

CRP 4080: Introduction to Geographic Information Systems for planners

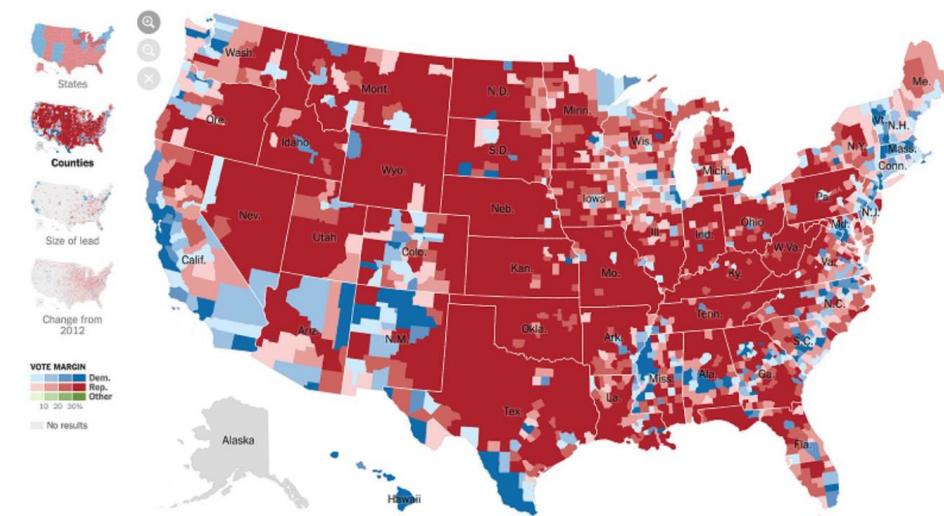
Lecture 12: GIS after this course

Wenzheng Li, Ph.D.
City and Regional Planning
Fall 2024

What we have learned so far

Detecting a spatial phenomon and asking a GIS question (lab 1/2)

- GIS basics
 - Important concepts: GIS and spatial analysis
 - Useful applications
 - Data type in GIS
- Thematic mapping and visualizations
 - Map layouts
 - Color scheme
 - Data classification
 - Data normalization

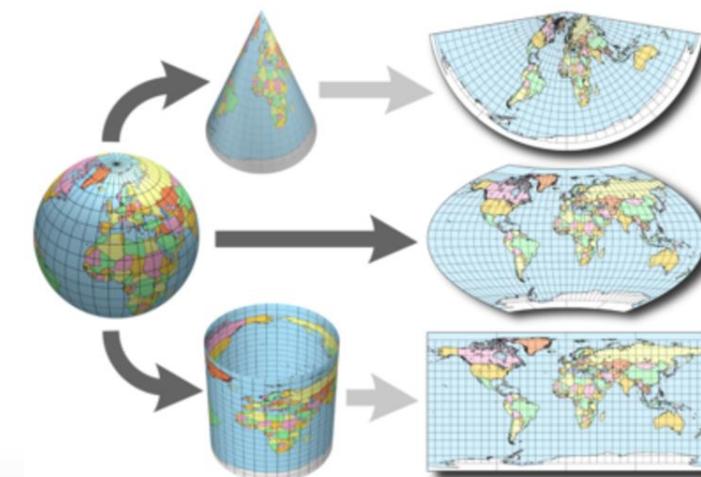


Choropleth Map - 2016 U.S. Presidential Election. Source: New York Times, 2016.

What we have learned so far

Spatial analysis (lab 2/3)

- Projection
 - Datum
 - Geographic Coordinate System and Projected Coordinate System
- Add and calculate attribute fields
- Descriptive and summary Statistics
- Selecting and extracting Features



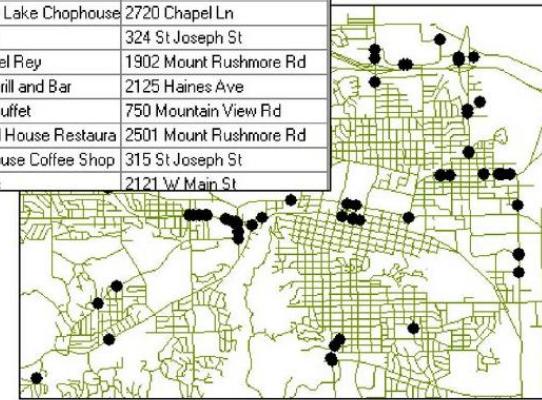
What we have learned so far

Collecting the spatial data (lab 5/6/7)

- Table data preparation
 - Data join
- Data source
- Georeferencing
- On-screen digitization (ArcGIS and Google Earth Pro)
- Geo-coding

RESTAURANT	ADDRESS
Cajun Caf,	2200 N Maple Av
Cajun Express	1301 Omaha St
Canyon Lake Chophouse	2720 Chapel Ln
Carini's	324 St Joseph St
Casa Del Rey	1902 Mount Rushmore Rd
Chili's Grill and Bar	2125 Haines Ave
China Buffet	750 Mountain View Rd
Colonial House Restaura	2501 Mount Rushmore Rd
Courthouse Coffee Shop	315 St Joseph St
Culver's	2121 W Main St

Address table



Reference layer

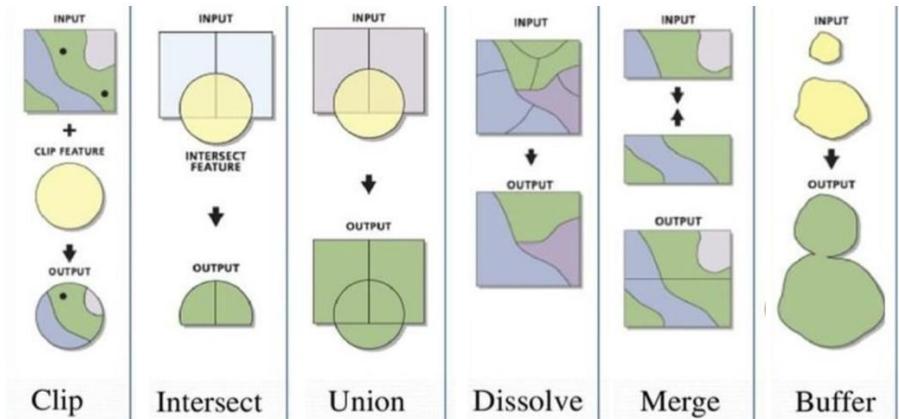


What we have learned so far

Spatial analysis (lab 4/8/9/10)

- Geoprocessing tools
 - Overlay
 - Merge
 - Proximity
 - Aggregation
- Spatial statistics tools
- Environmental justice analysis
- Raster analysis and functions/Land suitability analysis
- Online Interactive mapping

Recap – Geoprocessing tools



Future about GIS

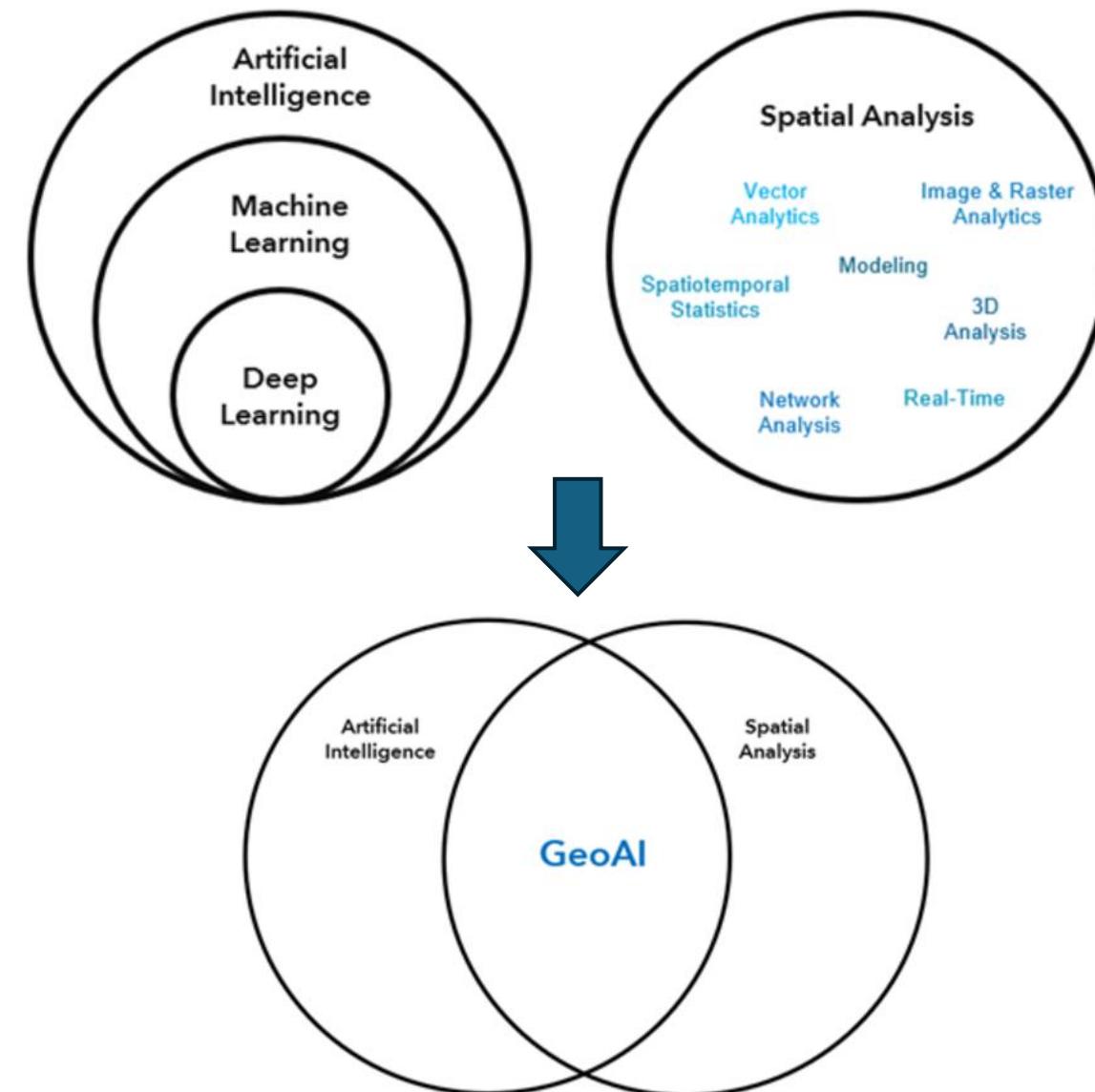
- Integration GIS with Artificial Intelligence and Machine Learning (***GeoAI***)
- Earth Observation and ***Remote Sensing*** Evolution
- Advancements in 3D GIS and ***Digital Twins***
- Cloud-Based GIS Solutions (e.g., ArcGIS Online, Mapbox, etc)
- Increased Use of Open-Source GIS (QGIS, GRASS GIS)
- Low-Code/No-Code GIS Applications

GeoAI: Transforming GIS with Artificial Intelligence and Machine Learning

- **Geospatial artificial intelligence (GeoAI)** is the application of artificial intelligence (AI) fused with geospatial data, science, and technology to accelerate real-world understanding of business opportunities, environmental impacts, and operational risks (ESRI).
- **Key Benefits:**
 - **Automation** the extraction, classification, and detection of information from data such as imagery, video, point clouds, and text.
 - **Predictive Capabilities:** Build more accurate models. Detect clusters, calculate change, find patterns, and forecast outcomes with spatial algorithms.

GeoAI—key concepts

- **Spatial analysis**
- **Artificial Intelligence (AI)**: The ability of a machine to perform tasks that traditionally require human intelligence, such as perception, reasoning, and learning.
- **Machine learning (ML)**: a set of techniques that allow computers to learn patterns within data and acquire knowledge without being explicitly programmed (-Arthur Samuel, 1959)
 - **statistical methods or data-driven algorithms that solve classification, clustering, and prediction problems.**
- **Deep learning (DL)**: A subset of ML that uses trainable and learned algorithms in the form of artificial neural networks.
 - think of DL algorithms like the human brain, in which the computer learns complex patterns and concepts by piecing together simpler concepts

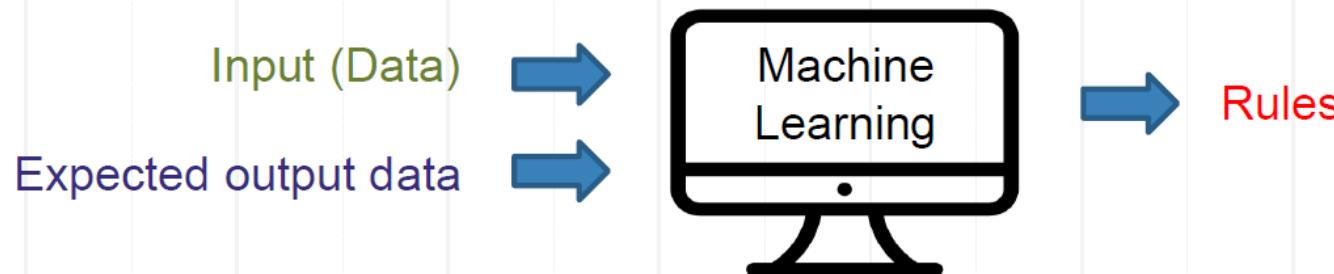


GeoAI—key concepts: programming and machine learning

Traditional program:
developers give computers explicit instructions to follow.



