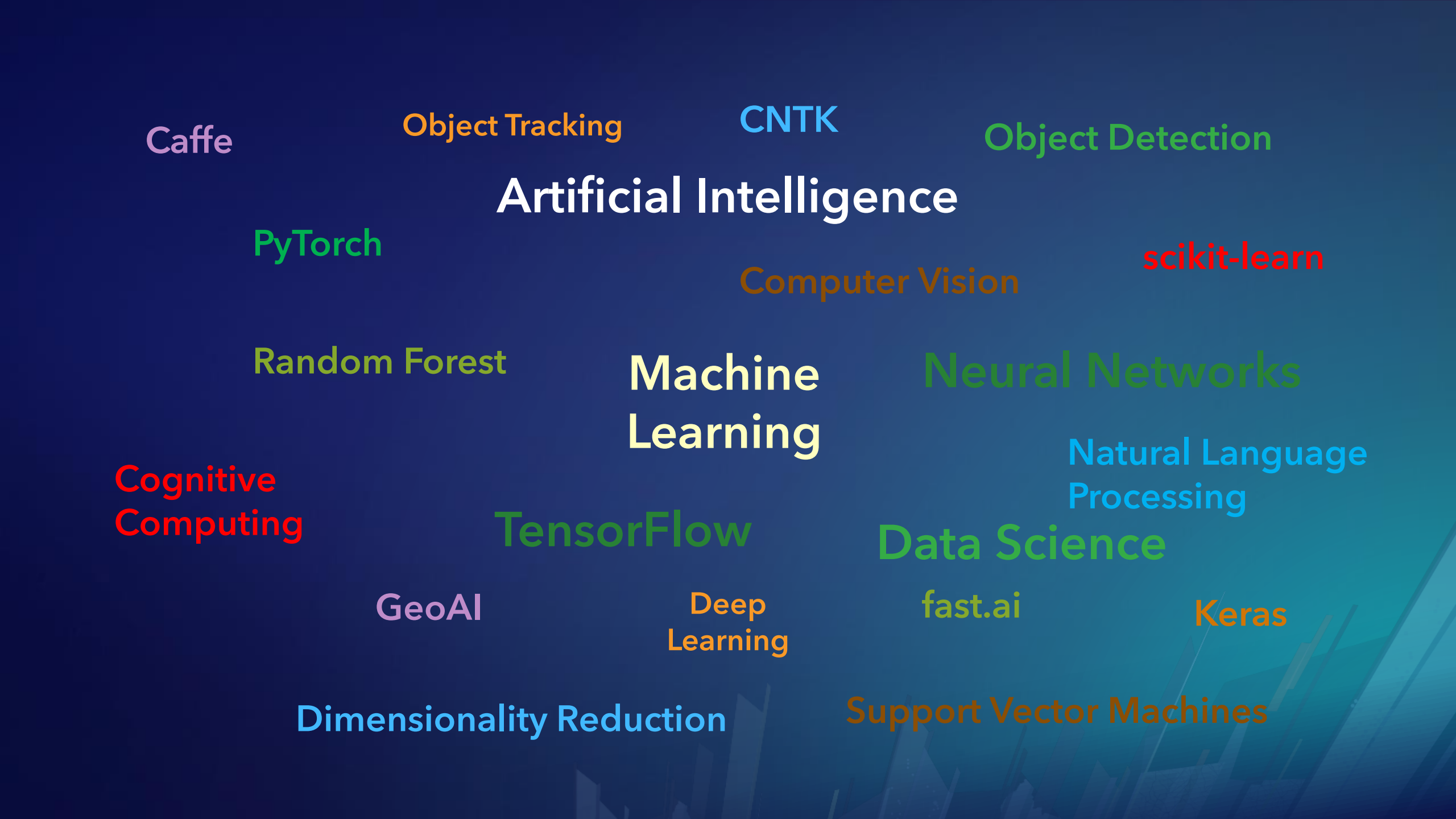
Deep Learning with ArcGIS

Rohit Singh
Sandeep Kumar

SEE WHAT OTHERS CAN'T

Session Overview

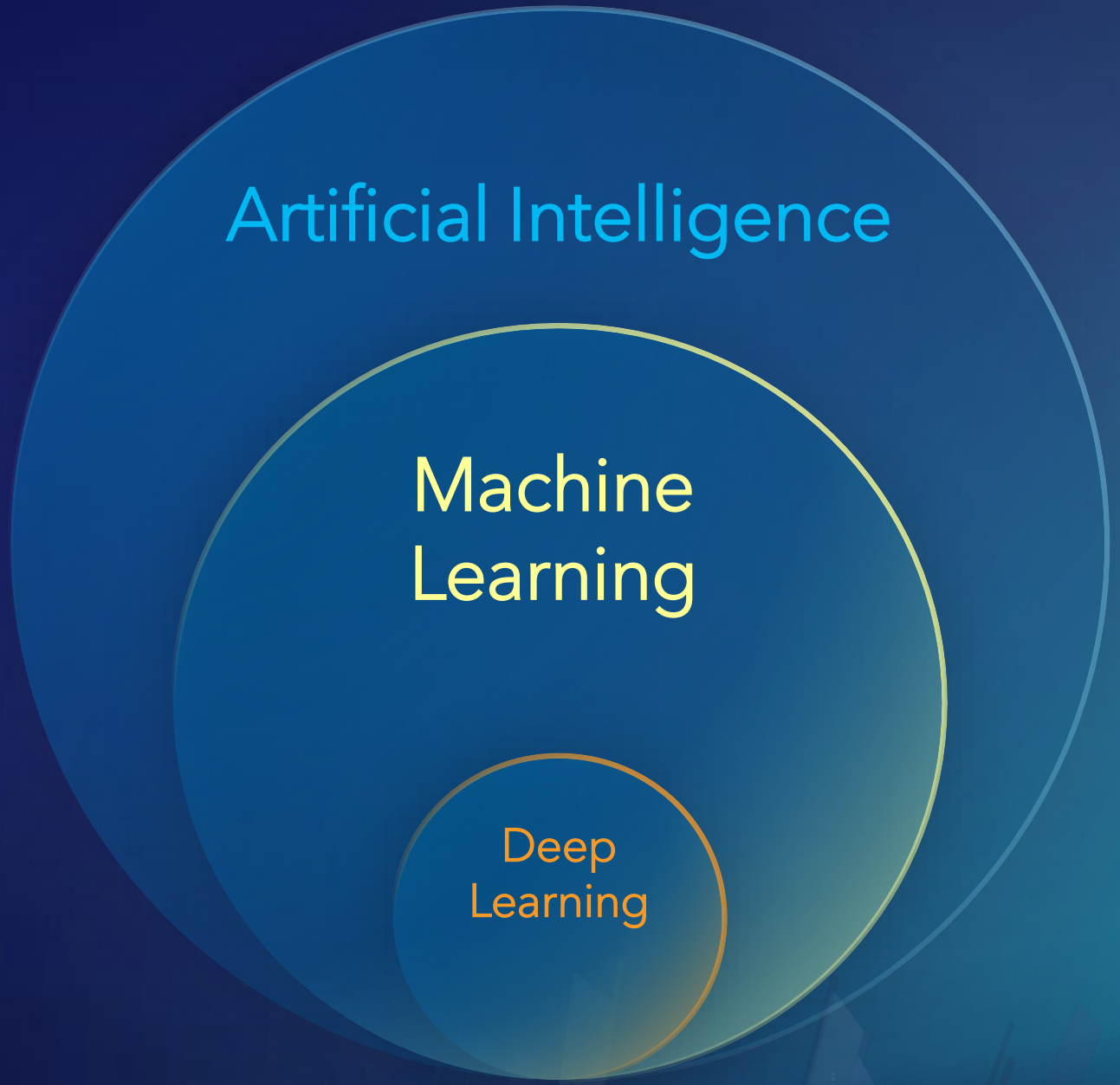
- AI, Machine Learning & Deep Learning
- Deep Learning Workflow
- Training Models
- Types of models and their applications
- Scalable deep learning with Image Server


Caffe
Object Tracking
CNTK
Object Detection
Artificial Intelligence
PyTorch
scikit-learn
Computer Vision
Random Forest
Machine Learning
Neural Networks
Natural Language Processing
Cognitive Computing
TensorFlow
Data Science
GeoAI
Deep Learning
fast.ai
Keras
Dimensionality Reduction
Support Vector Machines

