GeoAI: AI-Driven Geospatial Workflows

Matthew Twietmeyer, Solution Engineer Team Lead

Sandi Hirth, Senior Account Manager

esri THE SCIENCE OF WHERE

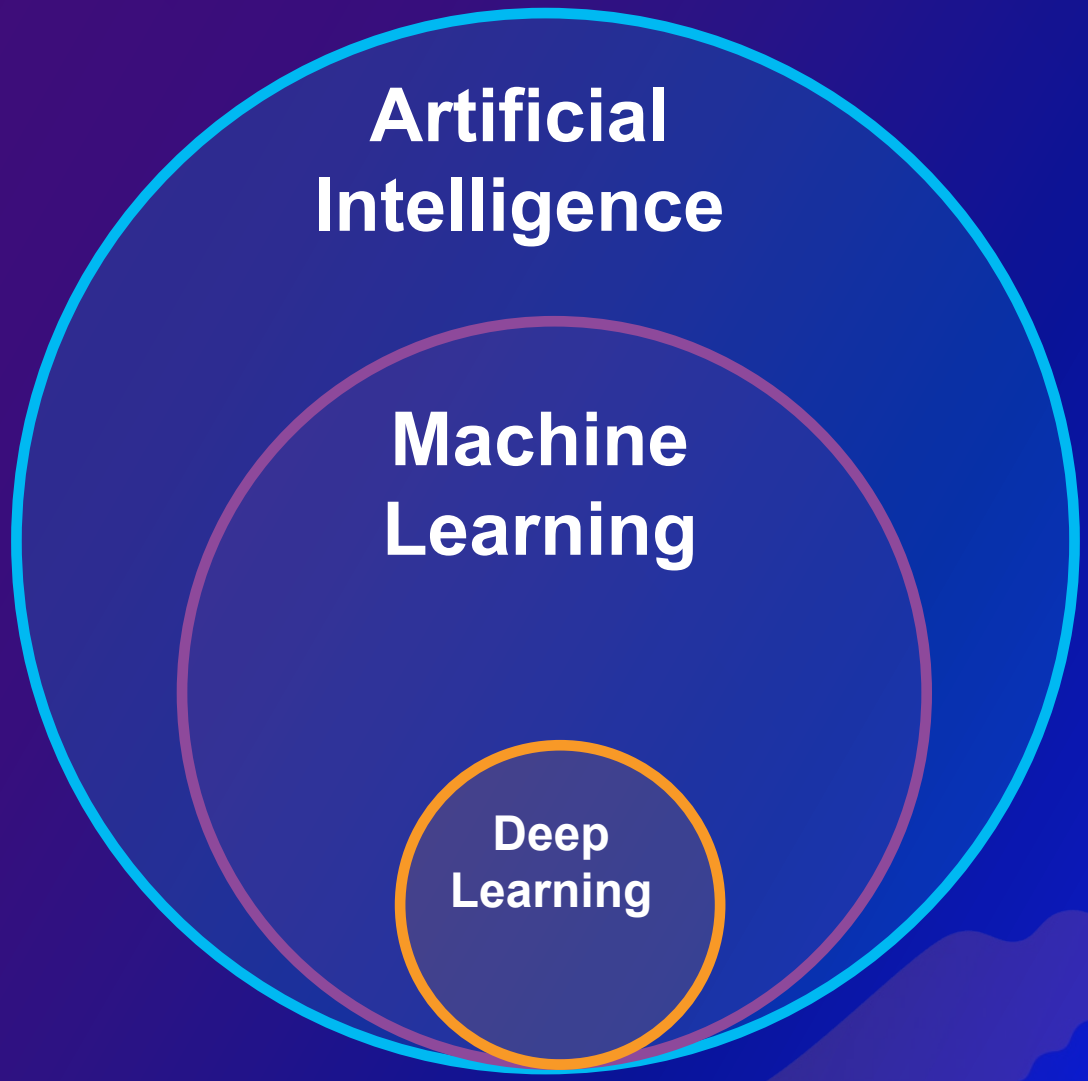
What Is AI?

Summary:

Really, **machine learning (ML)**

Machine learning is about extracting patterns from data to derive rules, instead of these rules being explicitly programmed.

Deep learning is a type of ML using deep neural networks to find complex patterns especially in unstructured data (such as images, text, voice, and lidar).



AI is not one product. It spans ArcGIS.

Where we offer machine learning integration.

ArcGIS API for Python

ArcGIS Velocity

ArcGIS Notebooks

ArcGIS Pro

ArcGIS Online

ArcGIS Enterprise

ArcGIS Hub

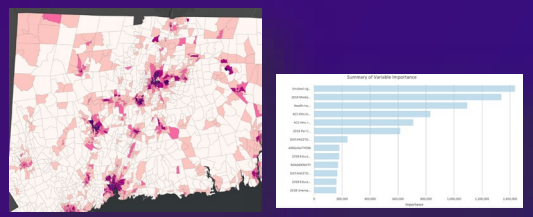
ArcGIS QuickCapture

ArcGIS Insights

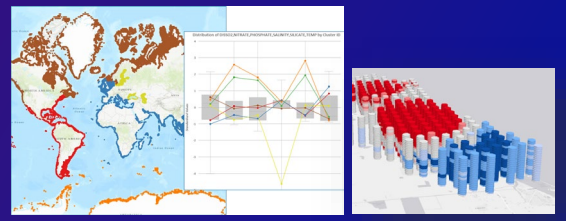
ArcGIS Survey 123

What Can Machine Learning Do?

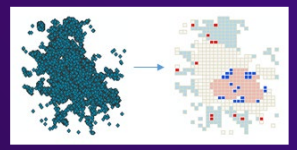
Extract features from imagery & lidar

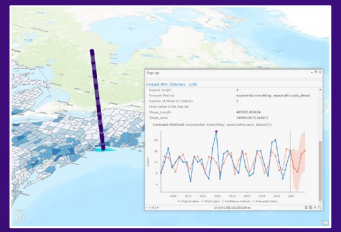


Make predictions



Find patterns & clusters

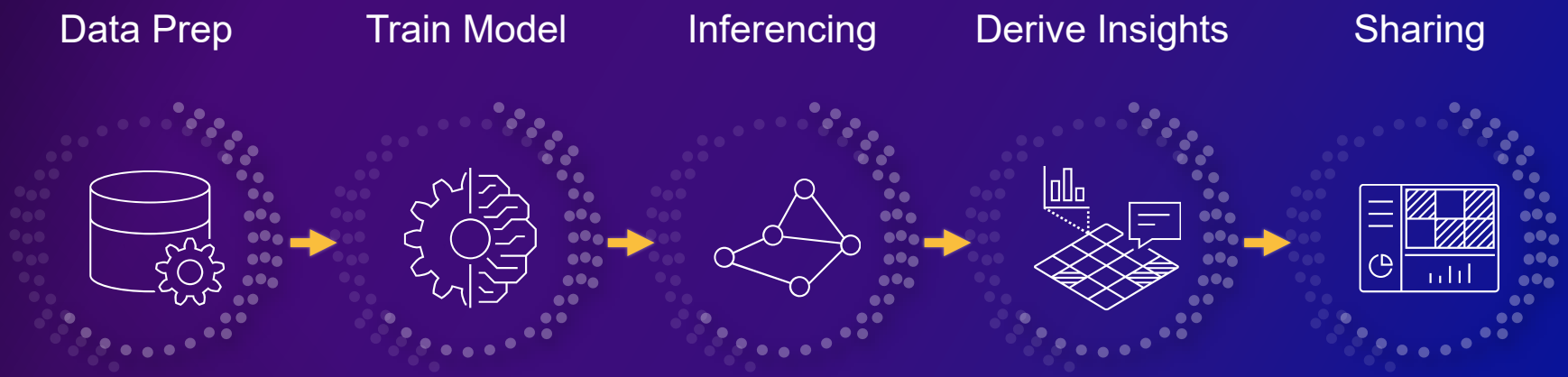




Detect anomalies

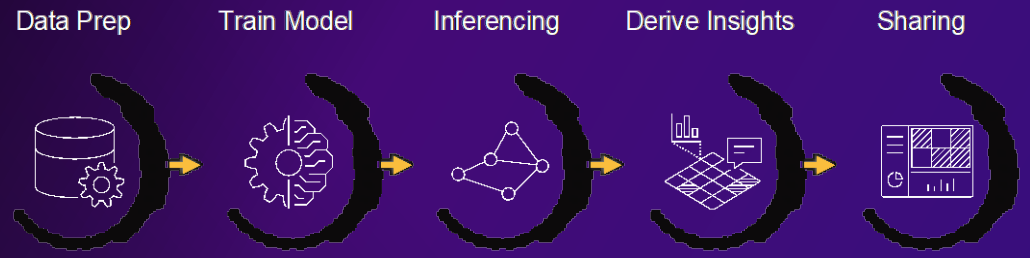
Extract insights from unstructured text

Machine Learning Lifecycle



Where Is AI in ArcGIS?