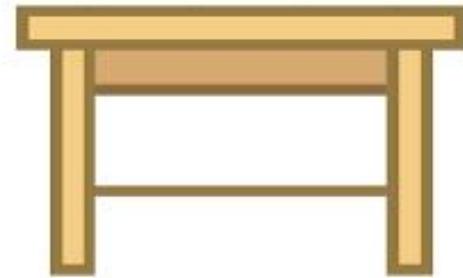
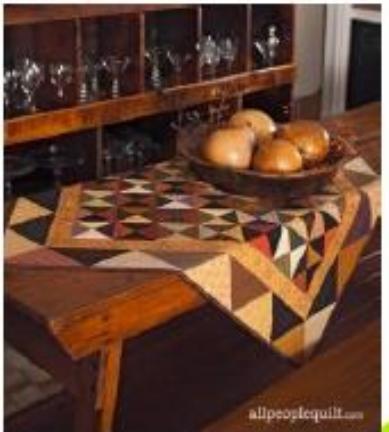
Machine Learning:
Machine learning uses algorithms to learn patterns from data and make predictions.



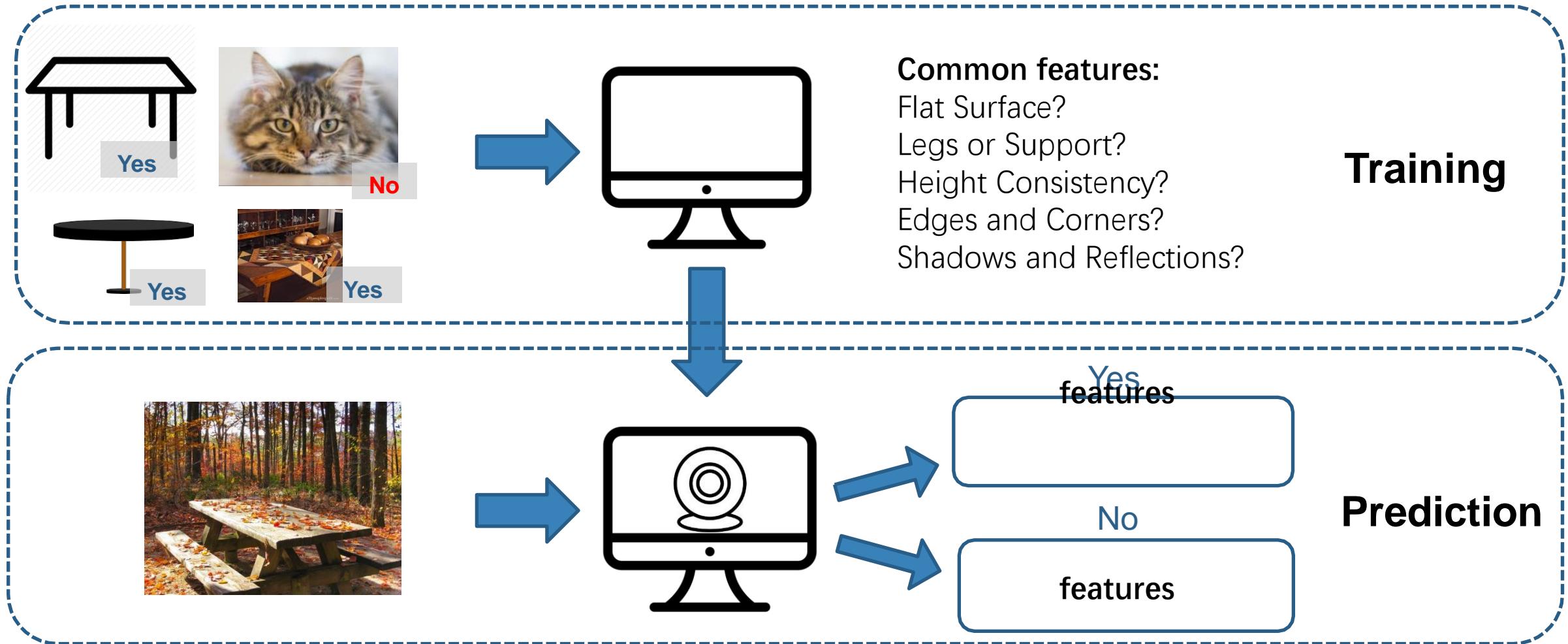
What is Machine Learning?

- **Example: Image Recognition**

Task: whether there is a table in the image



A table detector based on machine learning

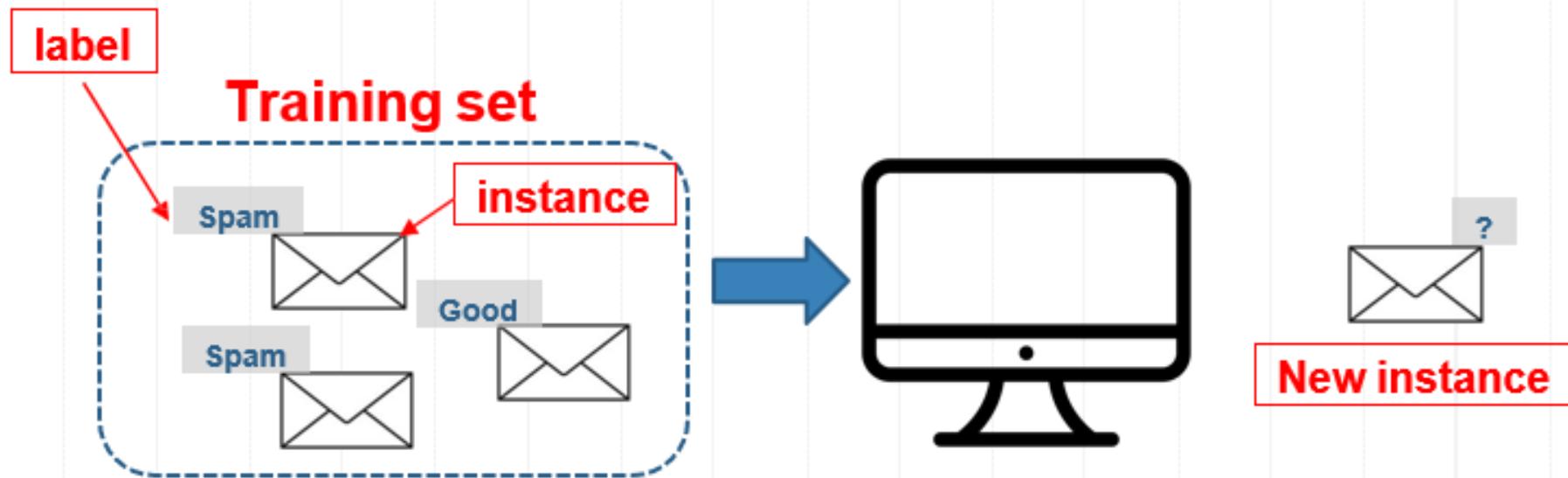


Machine Learning Types

1. Supervised Learning: machine is trained with human supervision
with a “teacher”, (the training set is labeled)
2. Unsupervised Learning: machine is trained **without** human supervision
without a “teacher”, (the training set is **not** labeled)
3. Semisupervised Learning
4. Reinforcement Learning

Supervised Learning

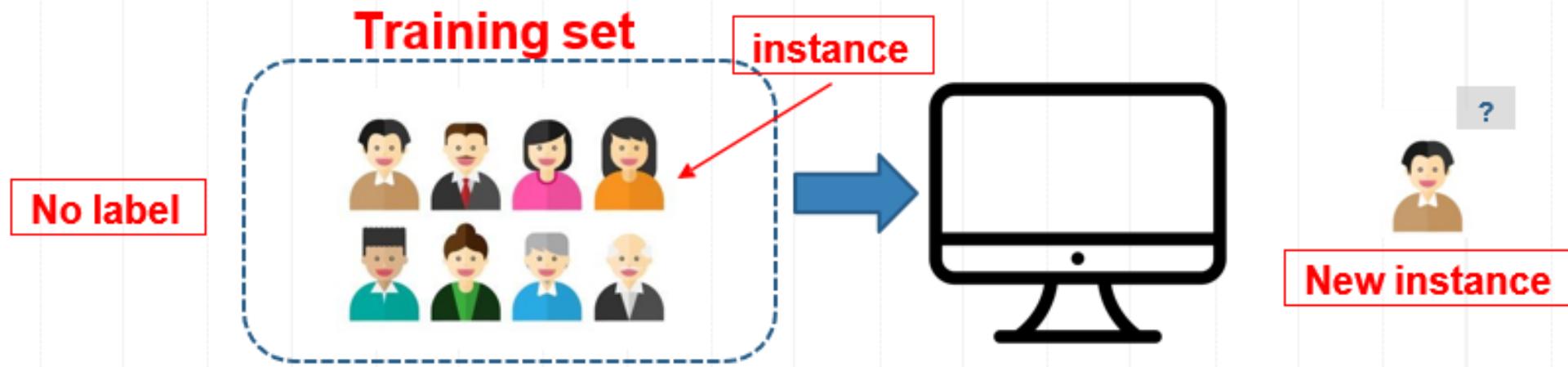
- Training



1. Supervised Learning: machine is trained with human supervision
with a “teacher”, (the training set is labeled)

Unsupervised Learning

- Training



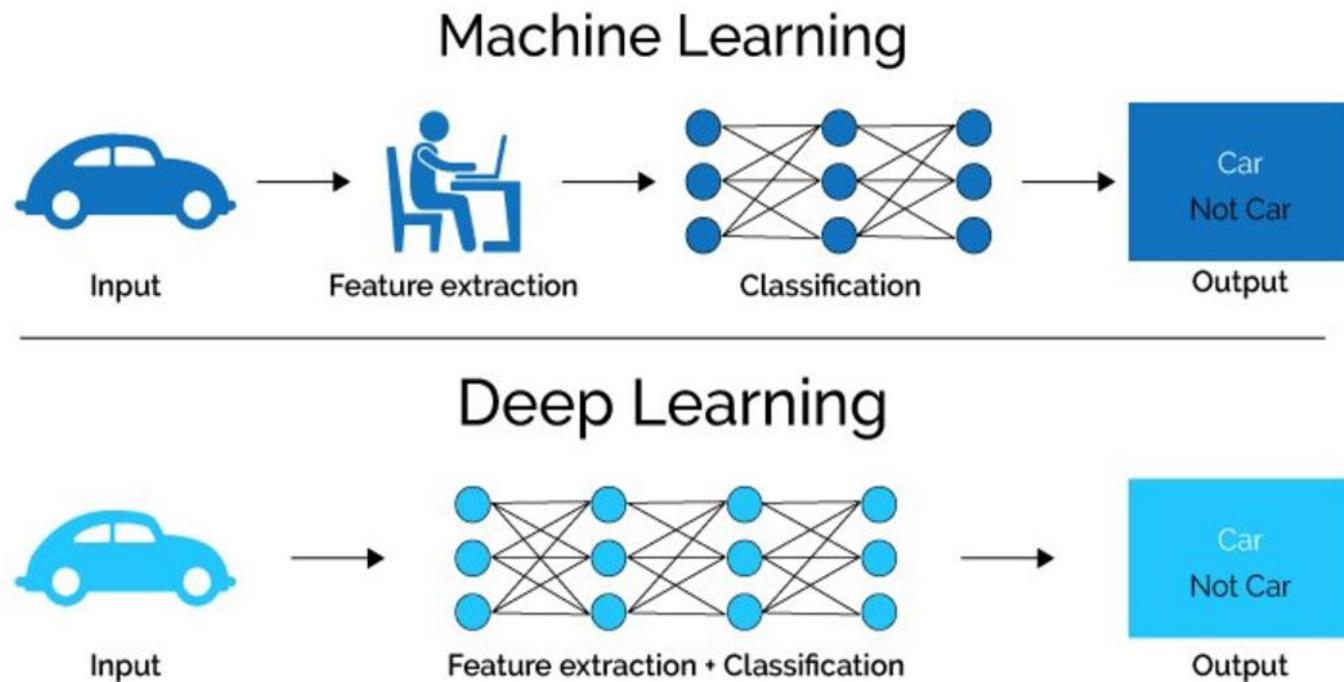
2. Unsupervised Learning: machine is trained **without** human supervision
without a “teacher”, (the training set is **not** labeled)

Machine Learning?