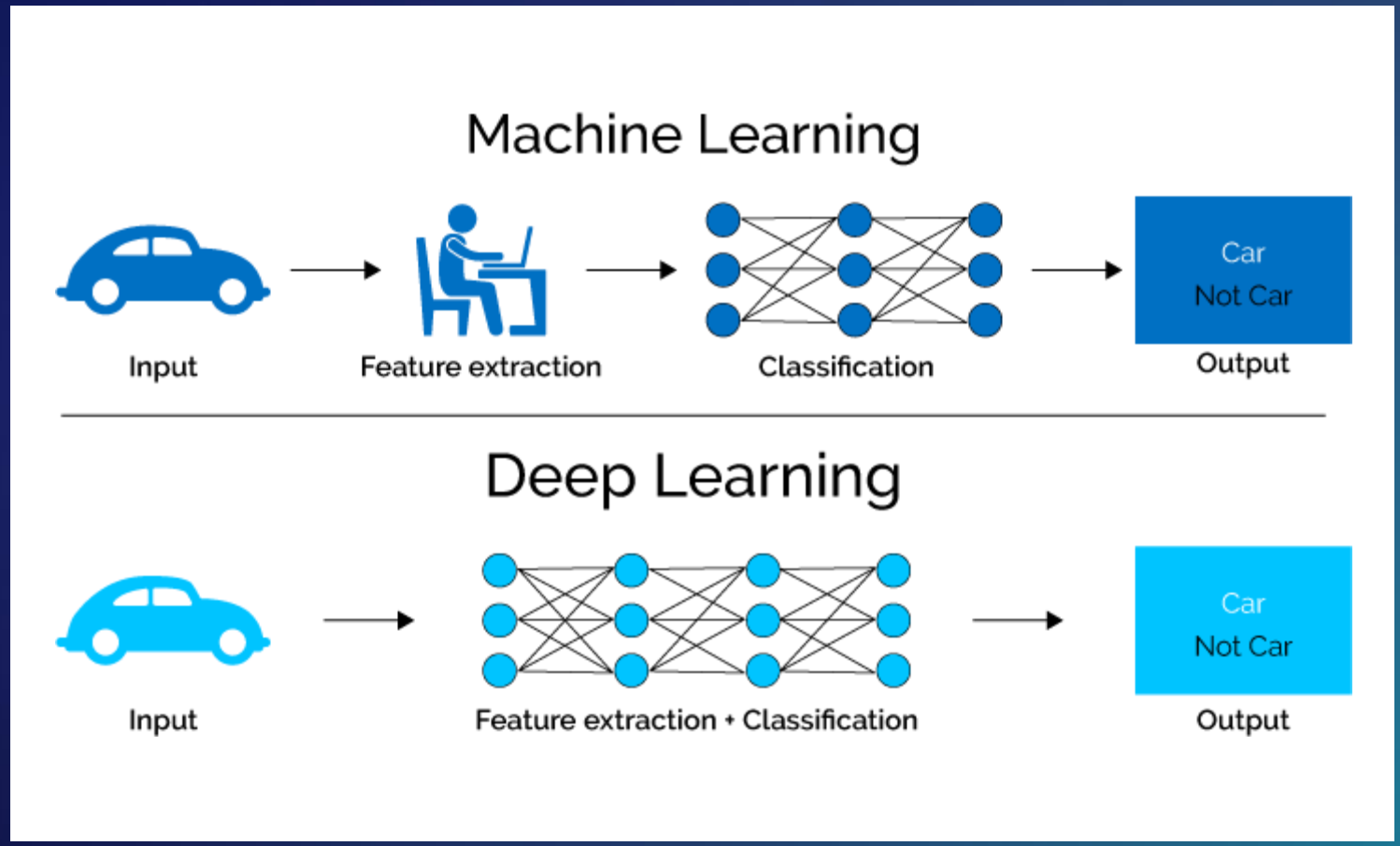
Artificial Intelligence

Machine Learning

Deep Learning


Artificial Intelligence
Machine Learning
Deep Learning

Contrasting Machine Learning with Deep Learning



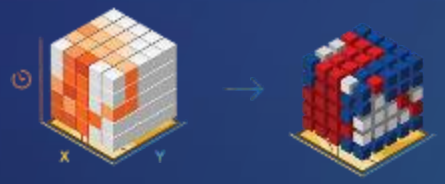
Machine Learning in ArcGIS

Classification

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

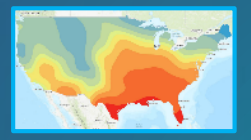
Clustering

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



Prediction

- Empirical Bayesian Kriging
- Areal Interpolation
- EBK Regression Prediction
- Ordinary Least Squares Regression and Exploratory Regression
- Geographically Weighted Regression



Deep Learning in ArcGIS

Data Preparation

- Label Objects
- Training Samples Manager
- Export Training Samples

Training

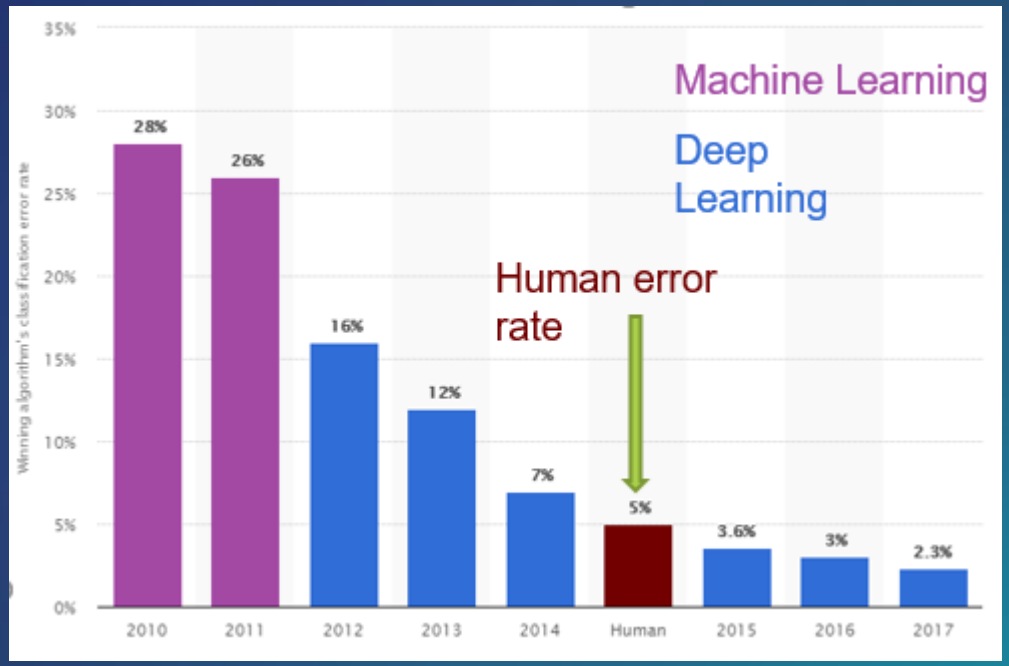
- arcgis.learn module (ArcGIS API for Python)
- Train Deep Learning Model (Pro 2.5)

