GeoAI with ArcGIS
Integrating AI in end-to-end workflows for NMCAs

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WHITE PAPER

On Artificial Intelligence - A European approach to excellence and trust

Europe's political guidelines on AI - and the Esri open A.I. Integration

- Regulatory and Investment oriented approach
- Promote the uptake of AI
- Address the risks associated with it by defining requirements:

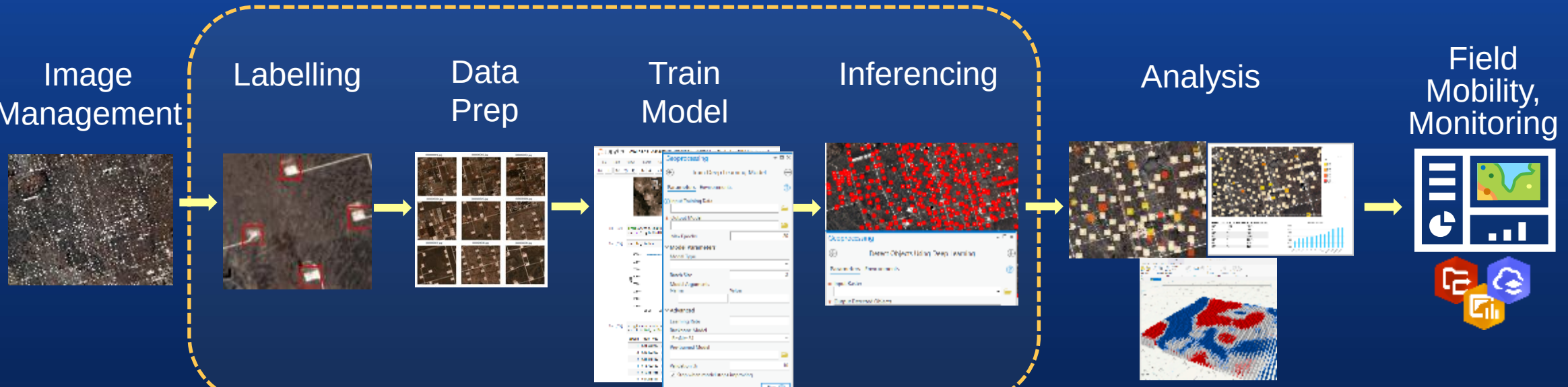
  - Human agency and oversight
  - Technical robustness and safety
  - Privacy and data governance
  - Transparency
  - Diversity, non-discrimination and fairness
  - Societal and environmental well-being
  - Accountability

ArcGIS A.I. Integration

Open

- Methodology
- Creation processes
- Collaboration
- Data access (in & out)
- Sharing of models