- **Applied science**: hypothesis testing, model assumptions, explanation, and interpretation
- In machine learning, different than in applied statistics, we are less interested in what these parameters are, and more in how well they can
 - **Make predictions**
 - **Describe underlying structures or characteristics in the data**

GeoAI—key concepts: machine learning and deep learning

- A human provides input and feedback to train an effective model.
- Neural networks decide which data to use for analysis, removing the need for manual input



GeoAI—applications

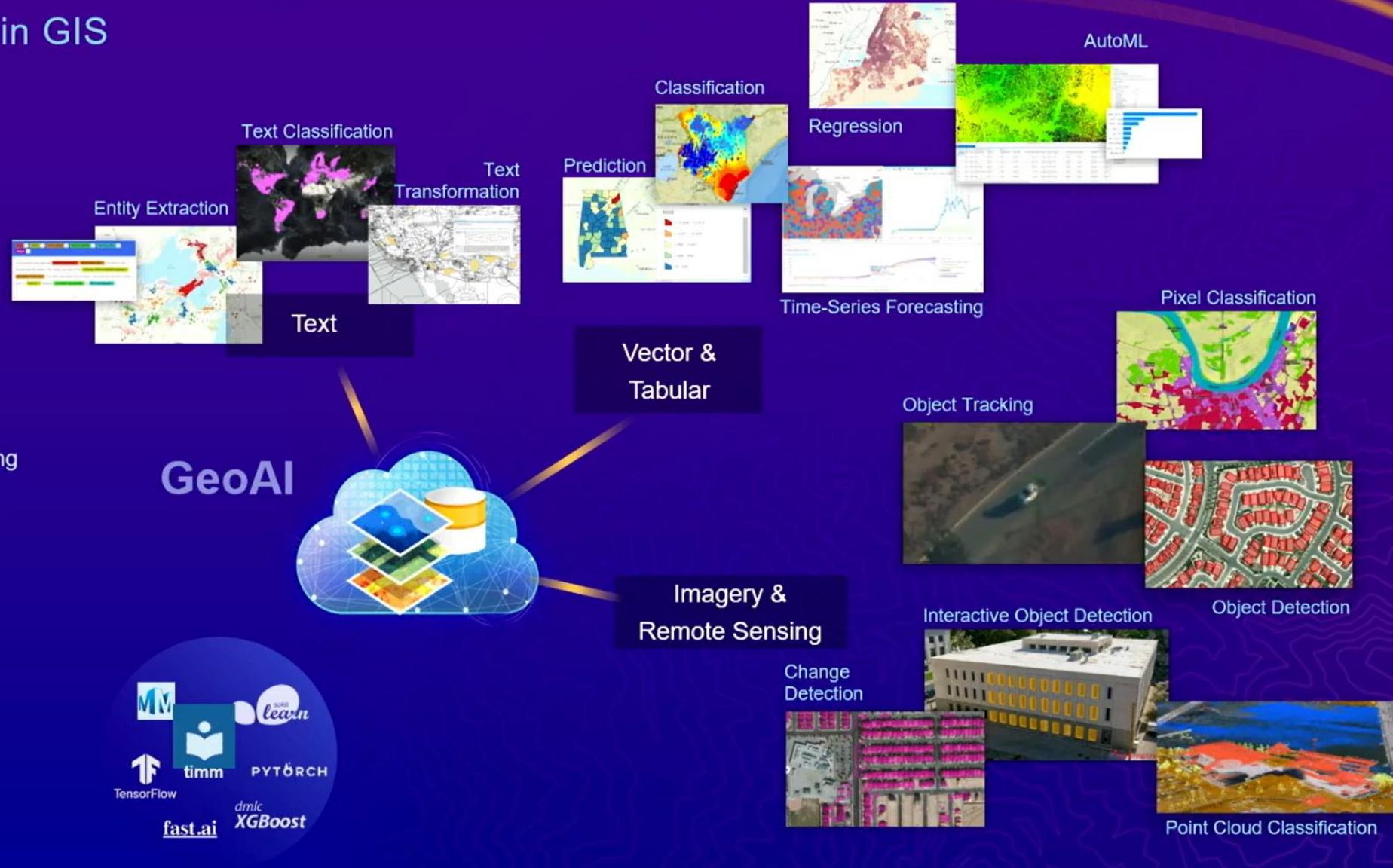
Unlock the power of AI in GIS

Advancing capabilities

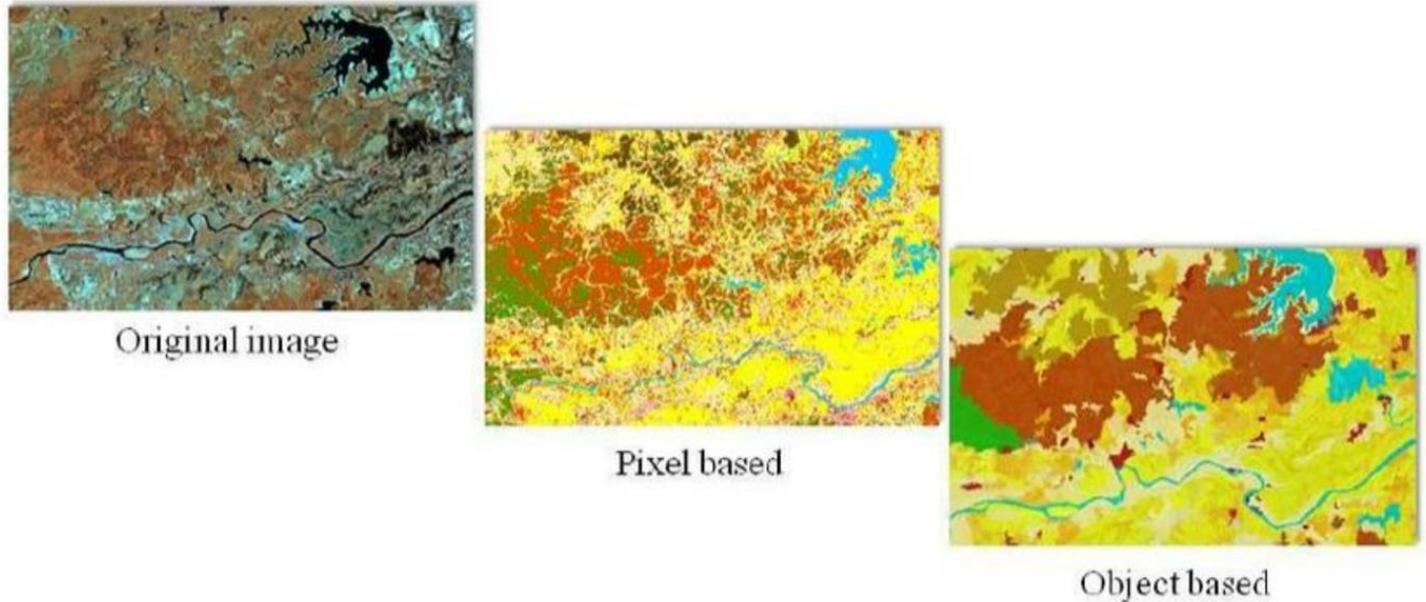
- GeoAI toolbox
- Pretrained models
- Ethical & Explainable AI

Simplifying workflows

- Automated machine learning
- Automated deep learning
- AI Assisted Labelling



Satellite imagery classification



Pixel-based Vs. Object-based classification. [Source](#)

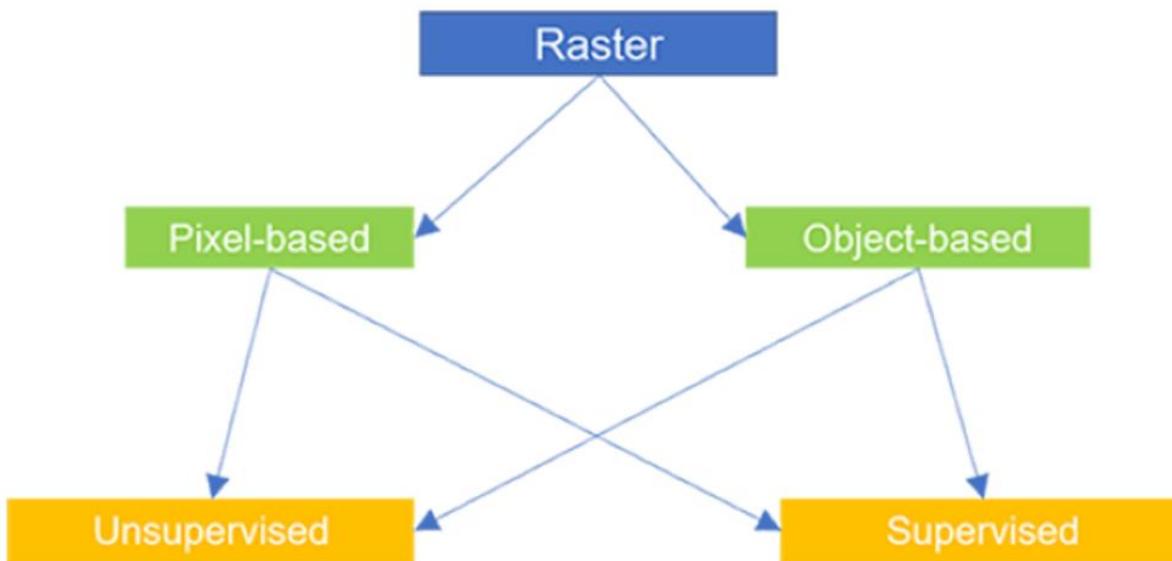
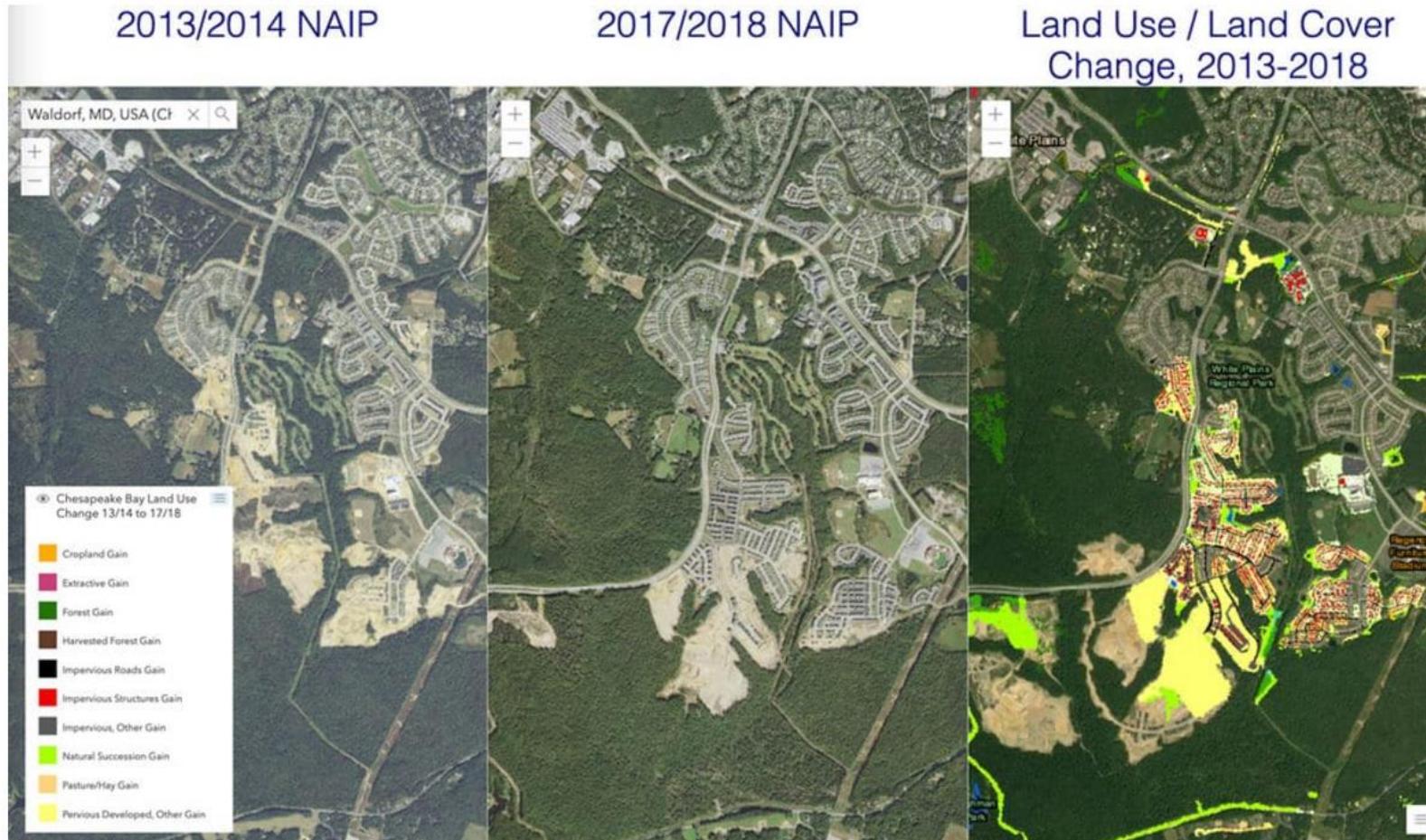


Image Classification Technique: Image Classification Type + Image Classification Method. Source: Esri

Applications-land cover and land use change



Side-by-side panels to show land use/land cover (LULC) change in Charles County, MD from 2014-2018. Screenshot from [Dynamic LULC Change, Chesapeake Conservancy](#) taken 25-October-2022.