Inferencing

- Detect Objects
- Classify Pixels
- Classify Objects
- Non Maximum Suppression

Why use Deep Learning for Imagery

Computer vision is now almost as good, if not better, than human vision



ImageNet Visual Recognition Challenge error rate

Applications of Deep Learning to GIS

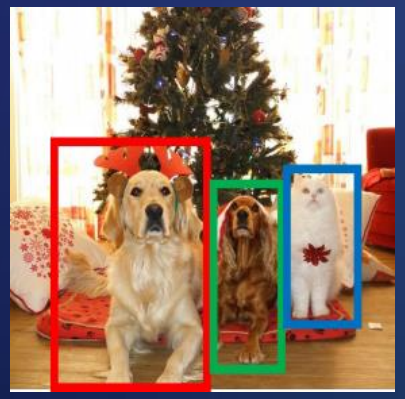
Impervious Surface Classification

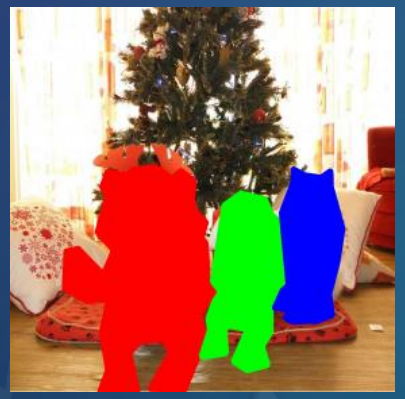
Coconut Tree Detection

Building Footprint Extraction

Damaged House Classification

End to End Deep Learning – Wide spectrum of deep learning models





Pixel Classification

Object Detection

Instance Segmentation

Image Classification

Deep Learning with Imagery in ArcGIS

ArcGIS supports end-to-end deep learning workflows

- Tools and APIs for:
  - Labeling training samples
  - Preparing data to train models
  - Training Models
  - Running Inferencing
- Supports the key imagery deep learning categories
- Supported environments
  - ArcGIS Pro
  - Map Viewer
  - ArcGIS Notebooks/Jupyter Notebook

Part of ArcGIS Image Analyst

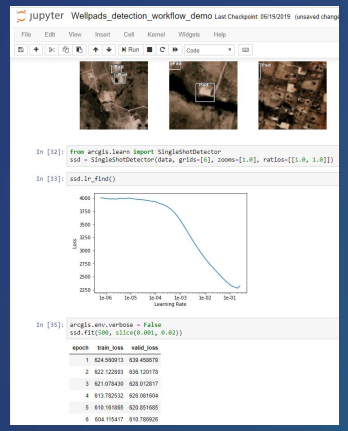
Run distributed on ArcGIS Image Server

Deep Learning Workflow in ArcGIS

Label
Training Samples

Prepare data for training

Train Deep
Learning Model

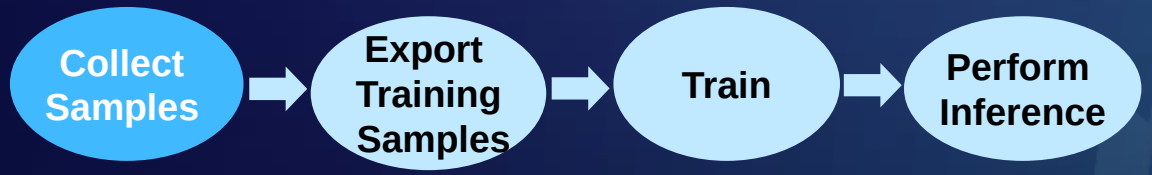


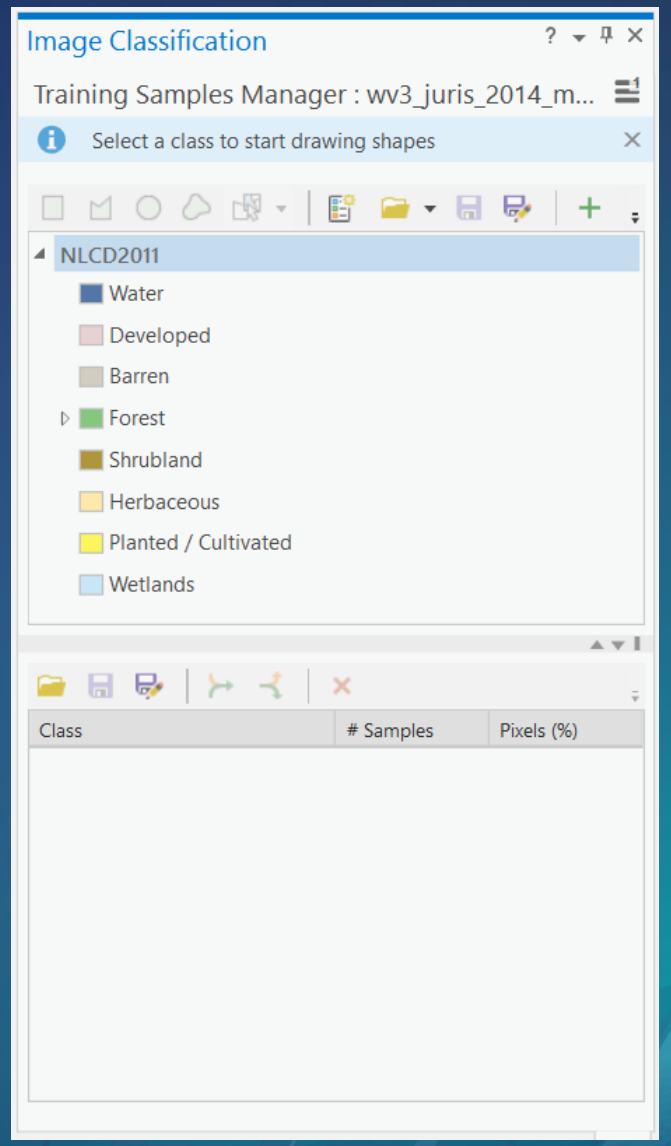
Inference

Collect Samples → Export Training Samples → Train → Perform Inference

Collect Training Samples / Label data

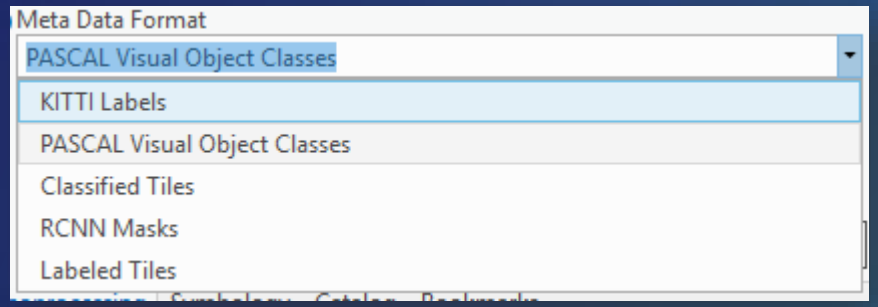
- Different methods
  - Training sample manager – ArcGIS Pro
  - Feature editing
    - ArcGIS Pro
    - Map Viewer
    - JS Web Apps
- Different data models
  - Feature class (local single user)
  - Feature services (collaborative experience)
  - Classified thematic rasters