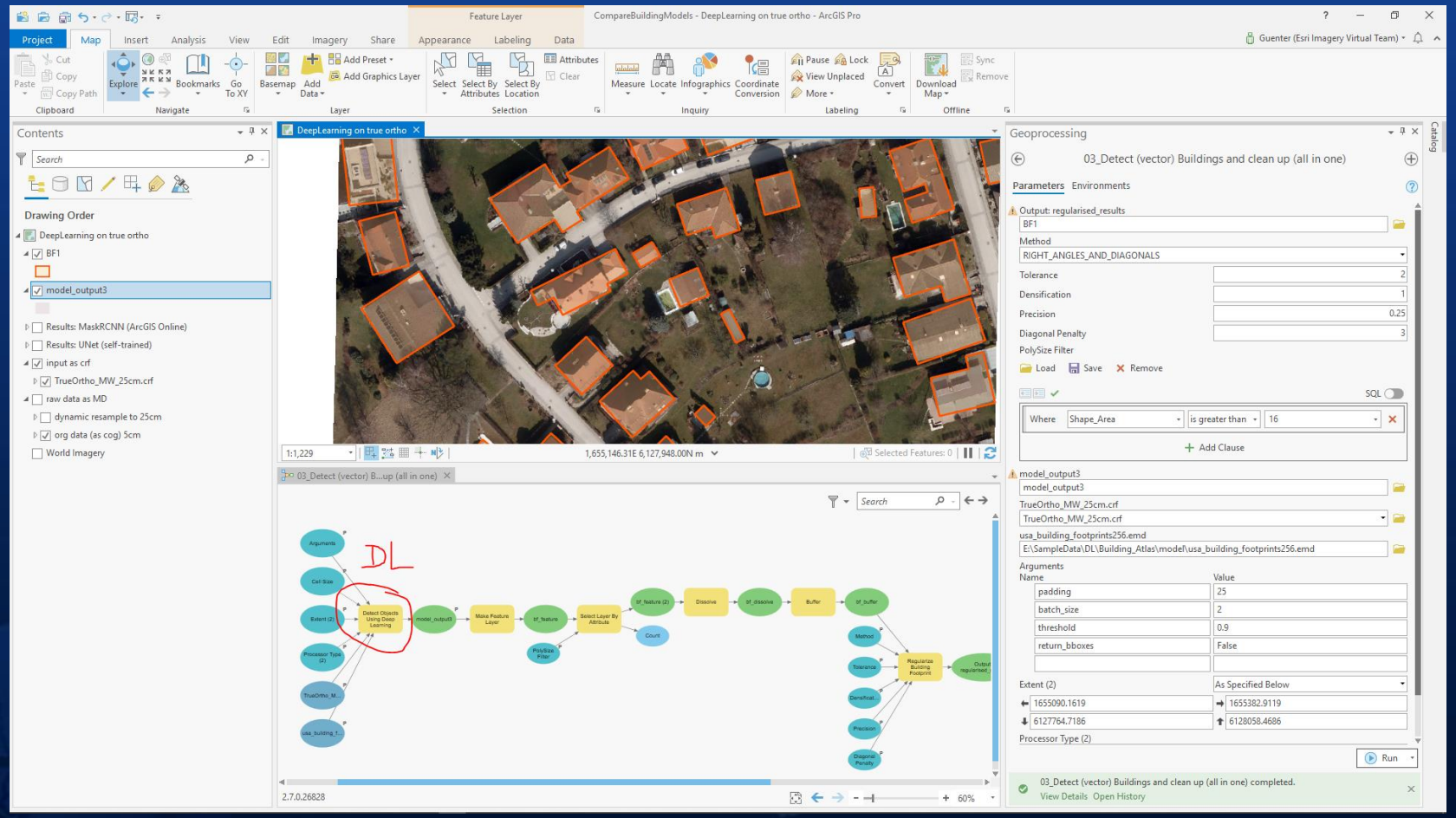
Deep Learning in ArcGIS – End-to-end workflow



ArcGIS being used for each step of the deep learning workflow

Live-Example: Building Detection & Postprocessing

- Trained for use with High Resolution 8bit RGB Imagery
- Training data: Continental US dataset (globally enriched)
- Postprocessing with ArcGIS GP Model



https://www.arcgis.com/home/item.html?id=a6857359a1cd44839781a4f113cd5934

PoC: Cyprus Cadastre – Update Building (tax) database

- Based on high-res 3Band Imagery
- Use Esri building detection model
  - maskRCNN
  - Detect Objects DL Tool
  - Postprocess geometry
- Compare to existing buildings DBs
- Test area (approx. 25 $km^{2)}$:
  - Processed in ~40 min
  - ~8.000 buildings
  - 40% difference to building DBs

PoC: Swedish Topographic Map – Update Building layer

- Based on high-res 4Band Imagery
- Use Esri building model workflow
  - Use Existing buildings to train
  - maskRCNN model
  - Detect Objects DL tool
  - All done in Python notebook
  - Postprocess geometry