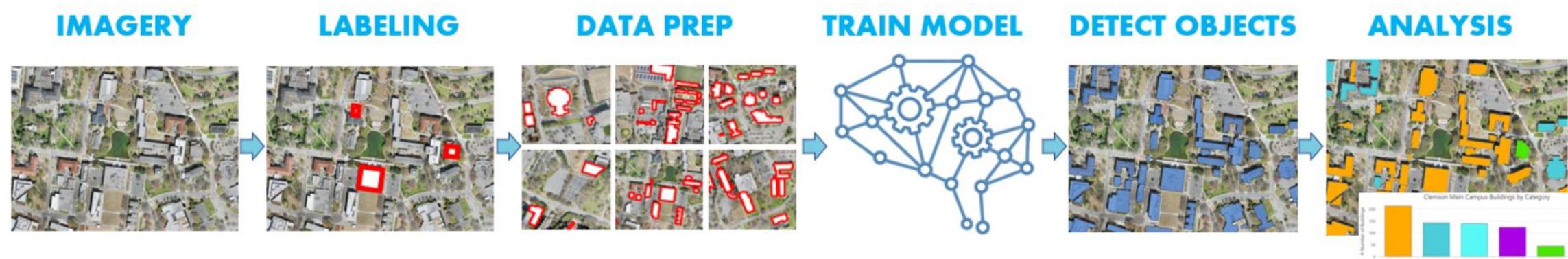
Applications-computer vision, object detection, and deep learning

Model the real world for prediction

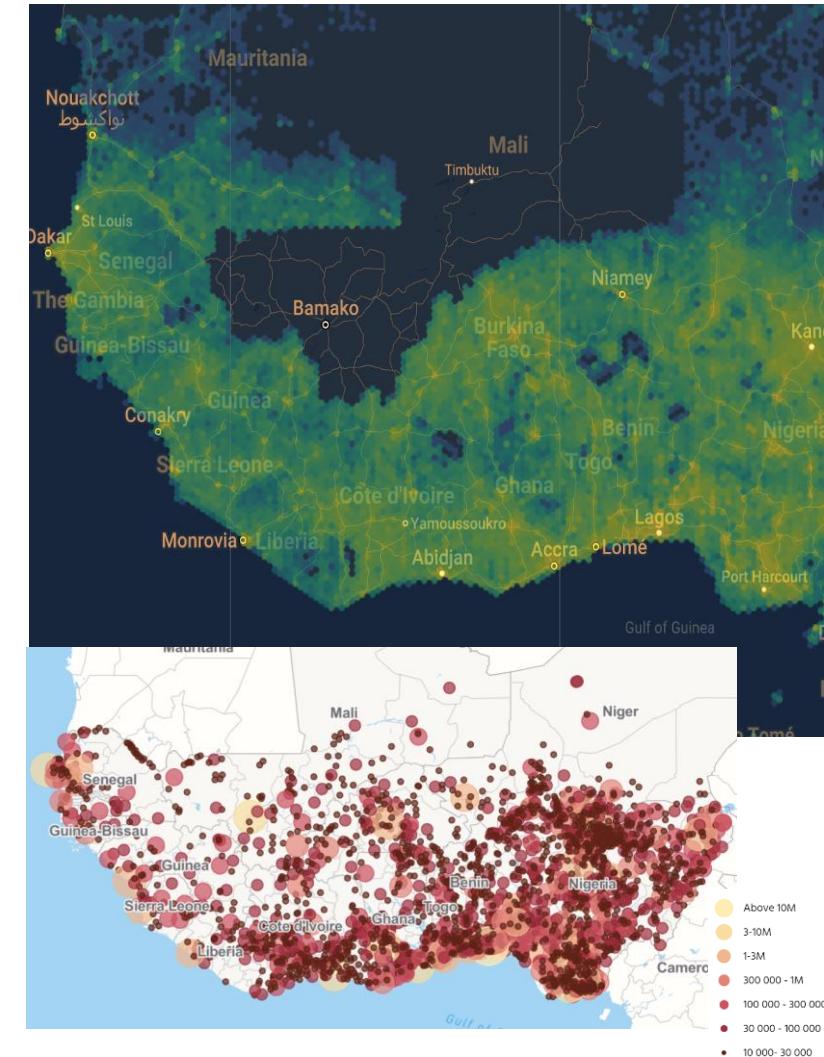
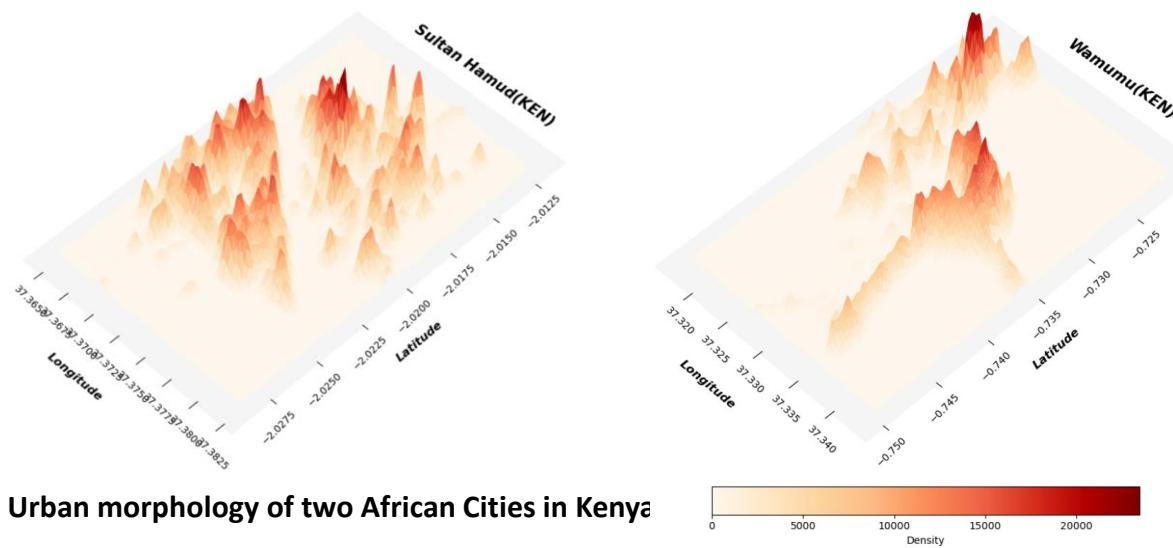
Aerial imagery is used to extract imagery of buildings and roads in Grenada to identify the population and infrastructure at risk for landslides.



Deep learning workflow: building detection



Applications-computer vision, object detection, and deep learning



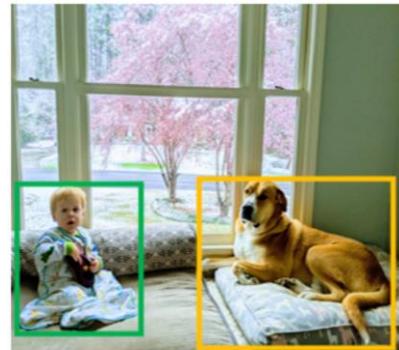
More applications – computer version and deep learning



DOG



DAMAGED BUILDING



CHILD, DOG



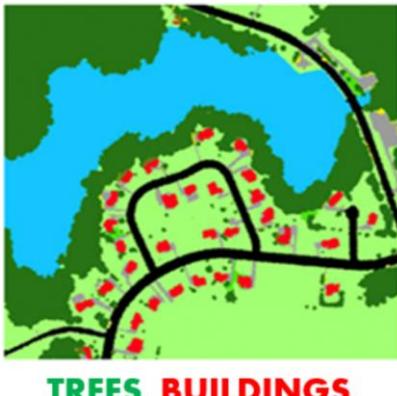
STADIUM

object classification or image recognition

Object detection: locate objects within an image



TREES, GROUND, DOG



TREES, BUILDINGS, GRASS, ROADS

pixel classification, image segmentation, or image classification



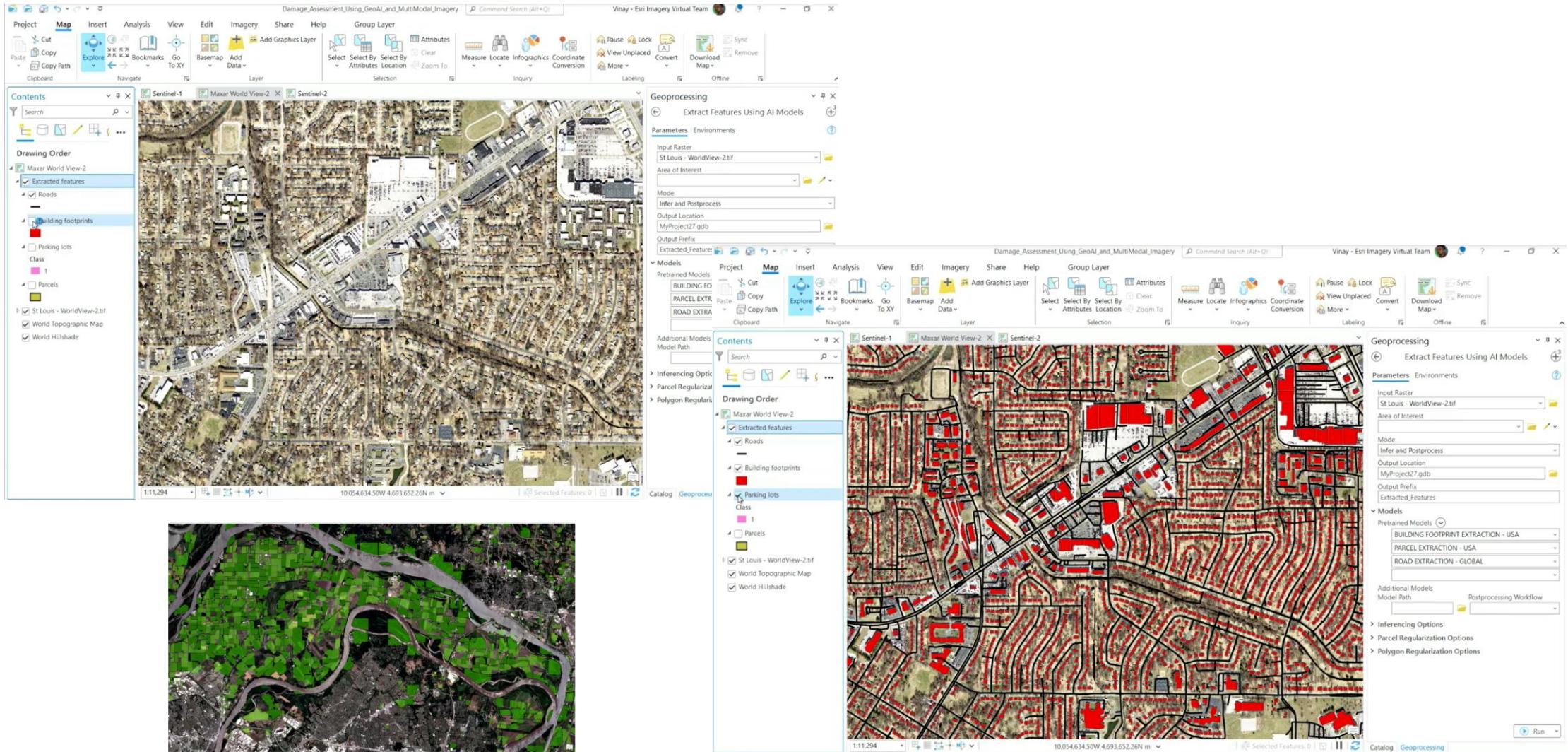
CHILD, DOG



BUILDINGS

object segmentation

You can do this via ArcGIS ProGeoAI Toolbox



Vector data analysis

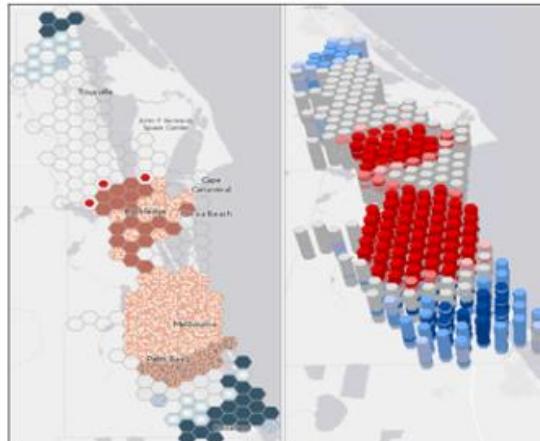
CLASSIFICATION

- Pixel & Object Based
- Image Segmentation
- Maximum Likelihood
- Random Trees
- Support Vector Machine