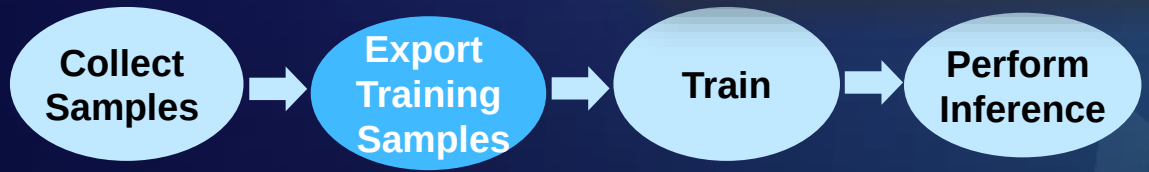


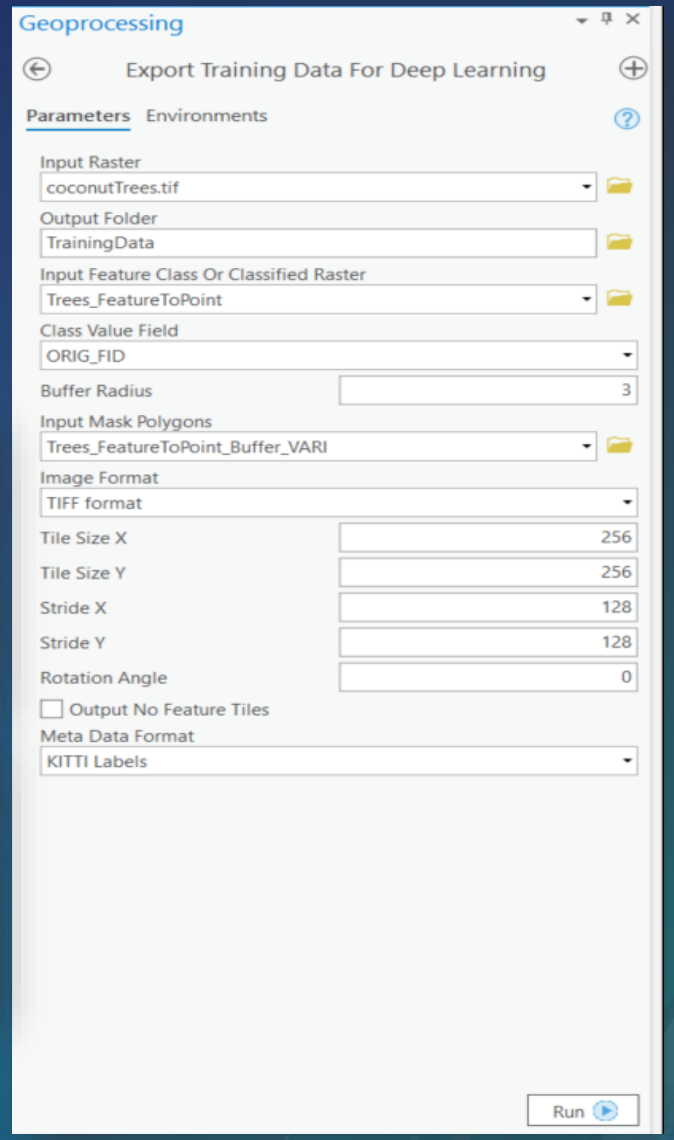
Export Training Data for Deep Learning

- Exports samples to training images
- Images have associated labels/metadata
- Used as inputs for model training
- Supports various formats



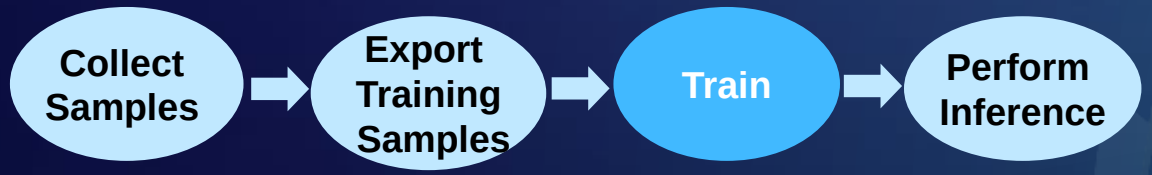

```
#Export training data
chips = export_training_data(sentinel_data,
                             well_pads,
                             "PNG", {"x":448,"y":448},
                             {"x":224,"y":224},
                             "PASCAL_VOC_rectangles", 75,
                             "well_pads")
```