See the Live-Dashboard (requires login)

```
paddings = ["8", "12", "16", "24", "32"]
mergedOutput = os.path.join(localGdb,"mergedoutput")
dissolvedOutput = os.path.join(localGdb,"dissolvedoutput")
multiPartOutput = os.path.join(localGdb,"multipartoutput")
env.workspace = localFile

tempOutputs = []
for padding in paddings:
    modelVariables = f'padding {padding};batch_size 16;threshold 0.9;return_bboxes False'
    output = os.path.join(localGdb, "output" +f"{padding}")
    tempOutputs.append(output)
    with arcpy.EnvManager(processorType="GPU"):
        arcpy.ia.DetectObjectsUsingDeepLearning(imagery, output, dlModel, modelVariables,
                                                "NMS", "Confidence", "Class", 0, "PROCESS_AS_MOSAICKED_IMAGE")
```

Usecase: Kuwait – PACI updates Kuwaits base map

- Use self-trained and updated model
  - Based on 75km^2 training data
  - To analyze 3000 km^2 data

  … what was digitized in 5 years

  … is now detected in 30 minutes

See also: This article

https://www.esri.com/about/newsroom/blog/deep-learning-helps-kuwait-automate-map-updates/

Many areas of application and models

Object Detection
Find objects and their locations (bounding boxes)

Models:
- SingleShotDetector
- RetinaNet
- YOLO
- FasterRCNN

Applications:
- Detect trees, cars, airplanes, swimming pools, well pads
- Detect encroaching structures
- Moving objects like road cracks/catfish on **video**
- Road signs, and other assets in oriented imagery
- Detecting and counting vehicles
- Shipwrecks in **Bathymetric data**
- Fire hydrants in **Oriented imagery**

Pixel Classification
Assign a label to each pixel

Models:
- UNetClassifier
- PSPNetClassifier
- DeepLab
- *PointRend support for better accuracy

Applications:
- Land Cover Classification
- Pervious/Impervious mapping
- Building Footprint Extraction
- Cloud detection
- Road detection
- Water Meters from oblique images

Object Classification
Assign a label to a given imag

Model:
- **FeatureClassifier**

Applications:
- Damaged building classification
- Clean or 'green' pools…
- Broken/flashed insulators
- Identifying plant species

Instance Segmentation
Find objects and their *precise* locations (polygonal features)

Models:
- MaskRCNN

Applications:
- Building footprint extraction
- 3D roof reconstruction
- Sinkholes

Scanned Map Digitization

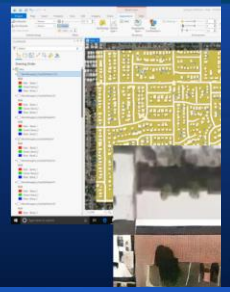
Class:
- ScannedMapDigitizer

Applications:
- Digitizing scanned maps
- Georeferencing scanned maps

Image Translation
Translate images from one domain to ar

Models:
- Pix2Pix
- CycleGAN
- SuperResolution

Applications:
- SAR to Optical Imagery
- Imagery to Map generation
- Annotate Imagery
- Increase image resolution



Point Cloud Classification

Models:
- PointCNN

Applications:
- Classifying point cloud data (buildings/ground, etc)
- Power line and utility poles extraction

Image Captioning
Provide a textual description of an image

Models:
- ImageCaptioner

Applications:
- Annotating Images
- Assessibility for Images

Road Extraction
Extract Roads from Aerial or Satellite Imagery

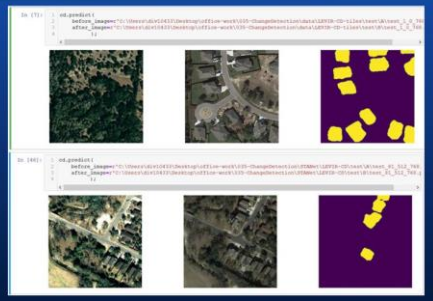
Models:
- MultiTaskRoadExtractor

Applications:
- Extract Road Networks
- Routing

Change Detection
Identify areas of persistent change

Models:
- ChangeDetector (based on STANet)