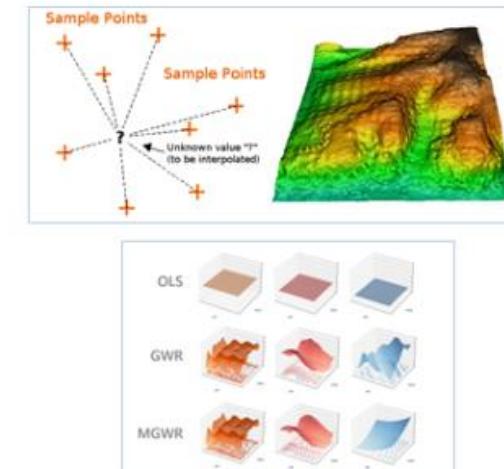
CLUSTERING

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



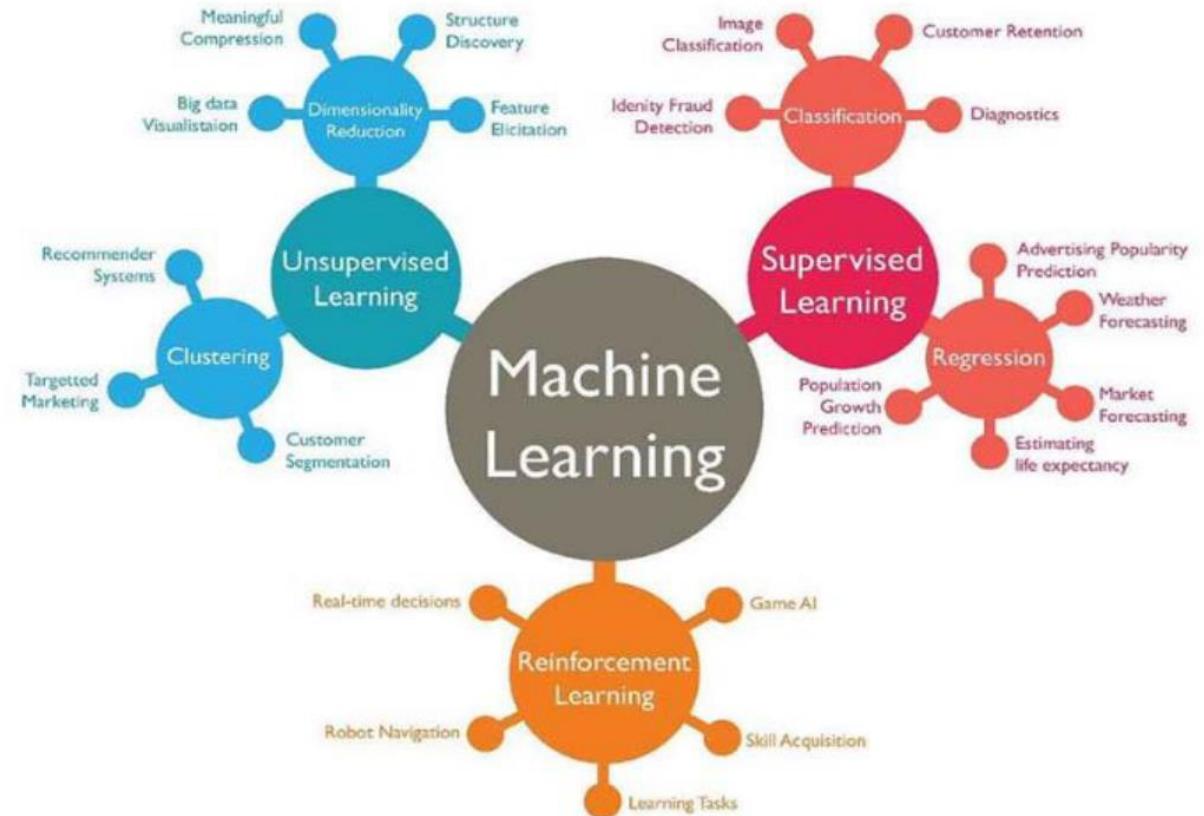
PREDICTION

- Interpolation
 - Empirical Bayesian Kriging
 - Areal Interpolation
 - EBK Regression Prediction
- Regression
 - OLS Regression
 - Exploratory Regression
 - (Multiscale) Geographically Weighted Regression



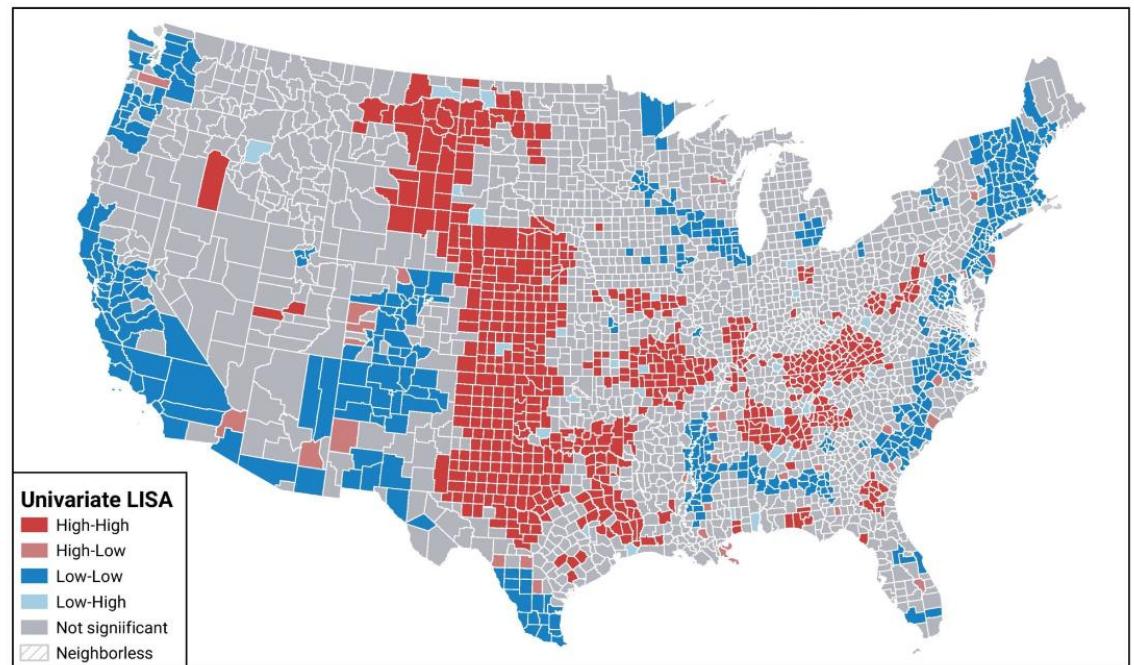
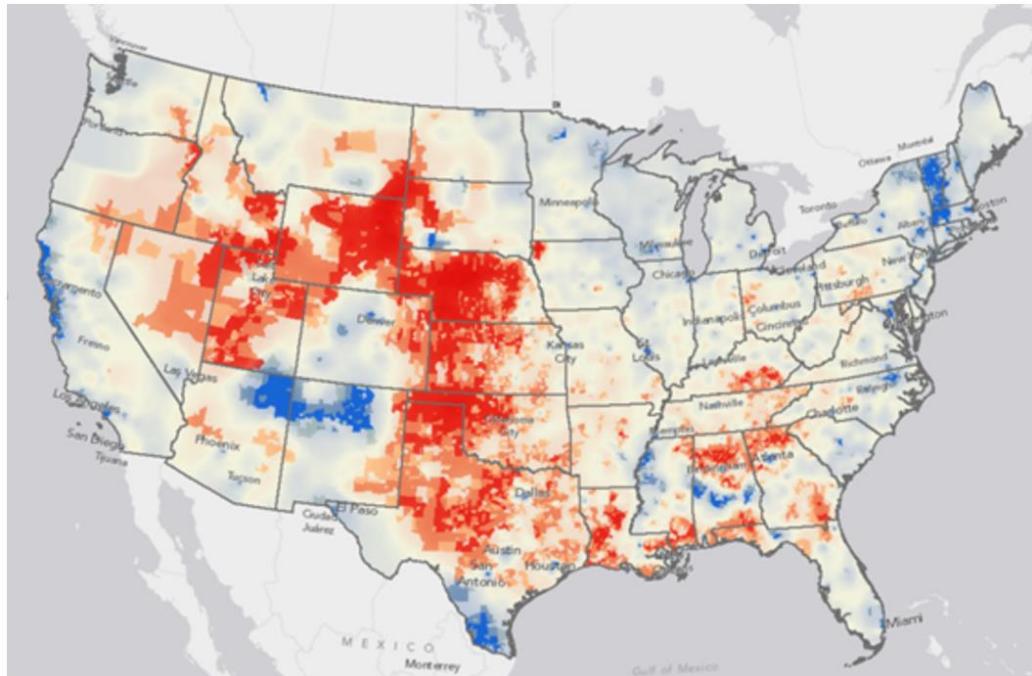
Machine Learning Algorithm

- **Supervised learning**
 - Classification
 - K-nearest neighbors
 - logistic regression
 - Random forest
 - ...
 - Regression
 - Linear regression
 - ...
- **Unsupervised learning**
 - Clustering
 - K-means clustering
 - ...
 - Dimensionality Reduction
 - PCA and factor analysis



Unsupervised learning: Clustering analysis

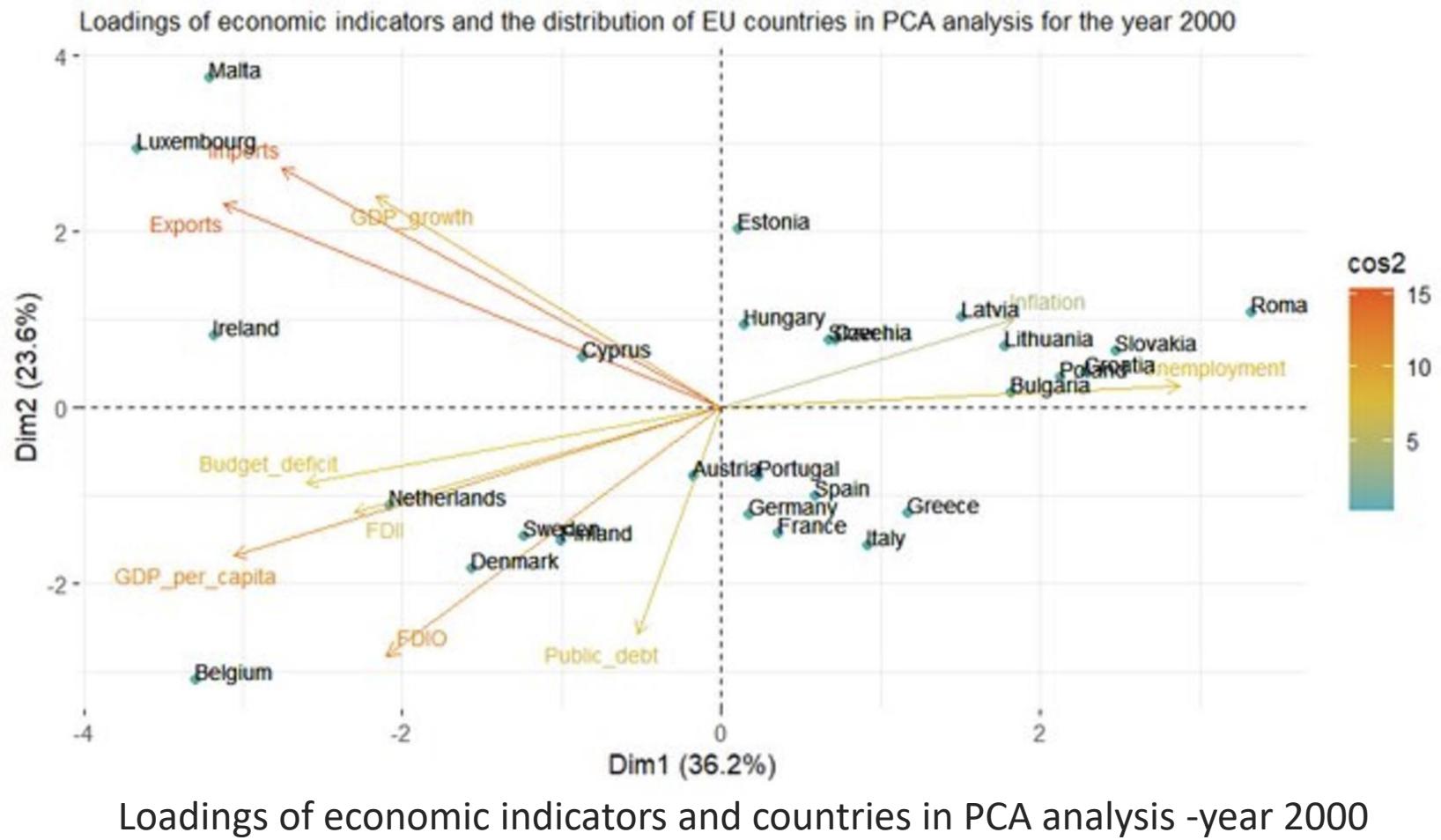
Moran's I and hot spot analysis



Map created by Ophelia Sin

2008 and 2016 Presidential Election Results with red areas reflect strong Republican party wins and blue areas reflect strong Democratic Party wins

Unsupervised learning: Dimension reduction PCA analysis



Supervised learning: regression and classification

Supervised Learning

- **Two tasks :**

- Classification: output is **categorical**
 - Spam email or not
 - With a table or not
- Regression: output is **numeric**
 - Housing price

Logistic Regression is here!!!

Linear Regression is here!!!



