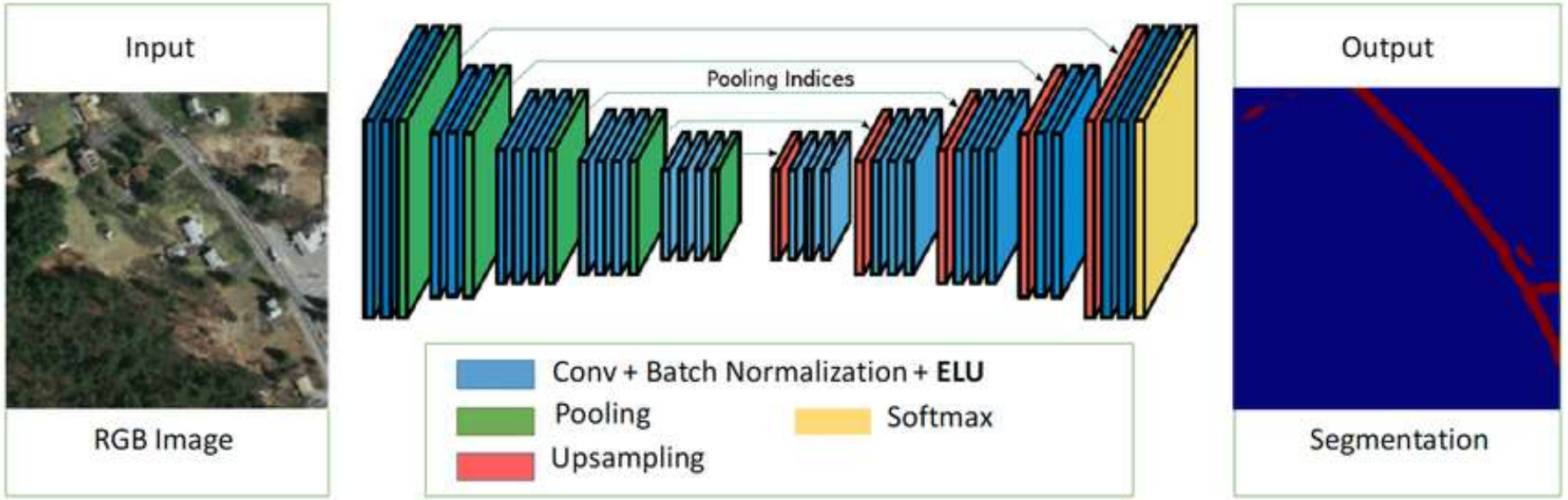


Instance Segmentation

https://desupervised.io/computer-vision

SEMANTIC SEGMENTATION to automatically detect the tie-points.

- Computer vision task in which the goal is to categorize each pixel in an image into a class or object.
- Output: dense pixel-wise segmentation map of an image, where each pixel is assigned to a specific class or object.

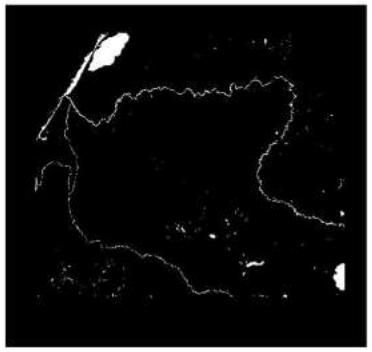


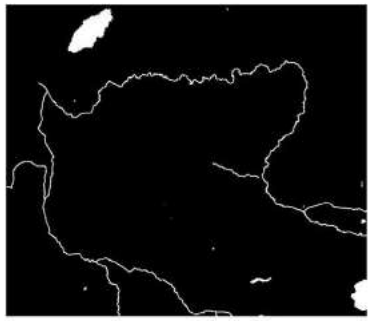
METHODOLOGY:

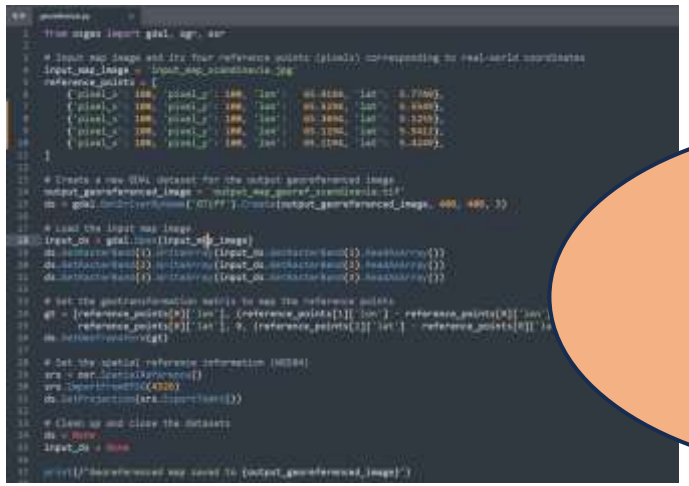
Tie-point dataset

Train models for tie-point detection.

Use the detected tie-points and their coordinate information for georeferencing.







GEOREFERENCE

Kort maar krachtig.