1. Tools for AI Workflows



Code-less Experience

ArcGIS Pro

Spatial Analyst

Image Analyst

3D Analyst

Code-first Experience

ArcGIS Notebooks

Python API

2. AI-Infused Capabilities

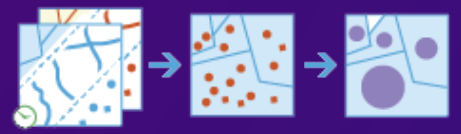
Tree extraction in 3D basemaps

Offline inference in ArcGIS Survey123

Machine Learning Tools in ArcGIS

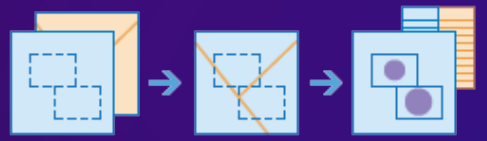
Classification

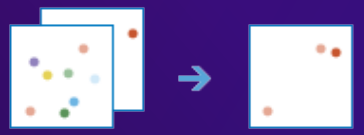
- Maximum Likelihood Classification
- Random Trees
- Support Vector Machine



Clustering

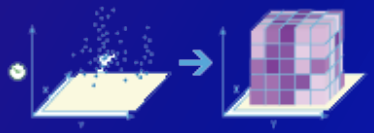
- Spatially Constrained Multivariate Clustering
- Multivariate Clustering
- Density-based Clustering
- Image Segmentation
- Hot Spot Analysis
- Cluster and Outlier Analysis
- Space Time Pattern Mining

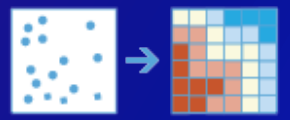


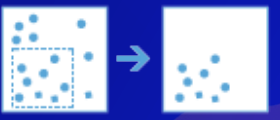


Prediction

- Empirical Bayesian Kriging
- Areal Interpolation
- EBK Regression Prediction
- Ordinary Least Squares Regression and Exploratory Regression
- Geographically Weighted Regression
- Forest Based Prediction
- Time Series Forecasting





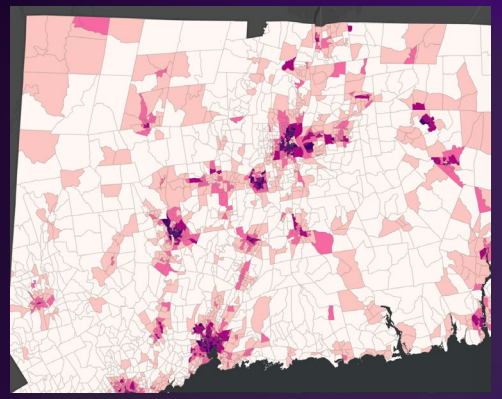


What Workflows Can These Tools Enable?

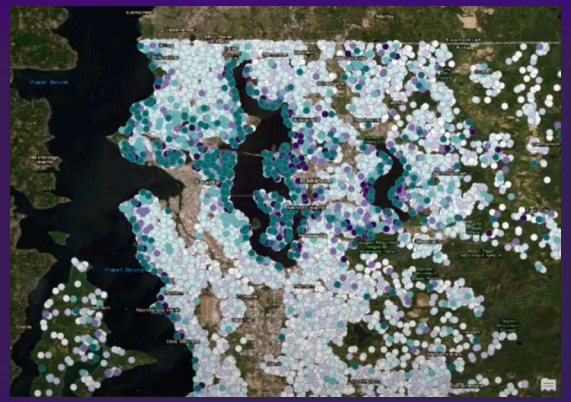
1. Predictive Analytics

Prepare Data, Make Predictions, Find Correlations, Understand Top Variables, and More

Predicting asthma rates

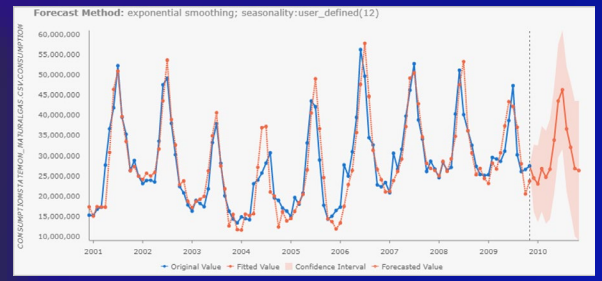


Predicting house pricing

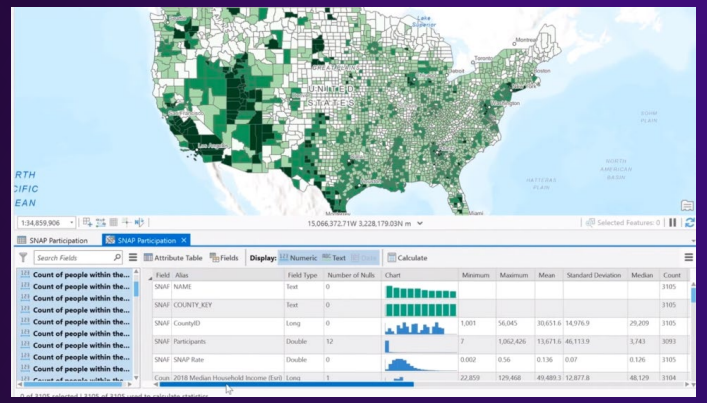


Predicting sea habitat

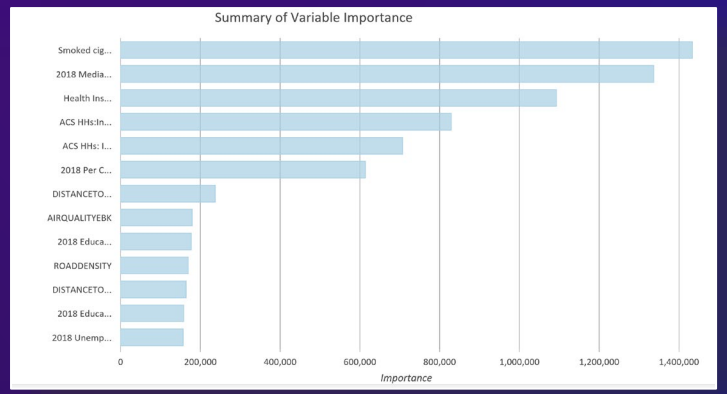
Time series forecasting



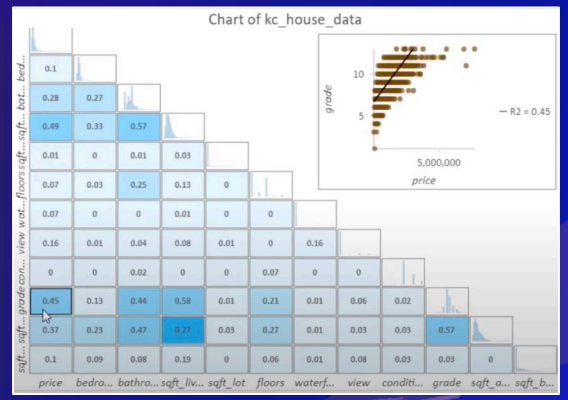
Data engineering



Variable importance

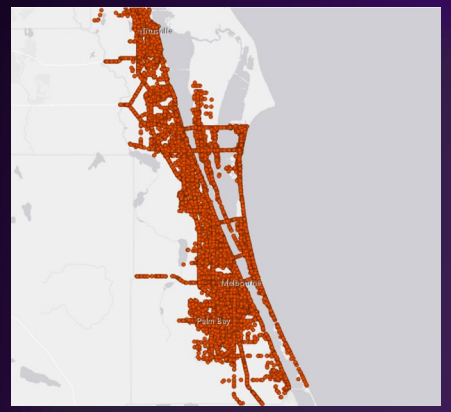


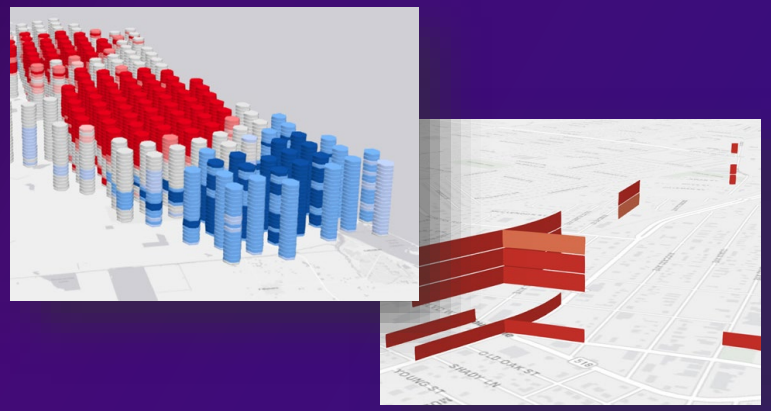
Variable correlation



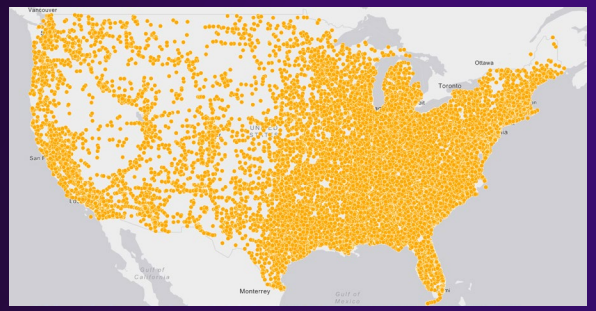
2. Pattern Mining and Clustering

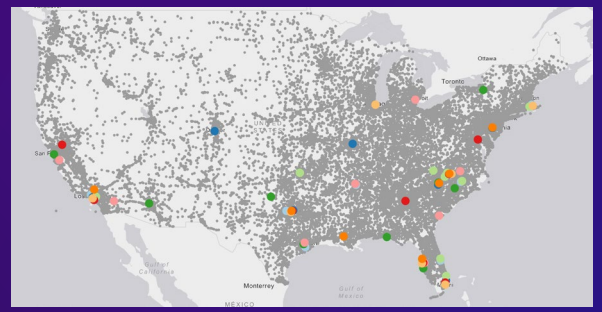
Understand Natural Groupings in Data That Are Statistically Significant