Machine Learning vs. Statistics

$$DTUP = \beta_0 + \beta_1 SDIST + \beta_2 FAREA + \beta_3 BED + \beta_4 BATH + \varepsilon$$

Machine learning cares about prediction

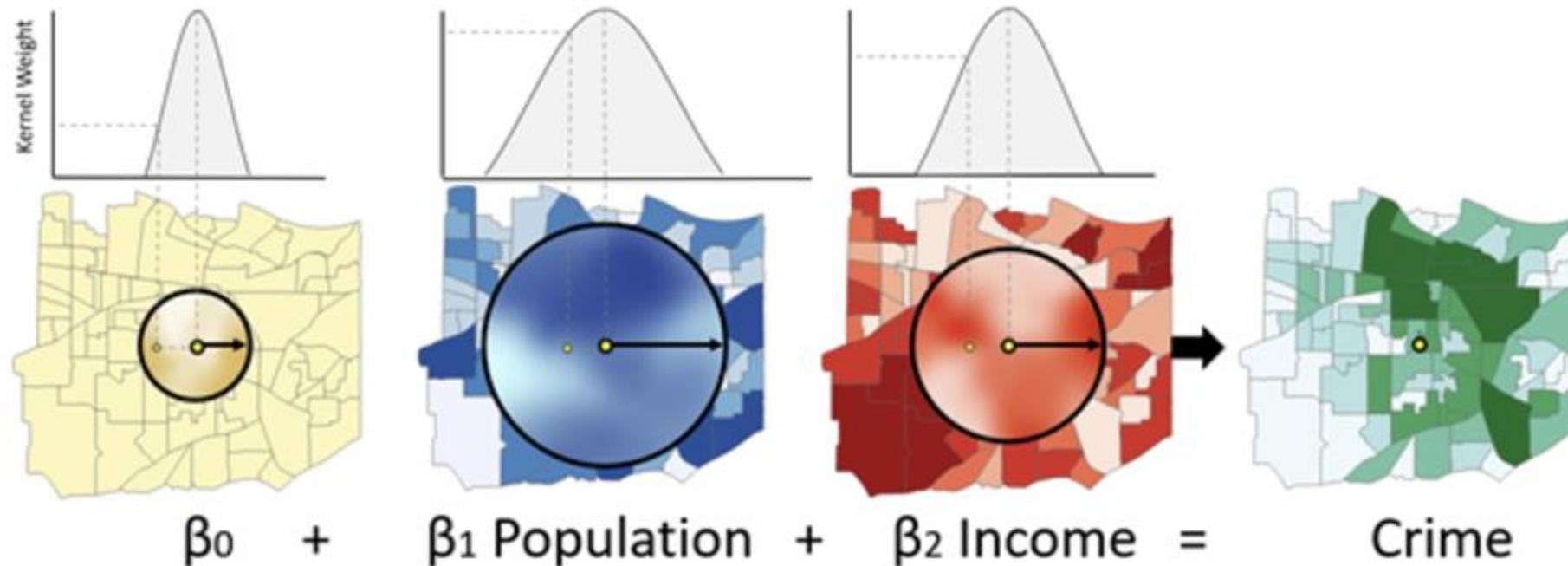
- field of predictive modeling
- concerned with minimizing the prediction error or making the most accurate predictions
- borrow algorithms from statistics for prediction purposes

Statistics cares about estimation and inference

- field of statistical modeling
- understanding the relationship between variables
- many models/algorithms have been borrowed by machine learning.



Regression – Geographical weighted regression



A bisquare kernel is applied to the neighborhood of each explanatory variable. Each explanatory variable uses a different bandwidth to capture varying spatial relationships.

GeoAI Toolbox

Text

Geoprocessing

Find Tools

Favorites Toolboxes

- GeoAI Tools
 - Feature and Tabular Analysis
 - Predict Using AutoML
 - Train Using AutoML
 - Imagery AI
 - Extract Features Using AI Models
 - Train Using AutoDL
 - Text Analysis
 - Classify Text Using Deep Learning
 - Extract Entities Using Deep Learning
 - Train Entity Recognition Model
 - Train Text Classification Model
 - Train Text Transformation Model
 - Transform Text Using Deep Learning
 - Time Series AI
 - Forecast Using Time Series Model
 - Train Time Series Forecasting Model
- GeoAnalytics Desktop Tools
- Geocoding Tools
- Geostatistical Analyst Tools
- Image Analyst Tools
- Indoor Positioning Tools

Catalog Symbology Geoprocessing

GeoAI Toolbox

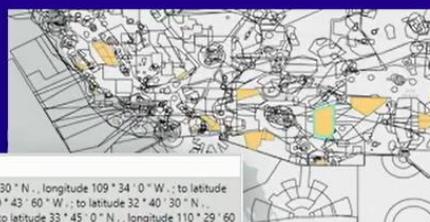
Text Classification



Entity Extraction Model



Text Transformation



Airspace	R-2103C
Boundary description	Beginning at latitude 32° 54' 30" N., longitude 109° 34' 0" W.; to latitude 32° 30' N., longitude 109° 43' 60" W.; to latitude 32° 40' 30" N., longitude 110° 29' 60" W.; to latitude 33° 00' 0" N., longitude 109° 34' 0" W.; to latitude 32° 54' 30" N., longitude 109° 34' 0" W.; to the point of beginning.
Geometry	[[- long (109, 34, 0), lat (32, 54, 29)], [- long (109, 43, 59), lat (32, 30, 0)], [- long (109, 29, 59), lat (32, 40, 30)], [- long (110, 29, 59), lat (33, 05, 0)], [- long (109, 34, 0), lat (34, 0, 0)], [- long (109, 34, 0), lat (32, 54, 29)],]

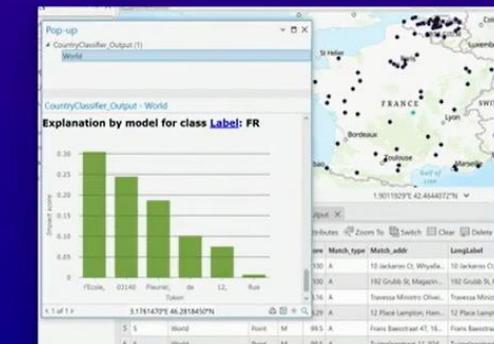
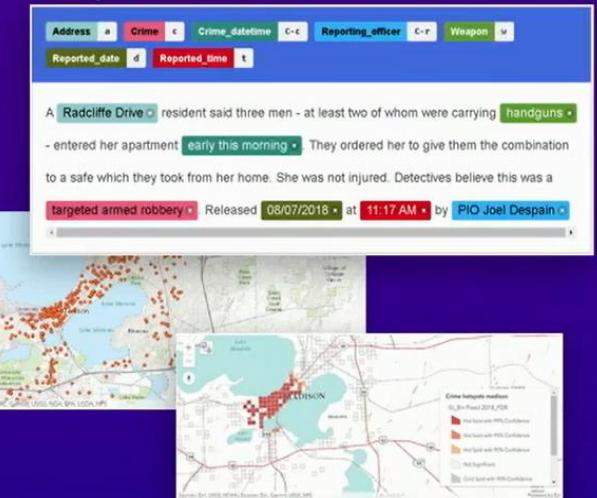
Address Standardization

new std_address	Result
1. 23, yemera crescent north east, medicine hat, ca	23, terrace crescent ne, medicine hat, ca
2. 83, cl private residence, 49574, es	8, cl private residence, 49574, es
3. 66, chemise de la cité, bossey, 69180, fr	66, chemise de la cité, bossey, 69180, fr
4. 132b, rue claus pasté, denain, 59260, fr	132b, rue claus pasté, denain, 59260, fr
5. 19, hofstraat, sandbergweg, 3100, at	19, hofstraat, sandbergweg, 3100, at
6. 14, mosheng, 49910, dk	14, mosheng, 49910, dk
7. 1, corrid clt et 20, 8000, dk	1, avond-clt et 20, 8000, dk
8. cl quipavil, 21000, es	10, cl quipavil, 21000, es
9. 26, cl patentes, 4100, es	26, cl patentes, 4100, es
10. campbellstrand, bondi beach, au	campbell strand, bondi beach, au
11. fa, avenue du moulle silvain, varengeve, 51810, fr	fa, avenue du moulle silvain, varengeve, 51810, fr
12. cl, gigan carlos, 31620, es	66, cl gigan carlos, 31620, es
13. ag apimentas, 21400, es	7a, ag apimentas, 21400, es

Text AI tools

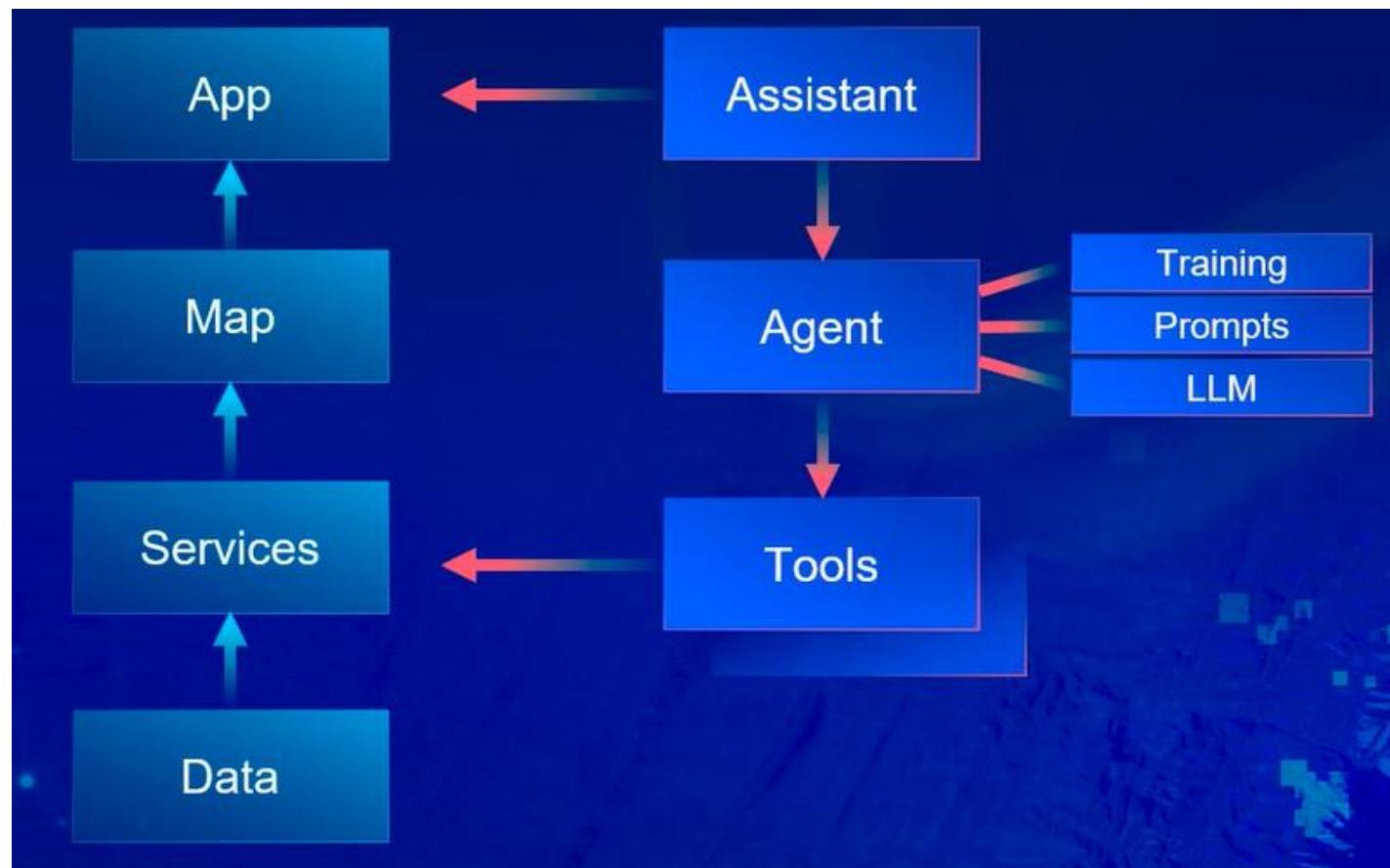
- Extract Entities tool
- Classify Text tool
- Transform Text tool

Entity Extraction



Model Explainability*

Example: DC compass AI (AI assistants integrate with GIS and open data portal)



https://mediaspace.esri.com/media/t/1_opret32t/

DC Compass AI Assistant (beta)

Chat

AI responses may be incorrect. Please provide feedback to help us improve.

how many trees are in the city

There are approximately 210,368 public trees in Washington, DC. You can find more information about the trees in the city in the [Urban Forestry Street Trees dataset](#).

AI responses may be incorrect. Please provide feedback to help us improve.

make me a map of trees at the convention center

Here is a map showing the location of trees near the Convention Center in Washington, DC:

AI responses may be incorrect. Please provide feedback to help us improve.

Map

Find address or place

McPherson Sq Metro Station, CenterDC, Treasury, United States Treasury Department, World War Memorial, Warner, Ford Theatre, Chinatown, etc.

Table

Urban Forestry Street Trees - UFA Street Trees (Total: 210,368 | Selection: 0)

Scientific Name	Common Name	Genus Name	Family
Ulmus americana	American elm	Ulmus	Ulmaceae
Ulmus americana	American elm	Ulmus	Ulmaceae
Ulmus americana 'Valley F...	Valley Forge elm	Ulmus	Ulmaceae
Acer saccharum	Sugar maple	Acer	Sapindaceae
Quercus lyrata	Overcup oak	Quercus	Fagaceae
Platanus ×	London plane tree	Platanus	Platanaceae

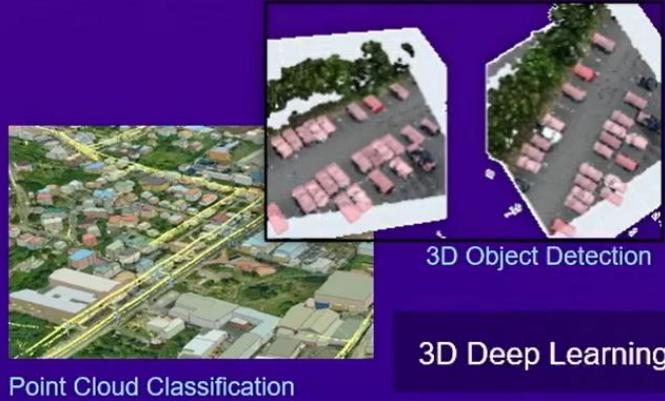
The AI Assistant with prompts (questions and requests) in blue. The AI is accessing the data in the designated ArcGIS Hub site.