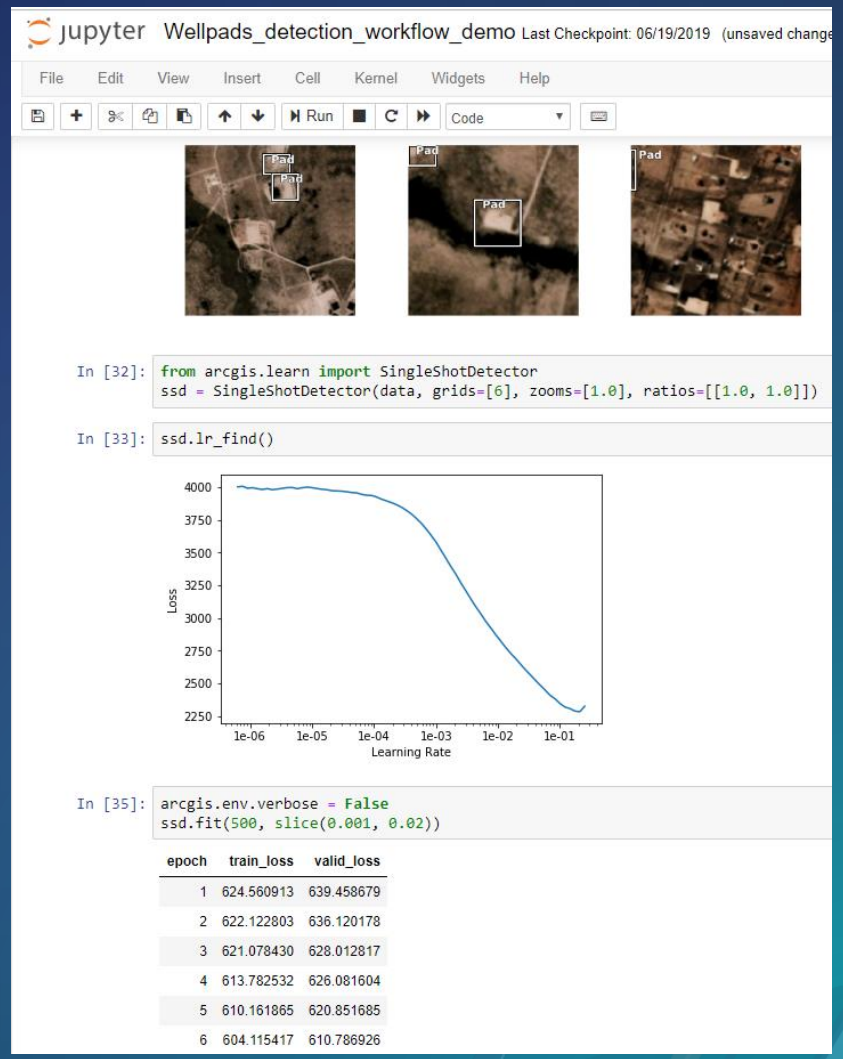




Train Deep Learning Model

- ArcGIS API for Python supports training
- arcgis.learn module in ArcGIS API for Python
- Supported Models:
  - Object Detection - SSD, RetinaNet, MaskRCNN
  - Object Classification – Feature classifier
  - Pixel Classification – UNET, PSPNet
- External Deep Learning Frameworks
  - TensorFlow
  - CNTK…

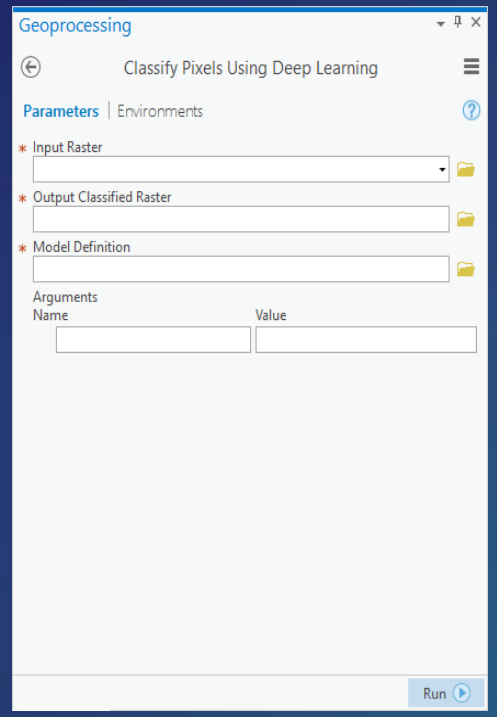


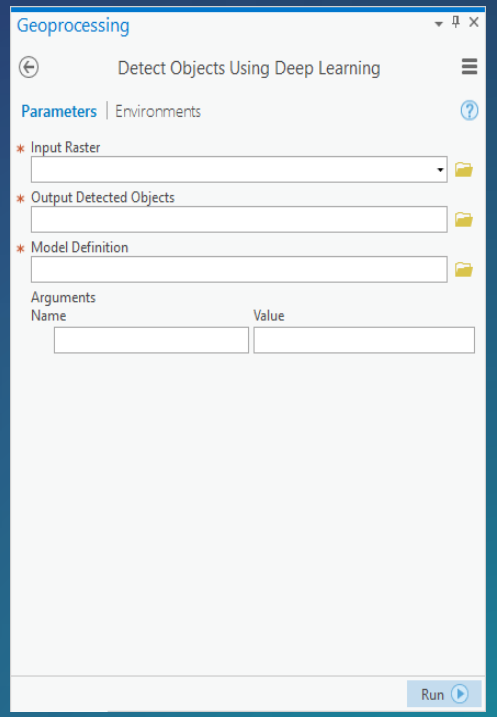


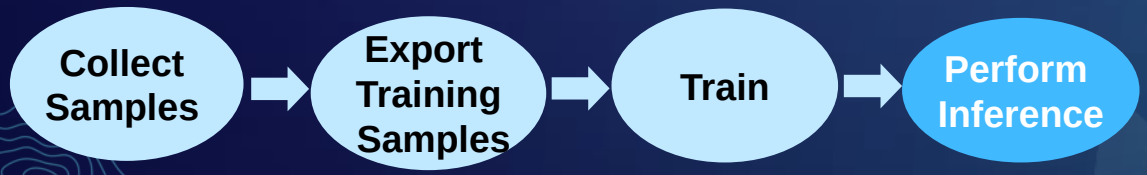
epoch	train_loss	valid_loss
1	624.560913	639.458679
2	622.122803	636.120178
3	621.078430	628.012817
4	613.782532	626.081604
5	610.161865	620.851685
6	604.115417	610.786926