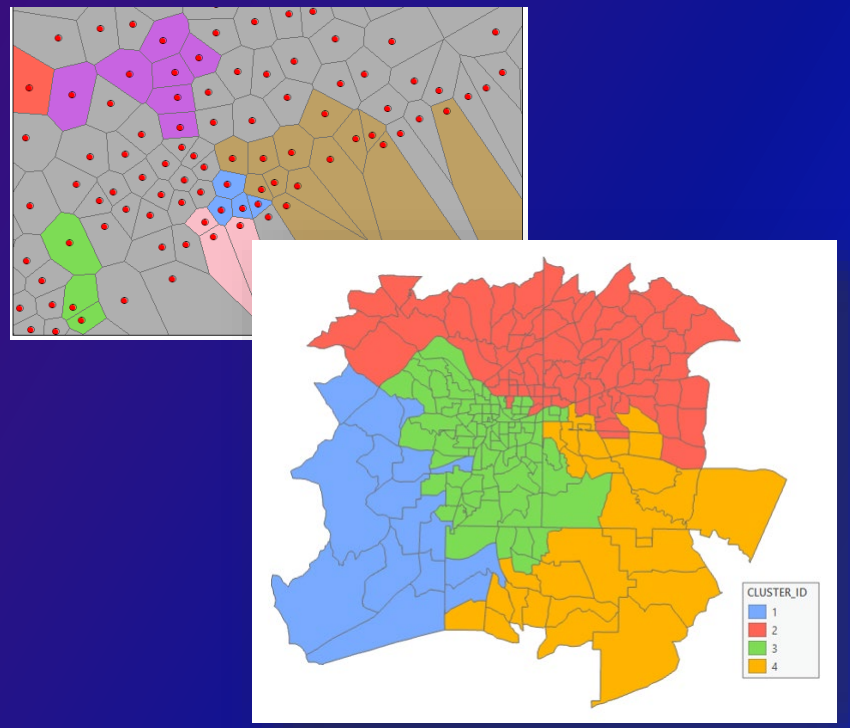


Emerging and fading hotspots for Crashes using **SpaceTime Pattern Mining Toolbox**





Most important fatal crashes clusters using **Density Based Clustering (DBScan)**

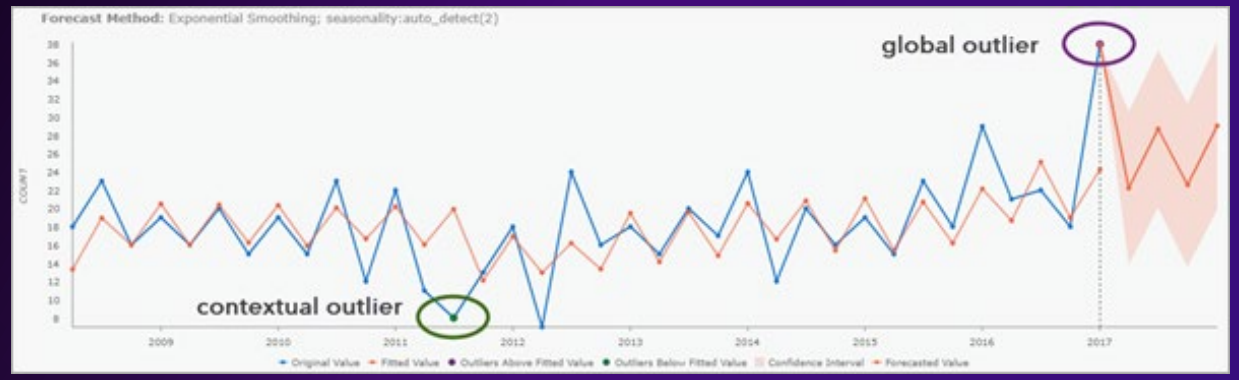


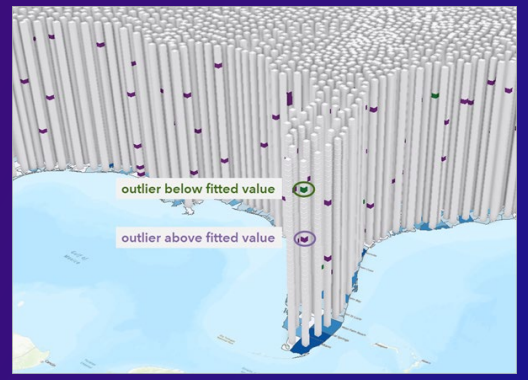
Find spatially contiguous clusters for animal territories using **Spatially Constrained Multivariate Clustering**

3. Anomaly Detection

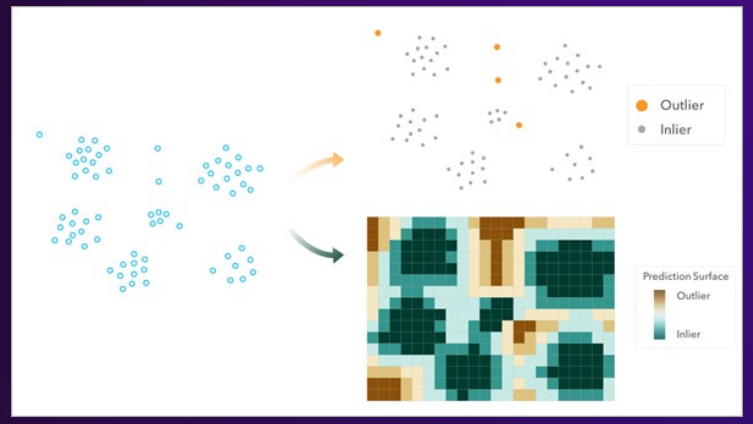
Spatial, Temporal, and Spatiotemporal Outliers

Time series outliers (temporal)

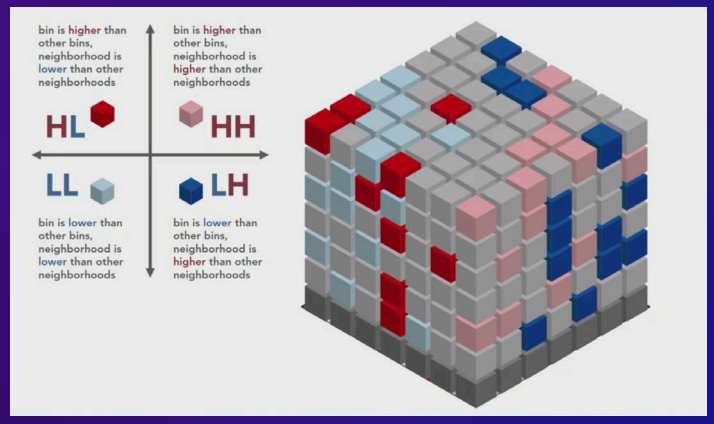


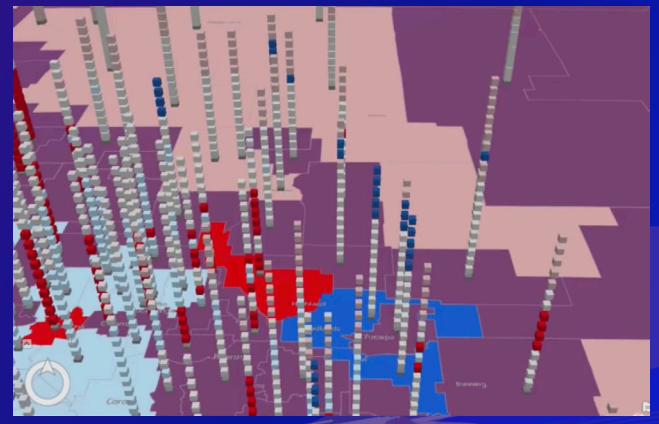


Spatial outliers (spatial)



Local outlier analysis (spatiotemporal)





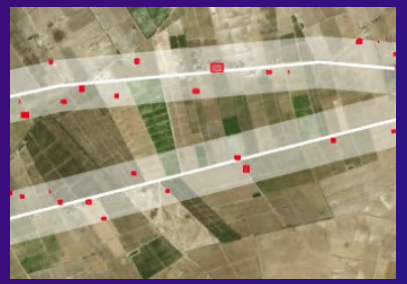
4. Object Detection, Pixel Classification, Object Classification, Tracking, and More

Damaged structures

Building footprints

Land cover

Pipeline encroachment



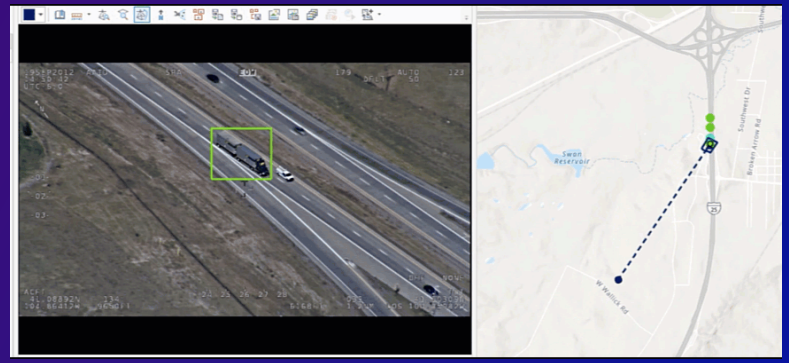
Palm trees

Roads

Oil pads

Road cracks

Tracking in FMV



Swimming pools

Parcel (edge) detection

Imagery AI: End-to-End Workflow

Extract Insights from Imagery at Scale, with High Speed and Accuracy

Image management

Labelling

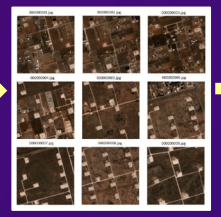
Data prep

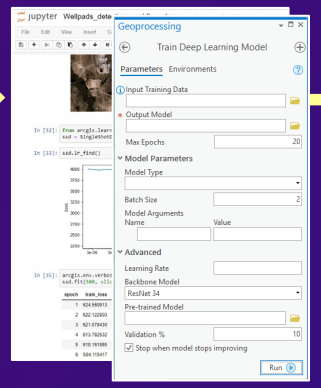
Model training

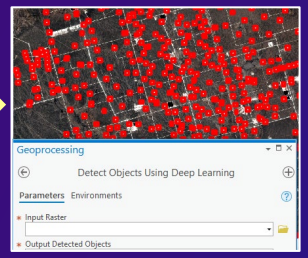
Inferencing

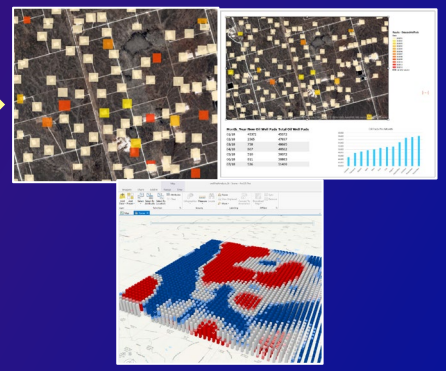
Analysis

Field mobility, monitoring









For Wide Range of Data Types

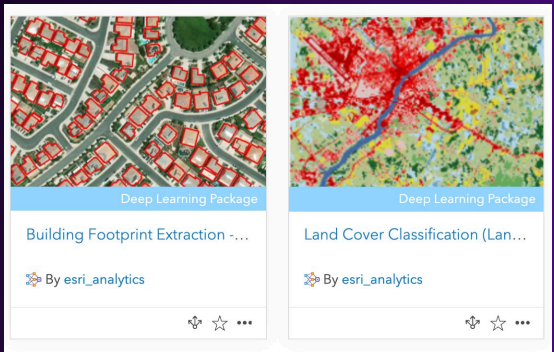
- Aerial
- Satellite
- Radar
- Lidar
- Motion imagery
- Bathymetry
- Point cloud
- Drone