<https://opendata.dc.gov/>

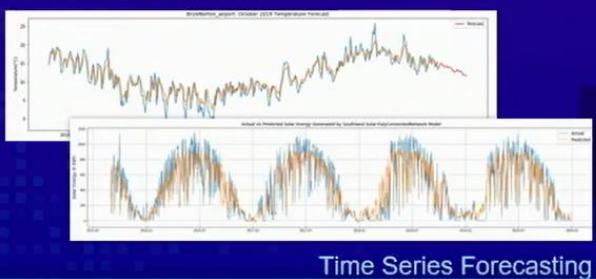
The `arcgis.learn` module (Python API)

New & Improved

- Open source integration
- Transformers support
- Model explainability

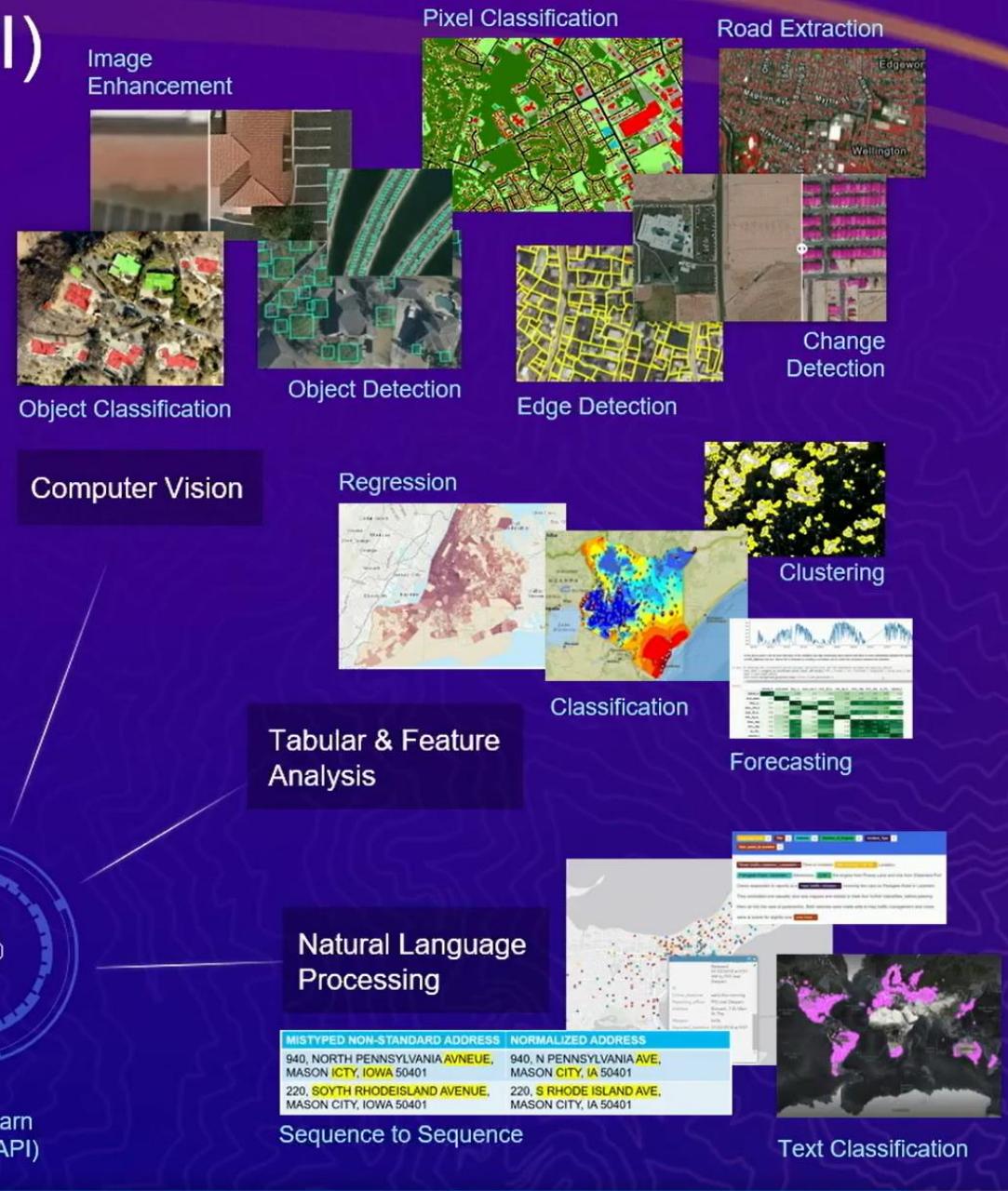


Video Tracking

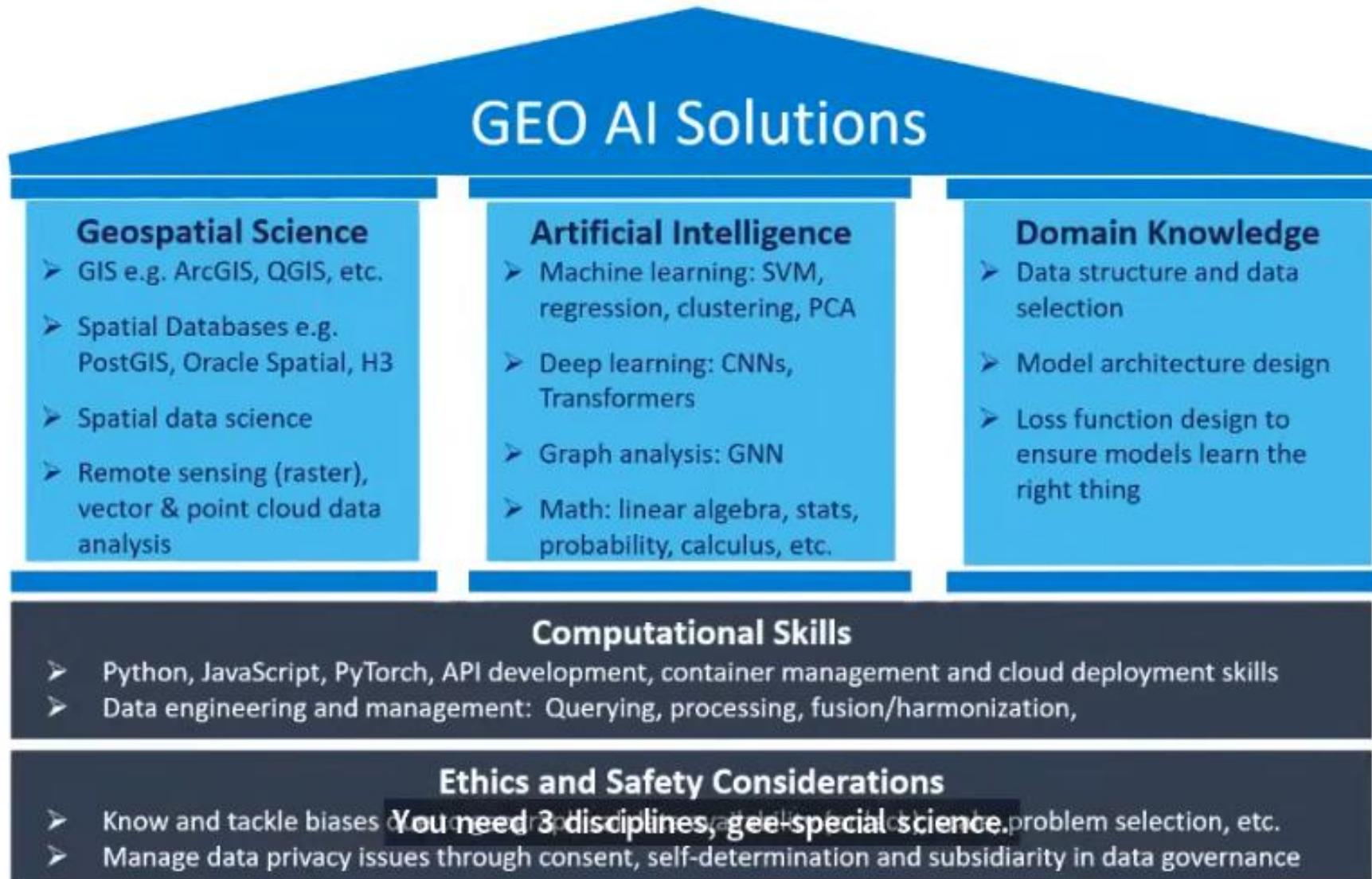


Time Series Analysis

`arcgis.learn`
(Python API)

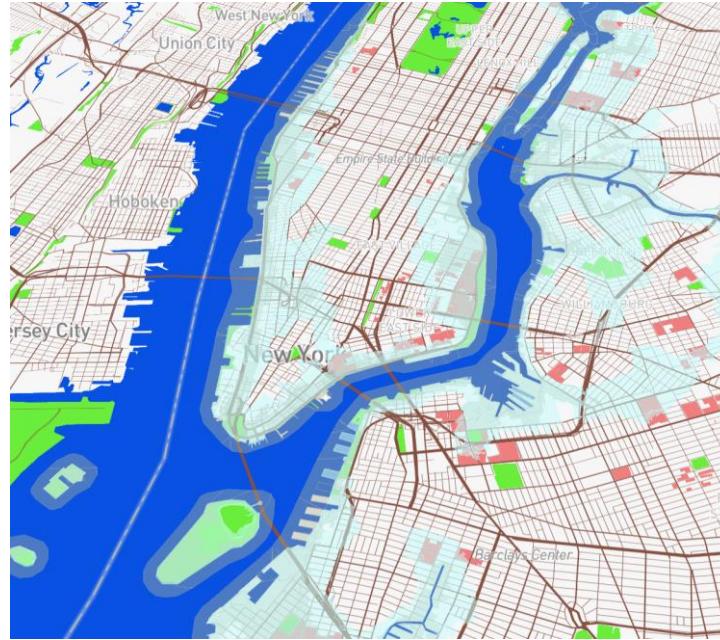
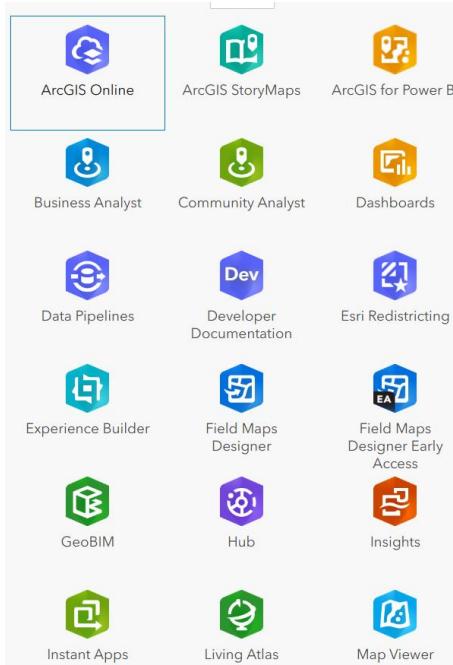


Skills and Competencies Requirement

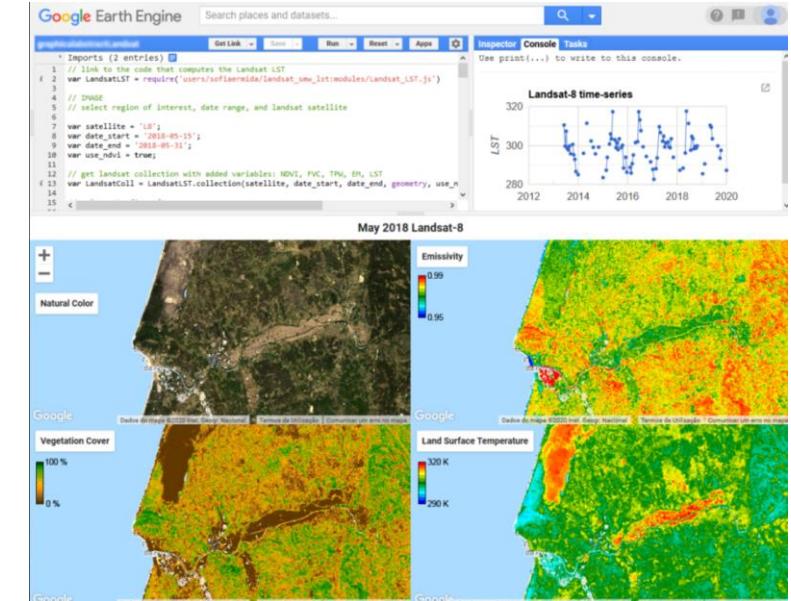


Cloud-Based GIS Solutions: Transforming Geospatial Workflows

- **Cloud-Based GIS:** GIS platforms hosted on cloud infrastructure. Users can access, analyze, share, and present geospatial data without relying on local hardware
- **Key benefits:** scalability, collaboration, and integration with other cloud services.
- **Leading Platforms:**
 - ArcGIS Online