Applications:
- Identify new buildings
- Identify new construction

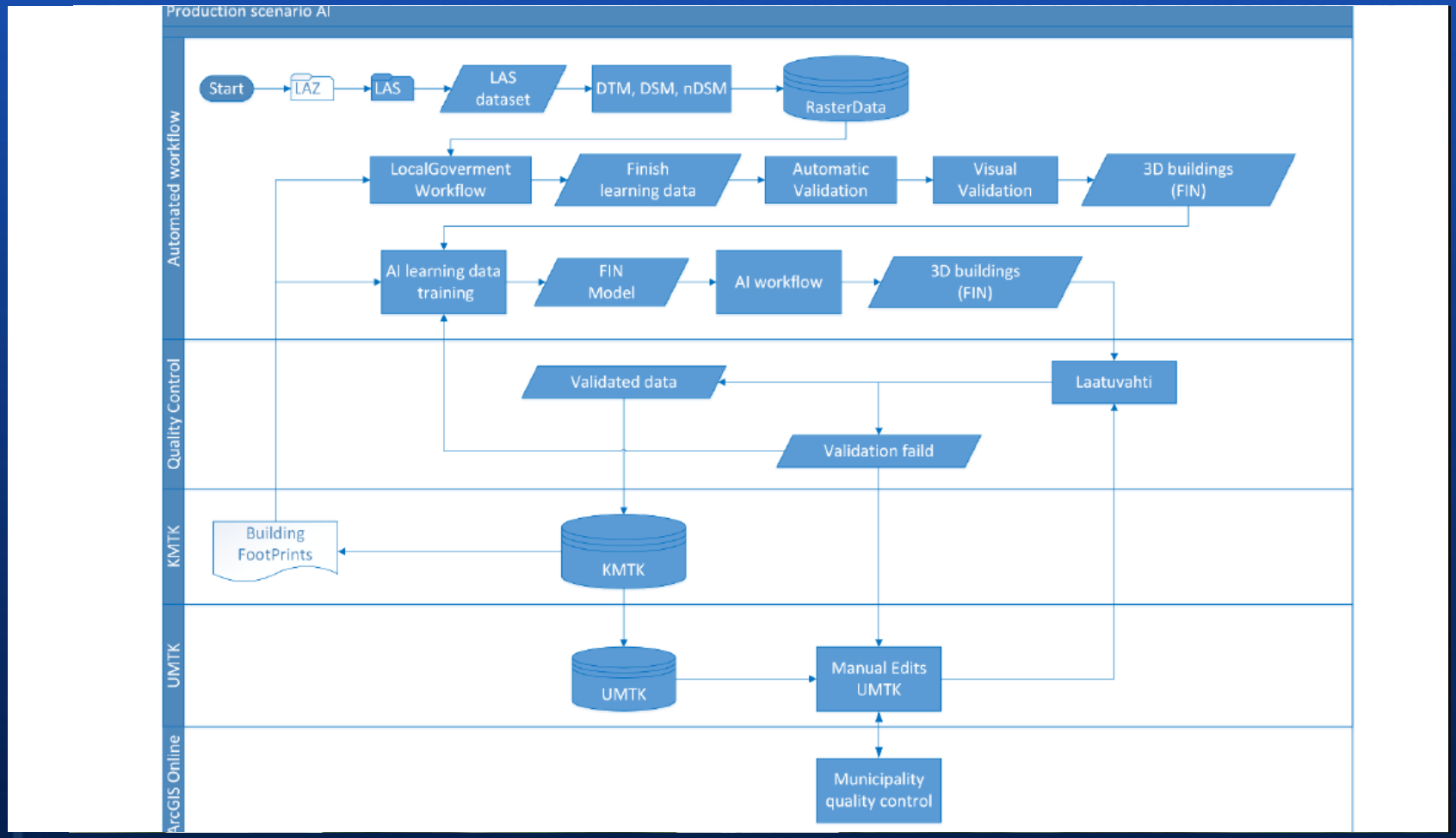


Edge Detection
Find pixels belonging to edges

Models:
- BDCNEdgeDetector
- HEDEdgeDetector

Applications:
- Residential parcel extraction
- Agricultural farm boundaries

PoC: NLS Finland – Create 3D Building geometry from LAS



- Based on LIDAR data
- Ran in Azure VM environment
- Use revised Esri sample workflow
  - Use NLS building footprints
  - Use LAS data
  - Train maskRCNN model
  - Add attributes to buildings with AI
  - Apply procedural rules based on the attributes to create 3D
  - Manual prostprocessing possible