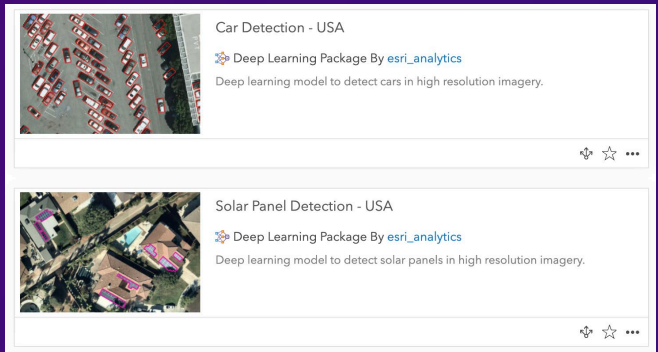
Implementing Many Tasks

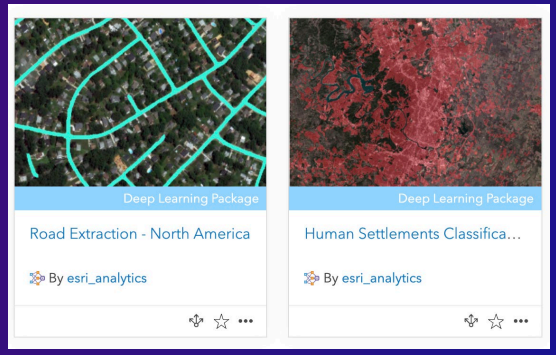
- Object classification
- Object detection
- Pixel classification
- Image translation
- Object tracking
- Scanned maps

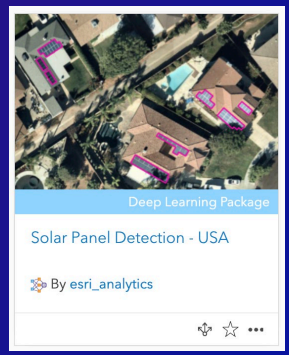
Pre-trained Models on ArcGIS Living Atlas

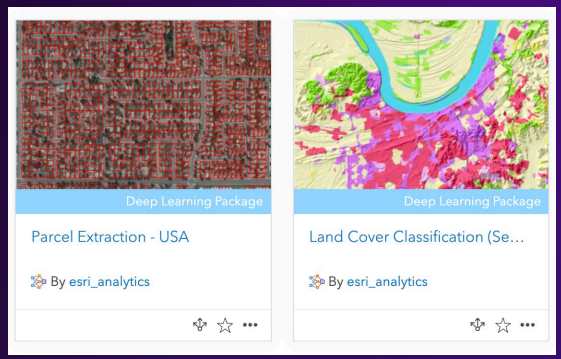
Plug-and-Play Models. No Training Needed. Easy Re-training Using Local Data.

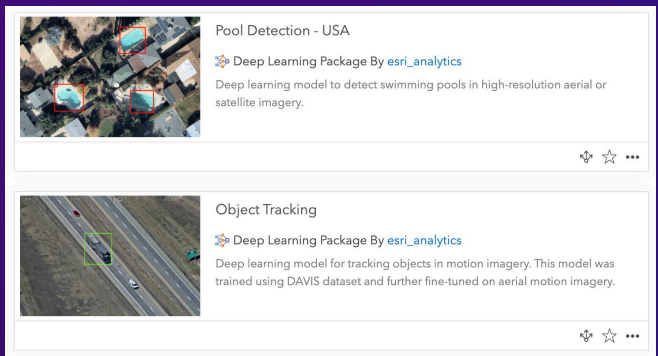












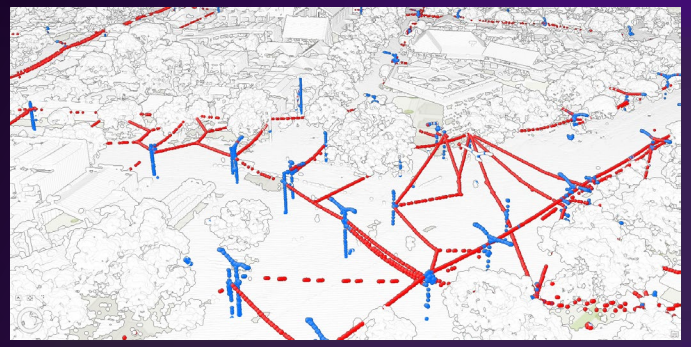
Use Models Within

- ArcGIS Pro (+ Image Analyst Extension)
- ArcGIS Enterprise (+ Image Server)
- ArcGIS Online (+ ArcGIS Image)