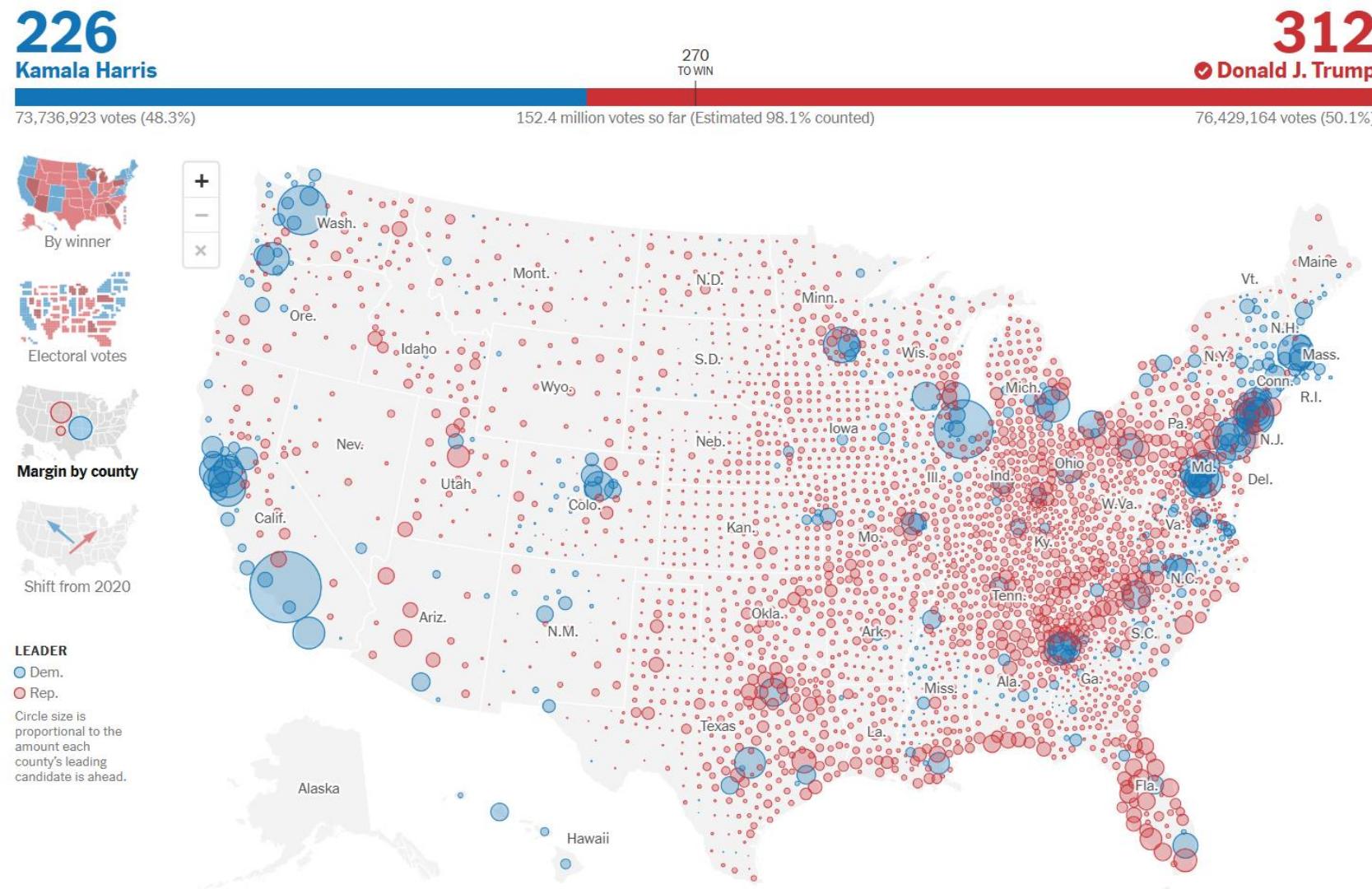


Mapbox



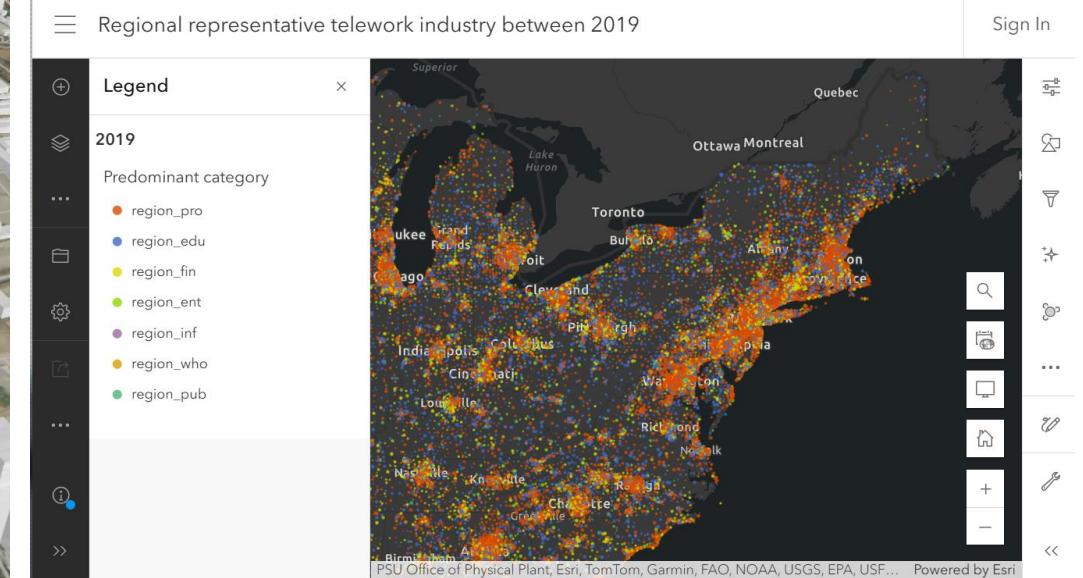
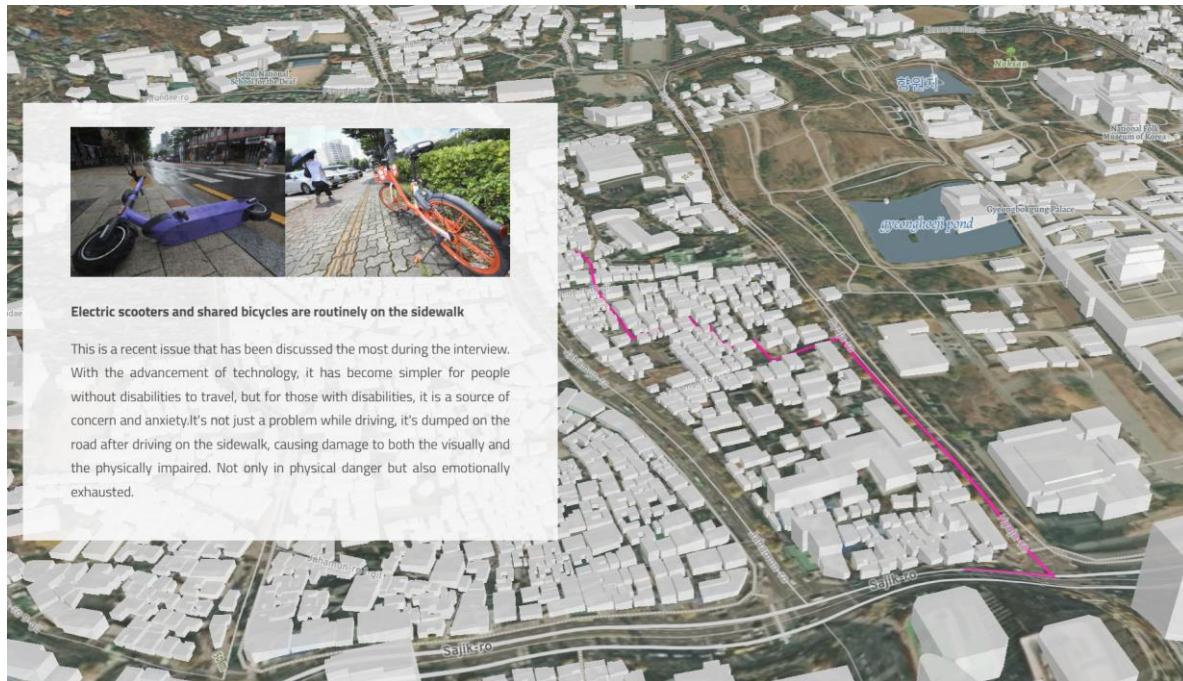
Google Earth Engine

- Some examples: [Presidential Election Results](#) (New York Times)



Mapbox and ArcGIS storytelling map

- Revealing the invisible challenges of pedestrians with disability. Focusing on Seoul, the Republic of Korea: <https://yk539.github.io/countermapping-webmaps/Project/index.html>



- Industry Structure in Telecommuting and Income Inequality-A Regional Perspective Study: <https://www.houpuli.com/wfh-industry-structure-and-income-inequalityLinks to an external site.>

Resources:

- ESRI video: https://mediaspace.esri.com/media/t/1_d3I2ir80?co3=true
- GeoAI: Machine Learning & Deep Learning with GIS
<https://storymaps.arcgis.com/stories/e9a337fafc5d4ad79e3f5fa8c55a54c9>
- What is GeoAI? [https://www.esri.com/en-us/capabilities/geoai/overview#:~:text=Geospatial%20artificial%20intelligence%20\(GeoAI\)%20is,environmental%20impacts%2C%20and%20operational%20risks.](https://www.esri.com/en-us/capabilities/geoai/overview#:~:text=Geospatial%20artificial%20intelligence%20(GeoAI)%20is,environmental%20impacts%2C%20and%20operational%20risks.)

GeoAI Toolbox

Imagery

Train using AutoDL

- Simplifies model training
- Determine model network and backbone

Extract multifeature

- Optimizes workflows
- Extracts multiple features in one go



Imagery & Remote Sensing

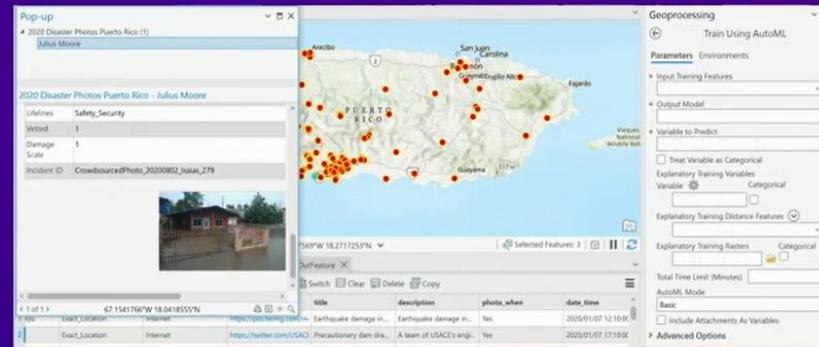
- GeoAI Tools
 - Feature and Tabular Analysis
 - Predict Using AutoML
 - Train Using AutoML
 - Imagery AI
 - Extract Features Using AI Models
 - Train Using AutoDL
 - Text Analysis
 - Classify Text Using Deep Learning
 - Extract Entities Using Deep Learning
 - Train Entity Recognition Model
 - Train Text Classification Model
 - Train Text Transformation Model
 - Transform Text Using Deep Learning
 - Time Series AI
 - Forecast Using Time Series Model
 - Train Time Series Forecasting Model

GeoAI Toolbox

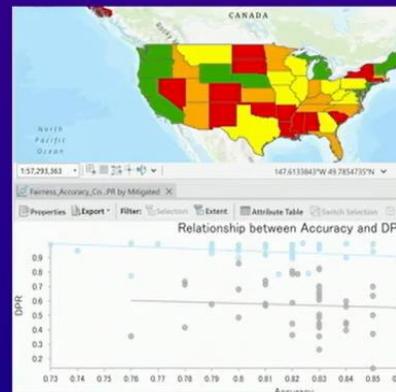
Vector/Tabular, & TimeSeries Forecasting

GeoAI Tools

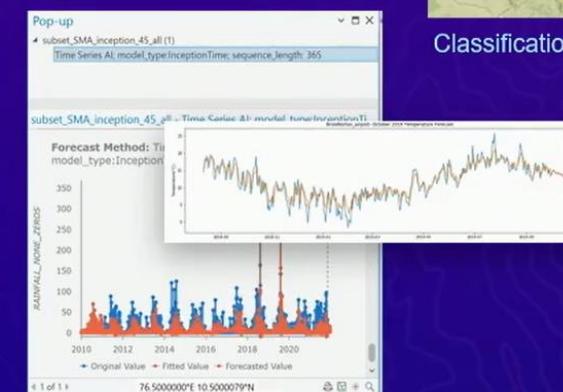
- AutoML - Automated Machine Learning
- Time Series Forecasting



AutoML



Bias Mitigation*



Time Series Forecasting



Prediction

GeoAI Toolbox