Perform Inference

- Run on desktop and enterprise
- Parallel processing using enterprise
- Types of inferencing
  - Object detection
  - Pixel classification



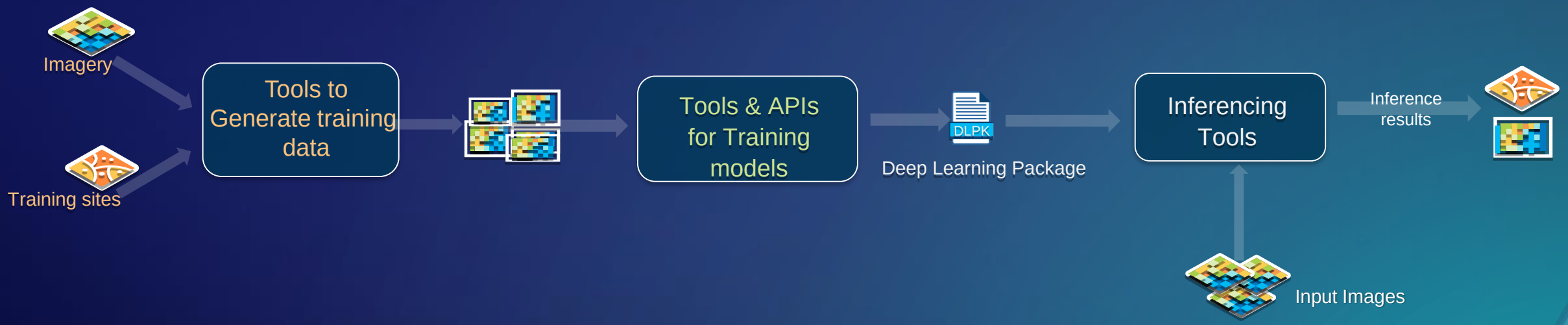





```
detect_objects(input_raster=input_layer,
               model=detect_objects_model,
               output_name="Well_Pad_Detection_Sentinel",
               context=context,
               gis=gis)
```

ArcGIS – Deep Learning Workflow

End-to-end deep learning workflow



Tools to generate training samples

- Image Analyst in ArcGIS Pro
- Image Server on ArcGIS Enterprise

Model Training

- Notebooks

Inferencing

- Image Analyst in ArcGIS Pro
- Image Server on ArcGIS Enterprise

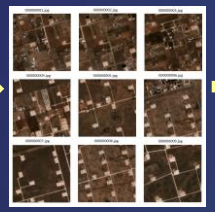
Deep Learning Workflow in ArcGIS

End-to-end from raw imagery to structured information products

Image Management

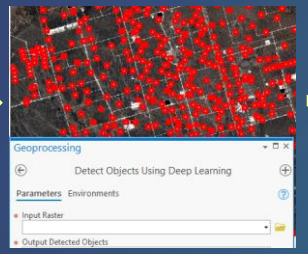
Labelling

Data Prep

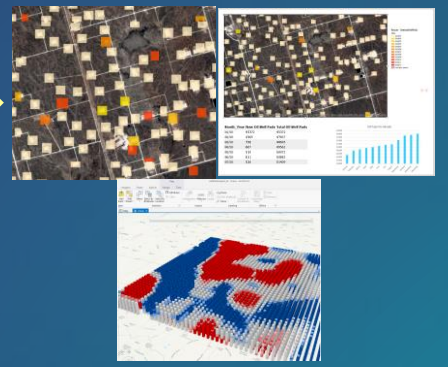


Train Model

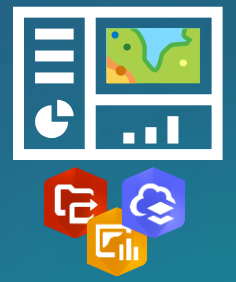
Inferencing



Analysis



Field Mobility, Monitoring

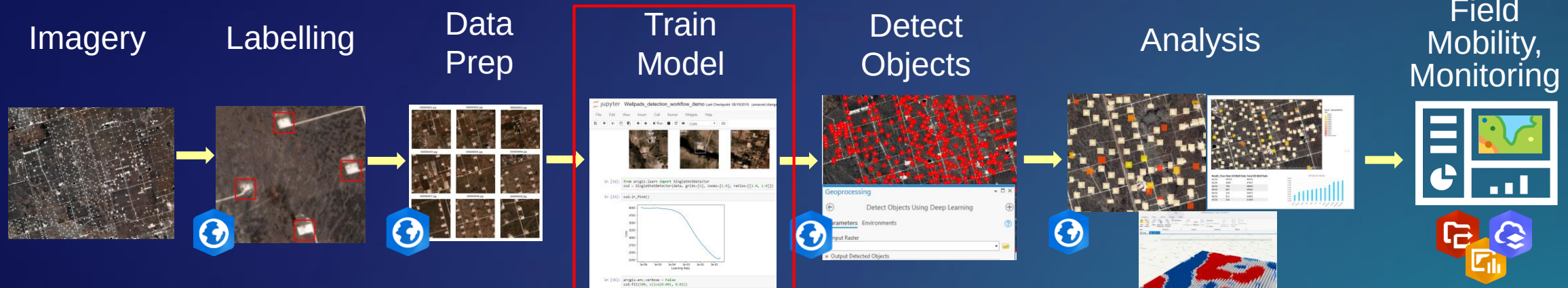


ArcGIS being used for each step of the deep learning workflow

Training Deep Learning Models

ArcGIS Deep Learning Workflow

End-to-end from raw imagery to structured information products



Tensorflow, PyTorch, CNTK…

- Installing External DL Frameworks
- Dozens of lines of Code
- HARD!