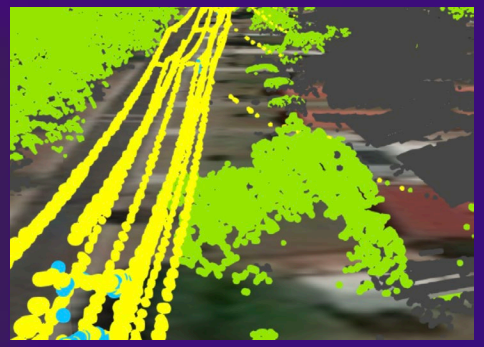
Feature Extraction from Lidar

Data Pre-processing, Labelling, Training, and Inference

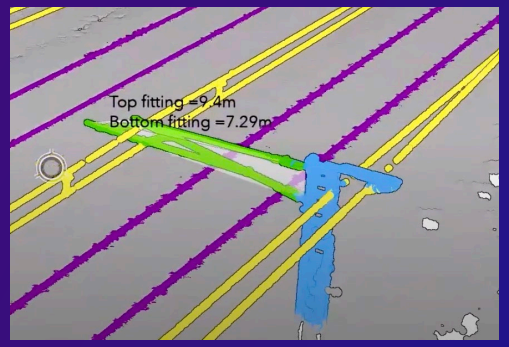
Utility poles and lines



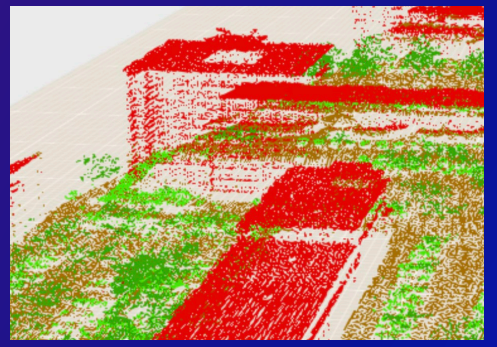
Encroachments and trees



Rail assets

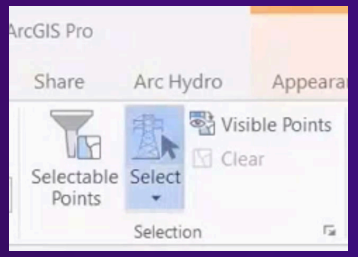


Buildings

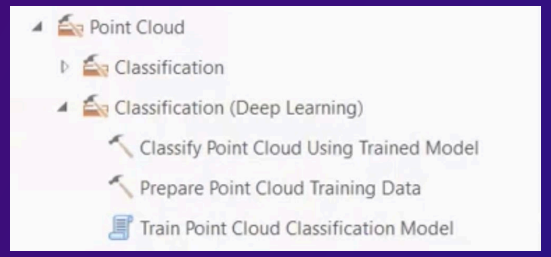


Streetlights

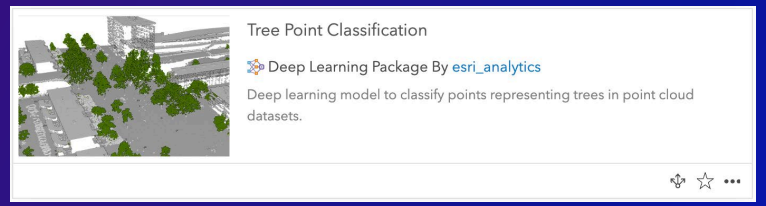
Labelling tools

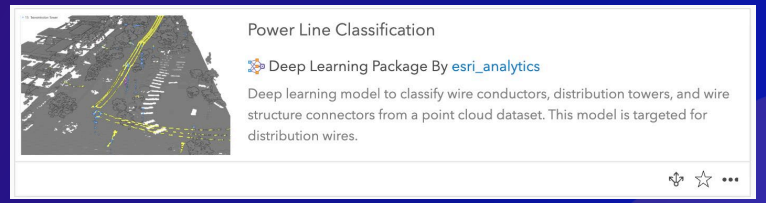


Training and inference tools



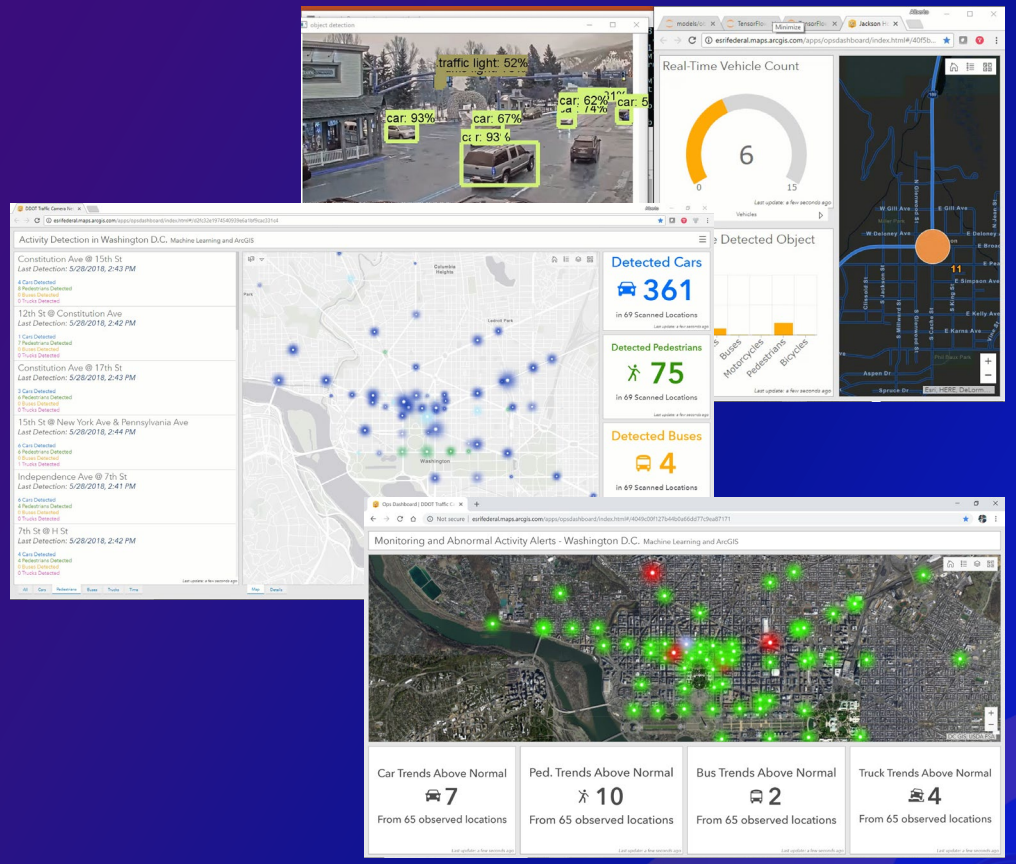
Pre-trained models (ArcGIS Living Atlas)





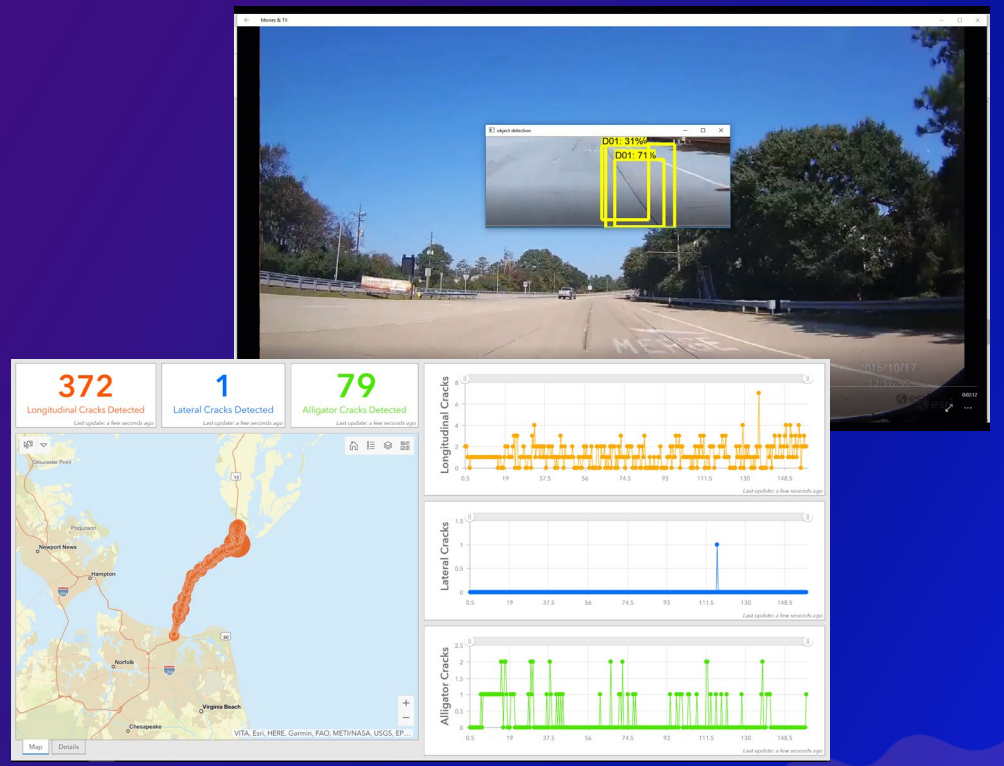
Traffic Analysis from CCTVs

- Detect Vehicles by Type & Pedestrians City-wide
- Can Infer Accidents, Sudden Stops, Traffic Anomalies
- Understand Traffic Patterns, Deal with Incidents Quickly, Supports Event Planning.
- Could be tailored to detect other features



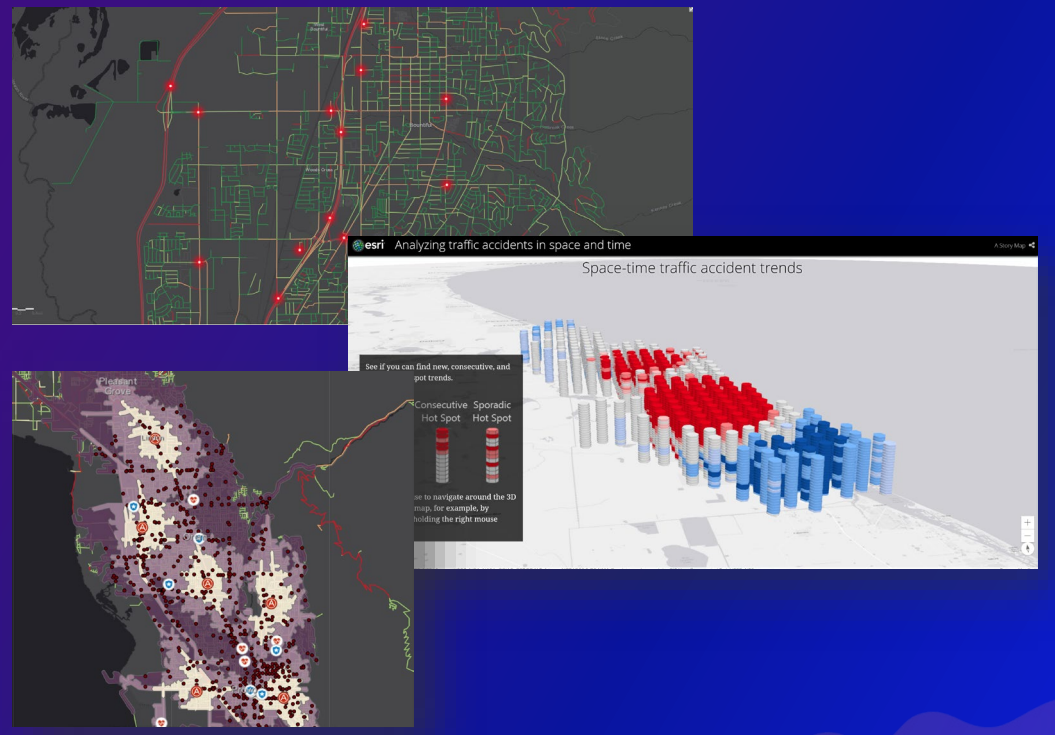
Road Crack Detection

- Automates Road Crack Detection for DOTs, Public Works
- Type of Crack, Possibly it’s Length and Width
- Fits with Partner Road Maintenance Solutions (e.g. VHB’s)