See also: This article

https://medium.com/geoai/reconstructing-3d-buildings-from-aerial-lidar-with-ai-details-6a81cb3079c0

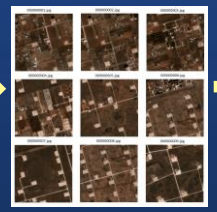
End-to-end Deep Learning in ArcGIS – The real challenges remain

Which model(s)?
Which data(types)
Training data?
Validation?
Accuracy?
Compute?

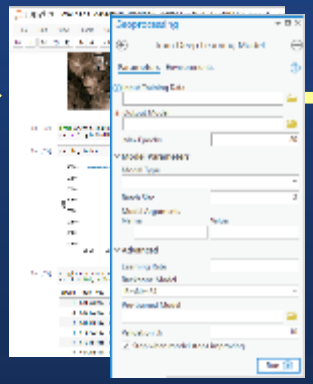
Image Management

Labelling

Data Prep

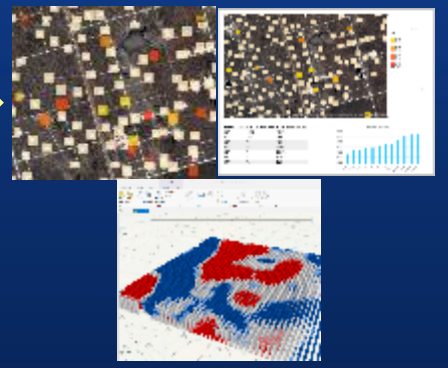


Train Model



Inferencing

Analysis



Field Mobility, Monitoring

ArcGIS being used for each step of the deep learning workflow

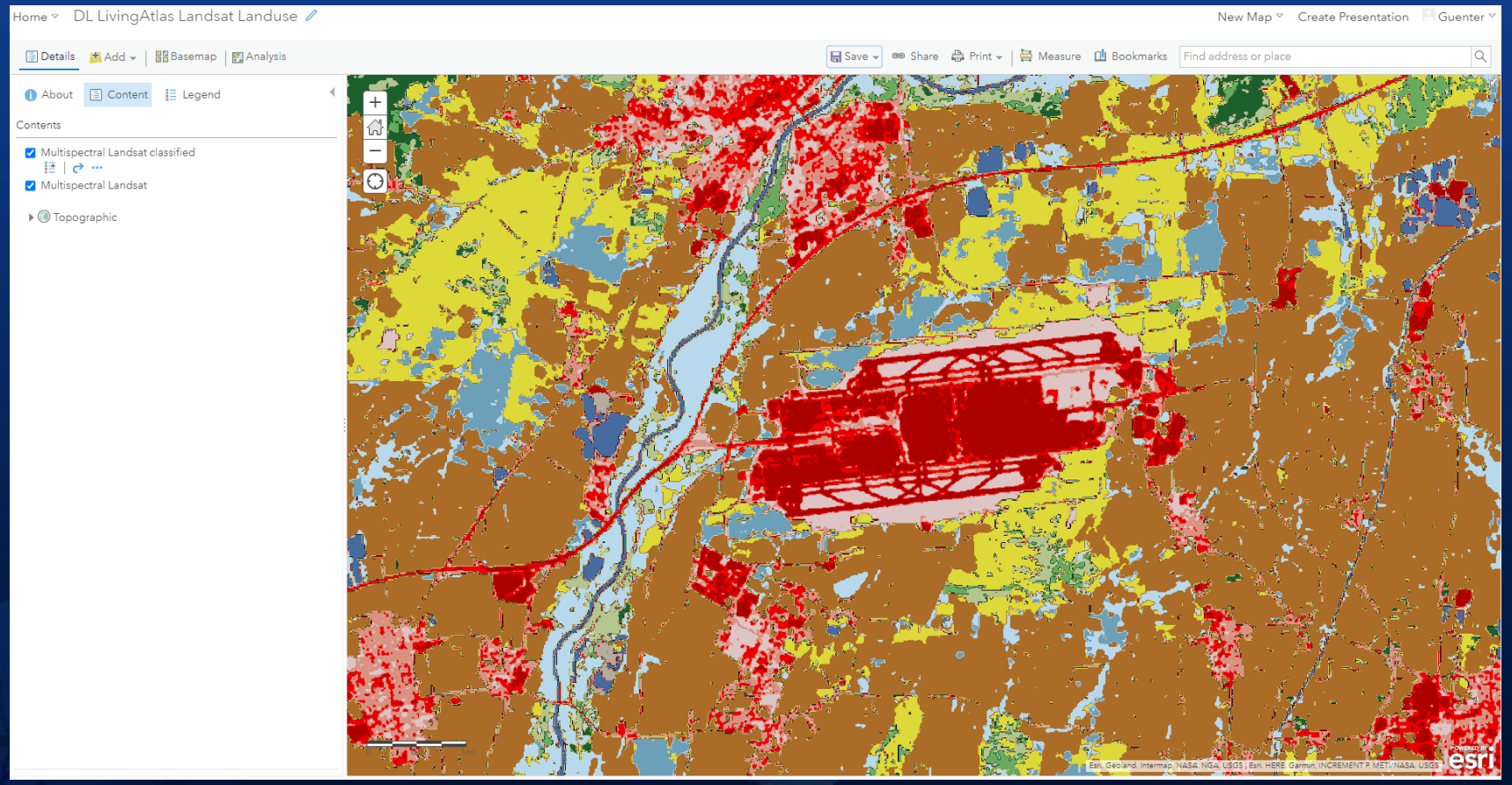
Ready-to-use Deep Learning Models

- Eliminates:
  - Imagery requirements for model training
  - Labelling requirements - Difficulty of capturing training samples
  - Training AI models - Complexity to train deep learning models
  - Massive compute requirements for model training

- Building Footprints (USA)
- Land cover classification (Landsat 8)
- Tree points classification
- Powerlines classification
- Doors and windows detection
- Ship wrecks detection
- More to come...

Live-Example: Web-based Land Cover Classification

- Trained for Landsat 8
- Training data: Multi-year continental US dataset



https://www.arcgis.com/home/item.html?id=e732ee81a9c14c238a14df554a8e3225

Deep Learning in ArcGIS - today

Data Types

Point Cloud

Text

Oriented Imagery

Feature Attachments

Motion Imagery

Satellite Imagery

LiDAR

Aerial Imagery

Bathymetric Data

Tasks

Pixel Classification

Super Resolution

Image Classification

Segmentation

Object Detection

Model sharing

New

Building Footprint Detection

Landcover Classification (LS 8)

LIDAR vegetation Classification

Frameworks

PYTORCH

OpenCV

SymPy

jupyter

fastai

TensorFlow

SciPy

matplotlib

pandas

CONDA

ArcPy

Integration

ArcGIS Pro

ArcGIS Server

Notebooks

APIs

Deep Learning Achievements & Roadmap

Recently

New Object Detection Models

- YOLOV3
- FasterRCNN

Applications

- Detect cars, trees, planes
- Shipwrecks
- Fire hydrants
- Detect encroaching features