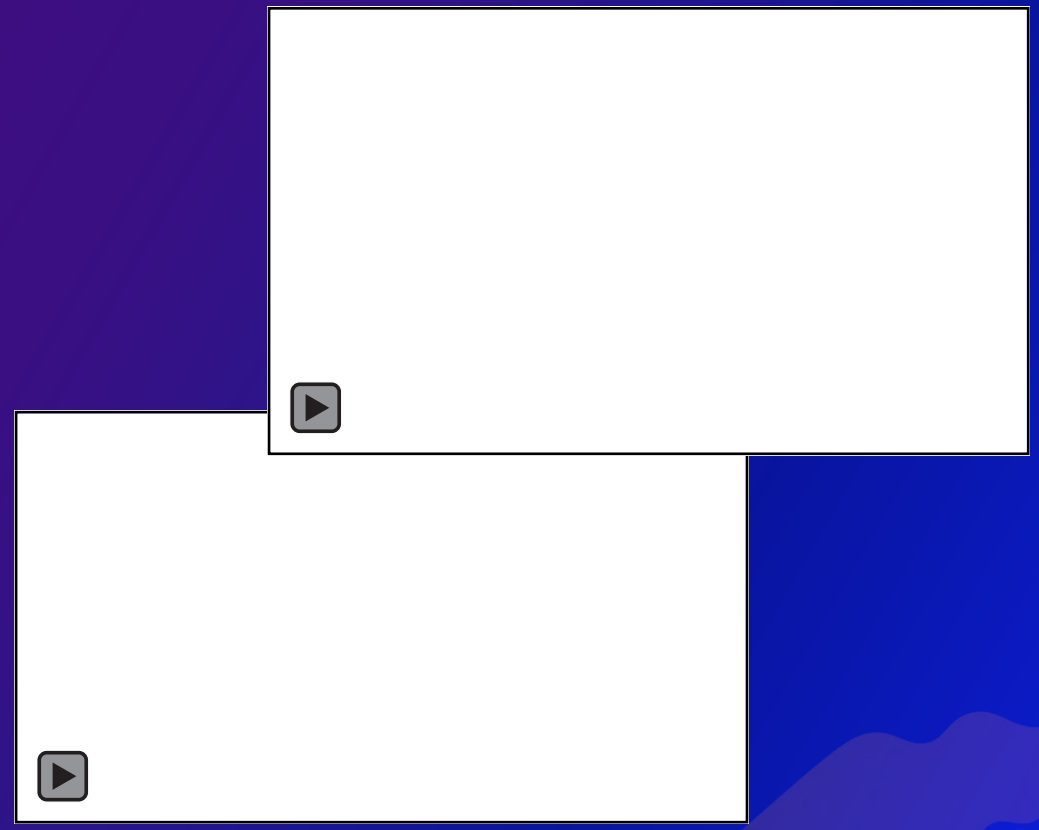
Crash Risk Prediction & Pattern Mining

- Predicts Crash Rate on a points on an LRS Network
- Highlights Top Factors leading to Crashes (Planning)
- Highlights interesting Spatiotemporal Patterns
- Recommends Safest Routes (Operational)
- Recommends Patrol Allocation



3D Building Extraction from Aerial Lidar

- Automated 3D Building Creation from Aerial Lidar
- Detects 1. Building Footprint 2. Roof Type then 3. Reconstructs using CityEngine Procedural Rules
- Saves significant time (a lot of manual work. Traditional tools aren’t good enough: noise, not reliable when there is vegetation around)



Road Asset Extraction from Oriented Imagery

- Automate Asset Extraction from Oriented Imagery. Examples: water meters, road signs, trash bins, pavement markings
- Geotagging of Assets supported
- Retrieve the results as a Feature Layer, consumable in Pro or Enterprise

Map Production Automation

Building Centroids & Footprints, Roads, Parcels, and Land Cover

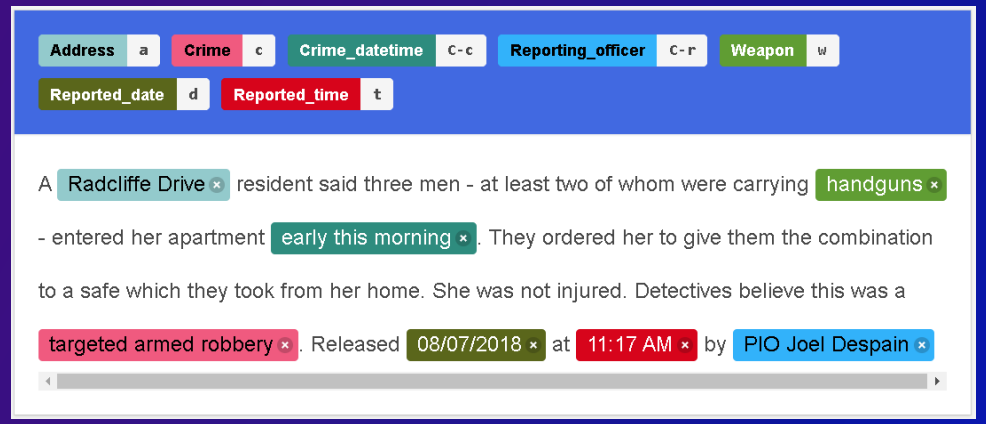
- Extract features from overheard imagery including building centroids and footprints, road segments, parcel boundaries (using object detection and segmentation)
- Classify land cover with high accuracy including water, scrub, forests, urban, and more
- Leverage Esri's pre-trained models with Sentinel-2 and Landsat 8 imagery

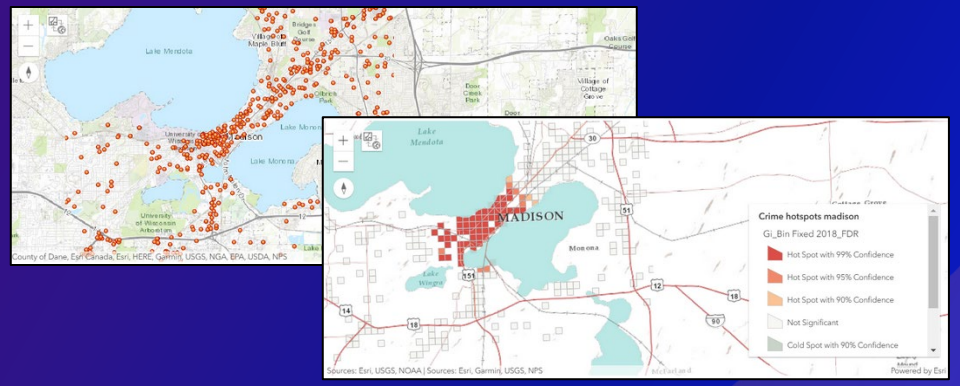
Identify Parcel Boundaries and Features per Parcel (for Taxation)

- Automate the process of parcel boundary identification
- Identify features for each parcel including swimming pools, solar panels, backyard, patio covers, decks, and more
- Identifying these features can help cities properly set property taxes based on new developments/construction per property

Crime Analysis from Unstructured Data (Text)

- Extract Entities (locations, people, events, time..) from Unstructured Text (docs, emails, social media..) and bring them to a map
- Do Spatial Analysis on extracted data to derive insights





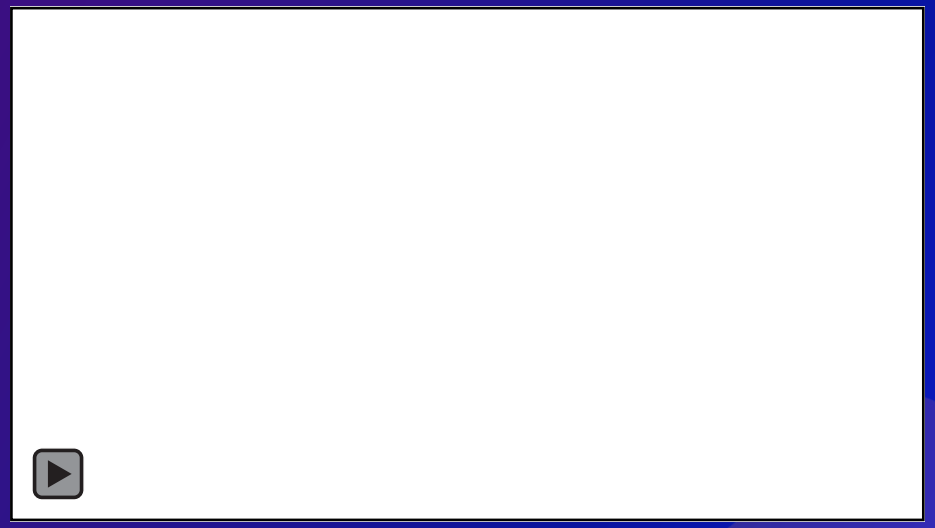
Police Patrol Optimization (to deter Violent Crimes)

- Predicts best Allocation for Police Patrols that would lead to reduction in Violent Crimes
- Works both Real-time and Batch/Daily Planning

Where should patrols go?

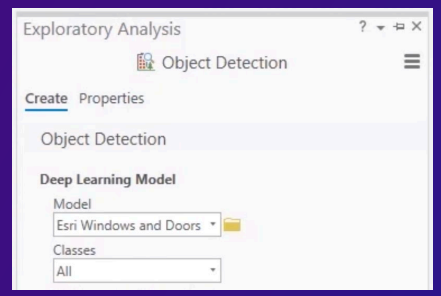
When should they go there?

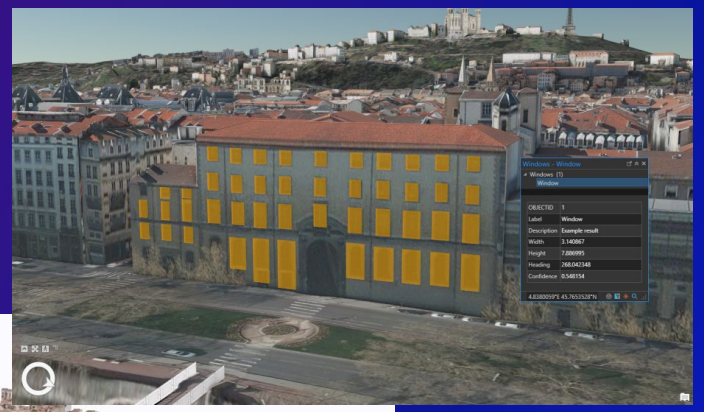
What should they do?