New Pixel Classification Models

- DeepLab

Applications

- Extract road networks
- Routing

Near future

Models

- More Frameworks and models
- Cloud masks

Applications

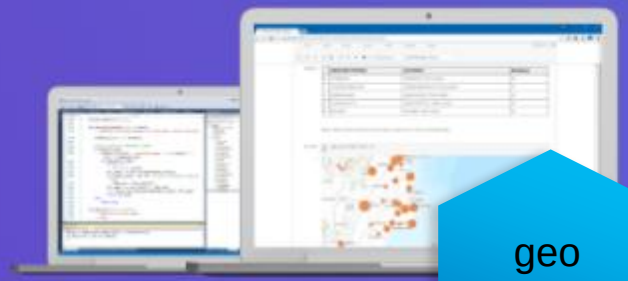
- Forestry, Agriculture
- Mapping (Object classes)
- More LIDAR analysis

Scripting and Automation / ArcGIS API for Python (1.6.1)

ArcGIS API for Python

Install the API

Version 1.6.1 · May 16, 2019



Home | Guide | Sample Notebooks | API Reference | Community

A powerful Python library for spatial analysis, mapping and GIS

ArcGIS API for Python is a Python library for working with maps and geospatial data, powered by web GIS. It provides simple and efficient tools for sophisticated vector and raster analysis, geocoding, map making, routing and directions, as well as for organizing and managing a GIS with users, groups and information items. In addition to working with your own data, the library enables access to ready to use maps and curated geographic data from Esri and other authoritative sources. It also integrates well with the scientific Python ecosystem and includes rich support for Pandas and Jupyter notebook.

Install the API | Get started | View samples

Understand your GIS

This "hello world" style notebook shows how to get started with the GIS and visualize its contents.

Manage your GIS

The ArcGIS API for Python provides APIs and samples for ArcGIS Online administrators to manage their online

Perform Spatial Analysis

Call sophisticated spatial analysis tools that work with online content, using a few lines of code.

dlpk

Search Examples

All Trending Basemaps Imagery Boundaries People Infrastructure Environment

All content types All time All regions Esri-only content Authoritative-only content Sort by: Relevance

5 Results

Imagery

Deep Learning Package

Building Footprint Extraction -...

By esri_analytics

Deep Learning Package

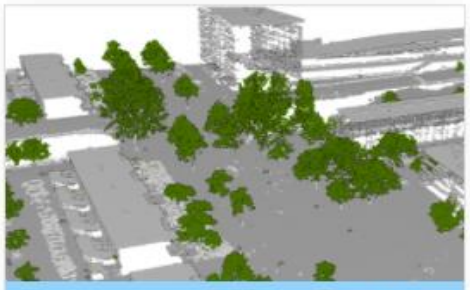
Land Cover Classification (Lan...

By esri_analytics

Deep Learning Package

Windows and Doors Extraction

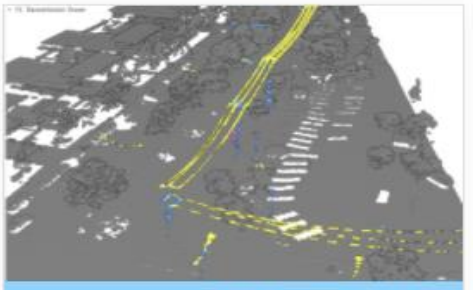
By esri_analytics



Deep Learning Package

Tree Point Classification

By esri_analytics



Deep Learning Package

Power Line Classification

By esri_analytics

Links

- **Esri GeoAI Hub Landing Page**
  https://landing-geoai.hub.arcgis.com/
- **Blog article on deep learning in ArcGIS**
  https://www.esri.com/arcgis-blog/products/api-python/analytics/deep-learning-models-in-arcgis-learn/
- **GeoAI Articles on medium.com**
  https://medium.com/geoai
- **ArcGIS Python Libraries start-page (with many Notebooks to download)**
  https://www.esri.com/en-us/arcgis/products/arcgis-python-libraries/overview
- **Developer documentation for arcgis.learn = DeepLearning python integration**
  https://developers.arcgis.com/python/guide/geospatial-deep-learning/

- **Search LivingAtlas for downloadable DeepLearning models**
  https://livingatlas.arcgis.com/en/browse/#d=1&q=dlpk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THE
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OF
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