Window Detection in 3D Buildings for Security Analysis

- Detect windows in 3D buildings (for example, from an integrated mesh) using the window detection pre-trained model or your own trained model
- Construct lines of sight to understand visibility to specific target areas
- Law enforcement could use this model in security analysis scenarios (visibility and line of sight)
- Public safety users might be interested regarding physical or visual access to restricted areas, or the ability to build evacuation plans
- It could be used for tax assessment with CAMA (computer aided mass appraisal) and impact studies for urban planning



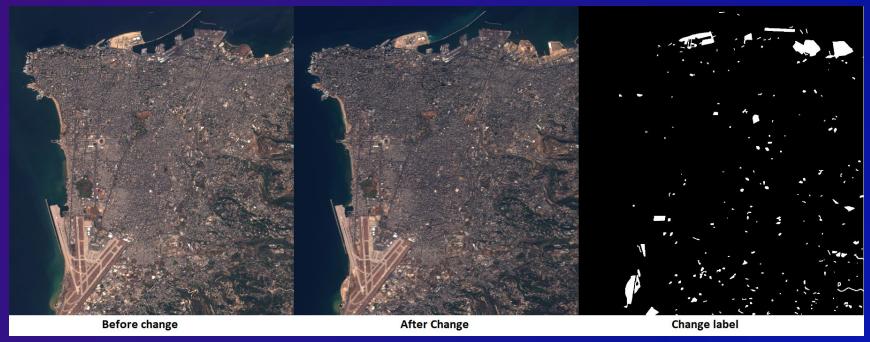


Blight, Graffiti, Overgrowth Detection

- Part of Neighborhood Stabilization Solution: https://bit.ly/2Z1oVJx & https://bit.ly/2AhqZmr
- Automates Detection of important Features (Blight, Graffiti, Overgrowth..) as a Feature Layer
- Could be consumed in Pro or Operations Dashboard for Analysis

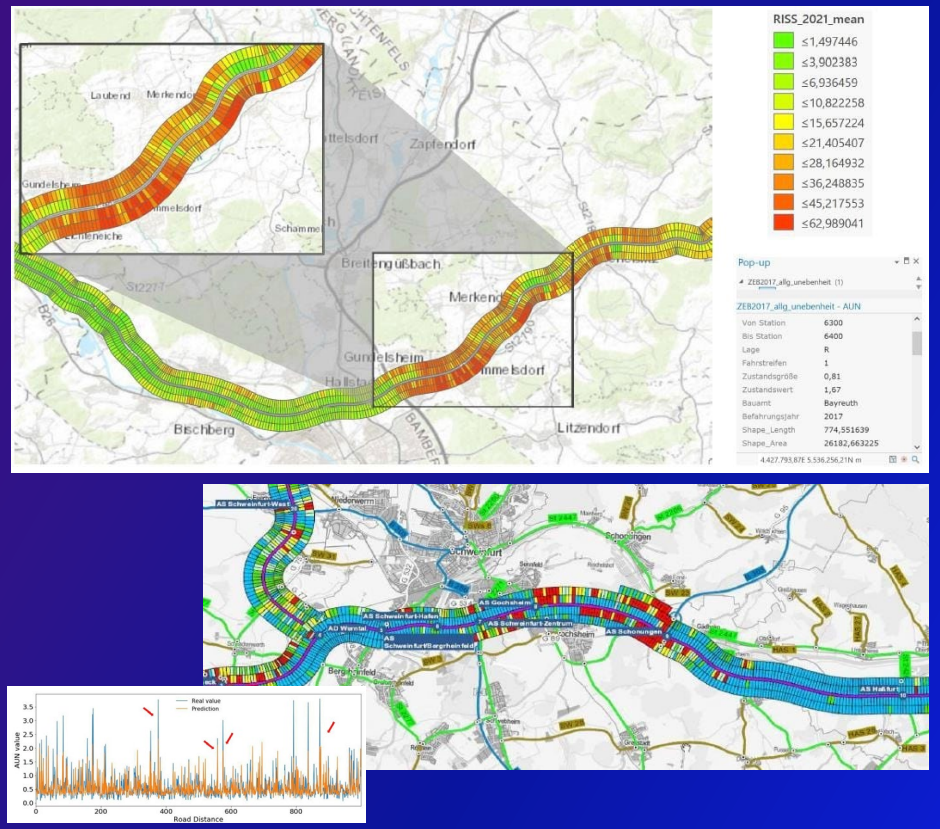
Persistent Change Detection

- Classic change detection tools could be less accurate with clouds, imagery mis-registration, and color differences
- Change detection empowered by deep learning can provide higher accuracy for persistent change (such as new buildings)
- This could be useful for many use cases like identifying urban growth patterns to provide recommendations for infrastructure planning, and identifying illegal construction



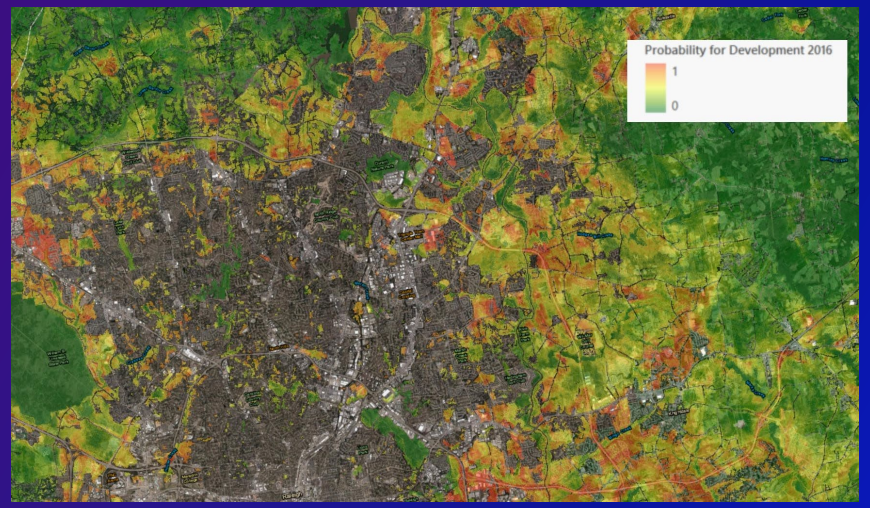
Road Condition (Deterioration) Forecasting

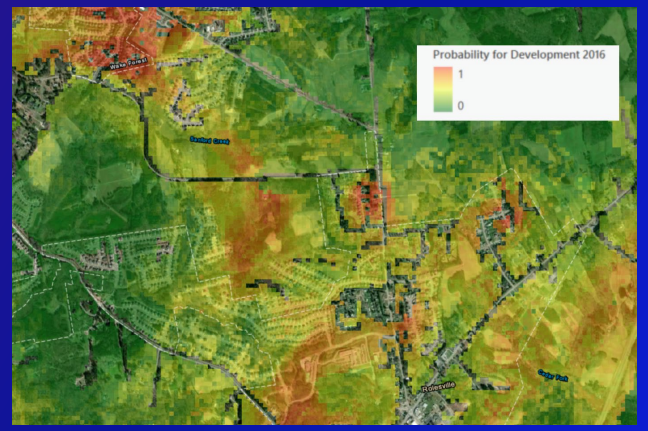
- Prioritize road infrastructure investment
- Efficiently plan road maintenance at the proper time and location
- Forecast road deterioration based on historical condition data, along with other data sets like traffic density, weather, and road type



Predicting Urban Growth

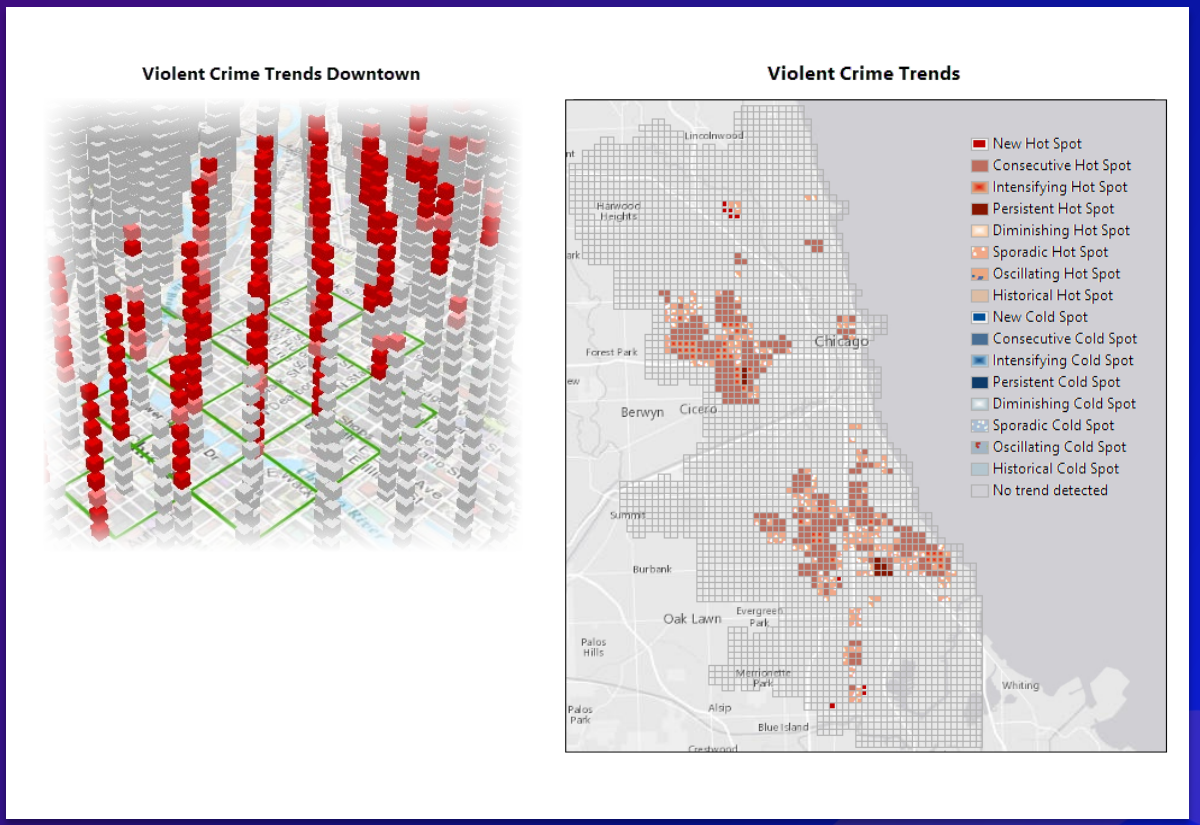
- Identify locations with a higher probability of urban development
- Use historical land cover raster data (urban and non-urban) along with other data sets as input variables (for example, drive time to the nearest urban center, proximity to freeways, proximity to environmentally protected areas, population growth, and slopes)
- Model development can take place in ArcGIS or other frameworks like R or Python





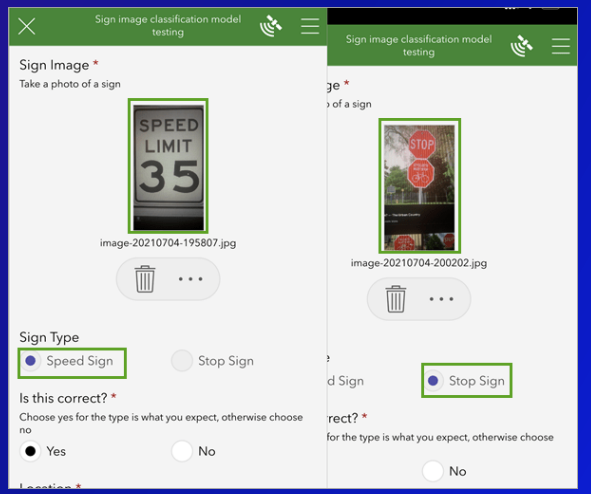
Mining Spatiotemporal Patterns in Crime Data

- Explore different factors correlating with crimes (such as liquor stores, unemployment, or poverty levels)
- Understand which areas experience a statistically significant increase in crimes (such as intensifying, persistent, and consecutive hotspots) using the SpaceTime Pattern Mining Tools



AI-Empowered Field Operations

- Accelerate field data collection using AI-empowered smart camera in ArcGIS Survey123
- Automatically identify objects and features within a photo and auto populate the survey with this data
- Works offline—just train a model using TensorFlow Light and deploy it within ArcGIS Survey123
- Examples include road signs, asset condition, utility assets, trash bins, blight and graffiti, and more



ArcGIS.Learn

Python-first Approach for Machine Learning Workflows. Part of ArcGIS API for Python.

Train SingleShotDetector Model

```
from arcgis.learn import SingleShotDetector

ssd = SingleShotDetector(data, grids=[9], zooms=[1.0], ratios=[[1.0, 1.0]])
```

```
In [8]: ssd.fit(10, lr=slice(1e-3, 1e-2))
```

Total time: 15:56

epoch	train_loss	valid_loss
1	629.015869	250.982254
2	400.904327	181.745972
3	315.588318	163.946136
4	268.519928	155.258881
5	234.541077	133.495728
6	209.463257	116.552231
7	189.608063	104.452789
8	172.239929	98.530197
9	157.103226	91.969261
10	146.046310	91.620415

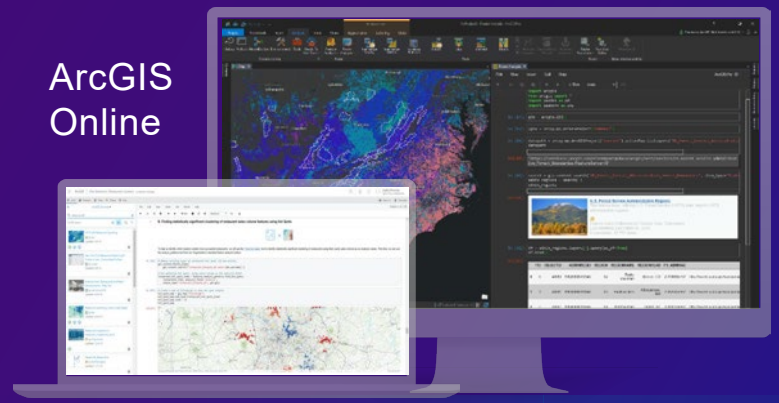
ArcGIS Notebooks

Spatial Analysis Meets Open Data Science

ArcGIS Notebooks

ArcGIS Pro

ArcGIS Online



Enterprise

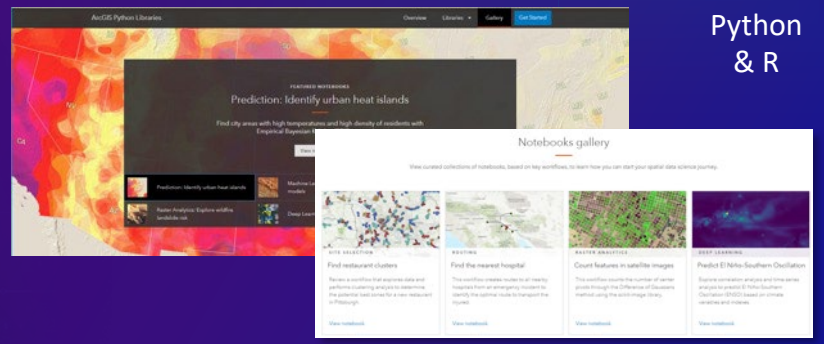
Specialized Server
Extensible

Pro

Integrated
Easy - No Setup

Online

Available as an Extension



Python & R

Open Source
Data Science Ecosystem

Notebook Gallery

Includes ArcGIS Python Libraries and
100s of Open Science Libraries

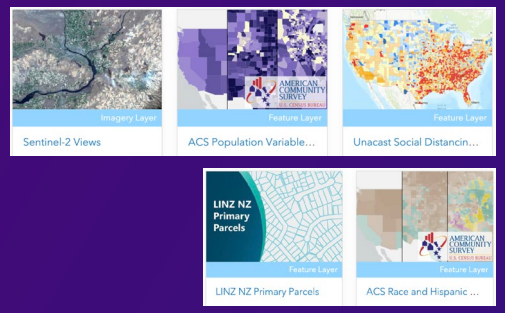
Scripting Processes and Workflows

ArcGIS for Data Science Teams

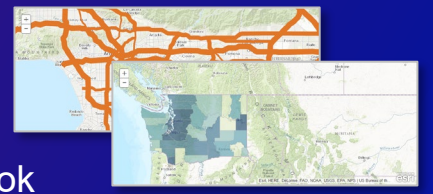
Bringing “Spatial” to Machine Learning, Using the ArcGIS API for Python

Spatial Data

- Multi-spectral, temporal, dynamic imagery layers
- Landsat, NAIP, MODIS, elevation
- Basemaps, imagery, demographics, transport

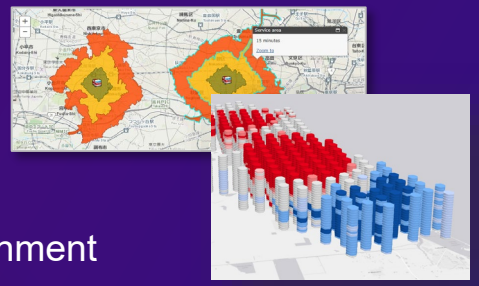


Spatial Visualization



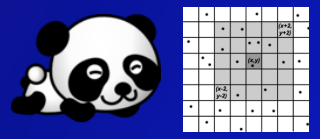
- Map widget in Jupyter notebook
- Web maps and web scene
- Feature layers, raster and imagery layer
- Smart mapping

Spatial Analytics & ML

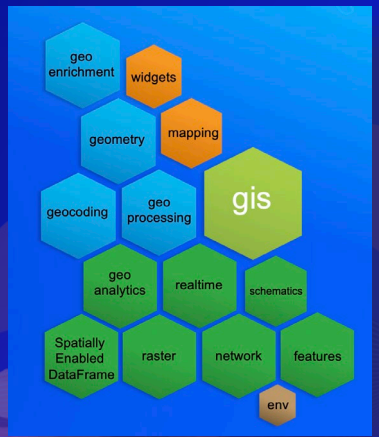


- Spatial analysis, routing and directions
- Network analysis, geocoding, geoenrichment
- Spatial ML (GWR, SpaceTime PM…)

Spatially-enabled DataFrame



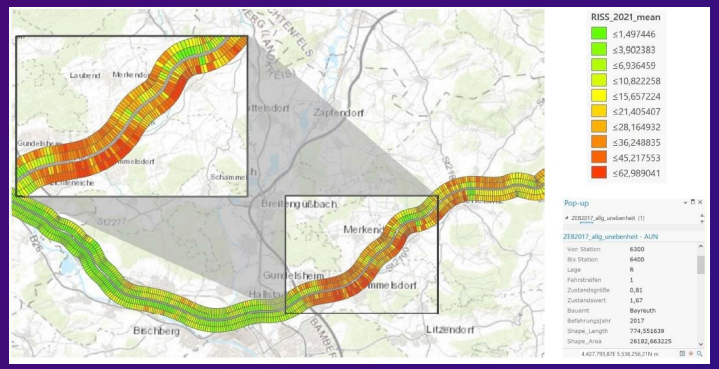
- Built on Pandas, facilitates spatial data wrangling
- Reads/writes GIS data
- On-demand spatial indexing
- Multiple geometry engine support



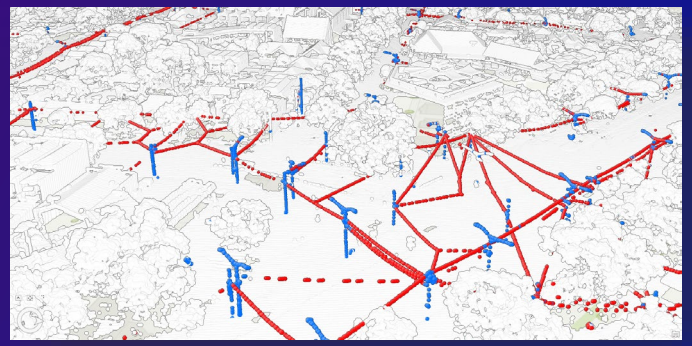
Success Stories

Kuwait PACI Automates Country Map Production 17X Faster

Bavaria Forecasts Road Deterioration using Machine Learning



Australian Utility Saves 50,000 Man Hours by Automating Asset Extraction from Lidar



USAA Automates Damage Claims Processing using Imagery AI

Nob Hill Water Association Predicts Water Main Failures with Machine Learning