arcgis.learn

- No Installation (Notebooks)
- 3-5 lines
- EASY

Train SingleShotDetector Model

```
from arcgis.learn import SingleShotDetector

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

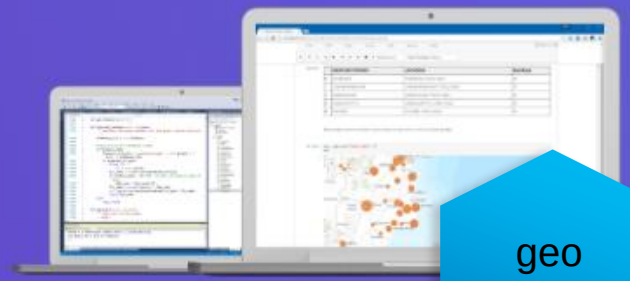
```
ssd.fit(10, lr=slice(1e-3, 1e-2))
```

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.

ArcGIS API for Python

arcgis.learn module

The `arcgis.learn` module in **ArcGIS API for Python** enables Python developers and data scientists to **easily train and use deep learning models with a simple, intuitive API.**

Train Models

Before

- Dozens of lines of Code
- Installing External DL Frameworks
- HARD!

After

- 3-5 lines
- No Installation (ArcGIS Pro & Notebooks)
- EASY

Train SingleShotDetector Model

```
from arcgis.learn import SingleShotDetector

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

```
ssd.fit(10, lr=slice(1e-3, 1e-2))
```

ArcGIS API for Python

Not just “training”!

Data Preparation

- arcgis.learn.export_training_data
- arcgis.learn.prepare_data

Training DL Models

- arcgis.learn.SingleShotDetector
- arcgis.learn.UnetClassifier
- arcgis.learn.FeatureClassifier
- arcgis.learn.PSPNetClassifier
- arcgis.learn.RetinaNet
- arcgis.learn.MaskRCNN
- arcgis.learn.Deeplab
- arcgis.learn.EntityExtractor

Model Management

- arcgis.learn.list_models
- arcgis.learn.Model
  - Model.install
  - Model.uninstall
  - Model.query_info

Inference APIs

- arcgis.learn.detect_objects
- arcgis.learn.classify_pixels
- arcgis.learn.classify_objects

Advantages of arcgis.learn

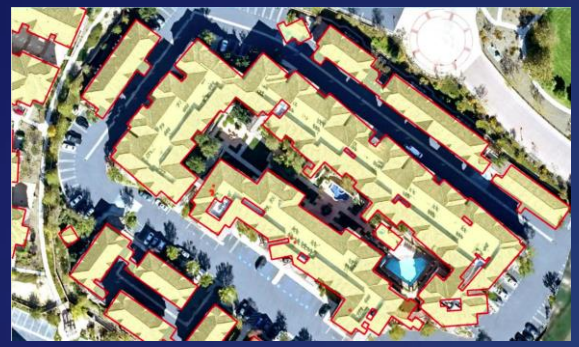
- Closely integrated with ArcGIS
  - Directly consumes exported training data from ArcGIS (no custom preprocessing)
  - Saved models (DLPKs) are directly usable in ArcGIS
    - No custom postprocessing of model output
    - Image space to map space conversion automatically handled
  - Preserves symbology
- Consistent API (prepare_data(), fit(), save() to train model, show_batch/show_results to visualize)
- Performs data augmentations suitable for satellite imagery
- Extensible using fast.ai transforms, custom loss functions, model backbones
- Fast.ai goodies: Automatic learning rate finder, transfer learning, early stopping, checkpointing, one-cycle learning
- Model metrics, sample results and training details are stored along with the model
- Padding support, multi-gpu training, CPU/GPU support, predict on videos, multispectral imagery*…

Things you can do today with arcgis.learn

Object Detection, Pixel Classification, Feature Classification, Instance Segmentation

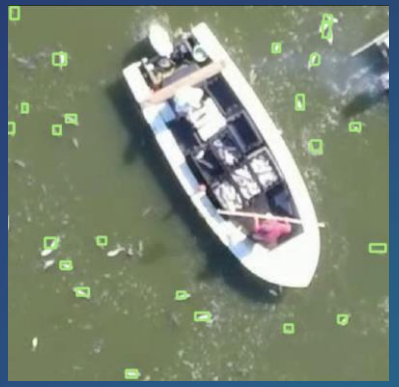
Damaged Structures

Building Footprints



Land Cover

Catfish



Brick Kilns

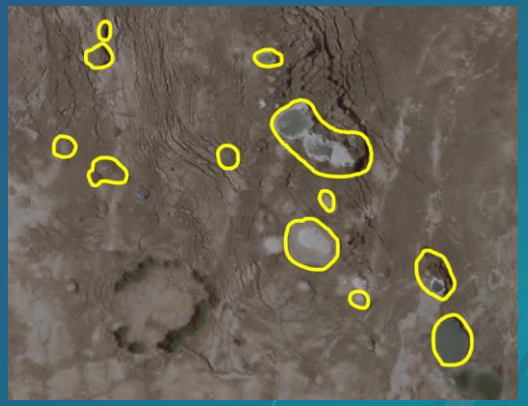
Swimming Pools

Oil Pads

Palm trees

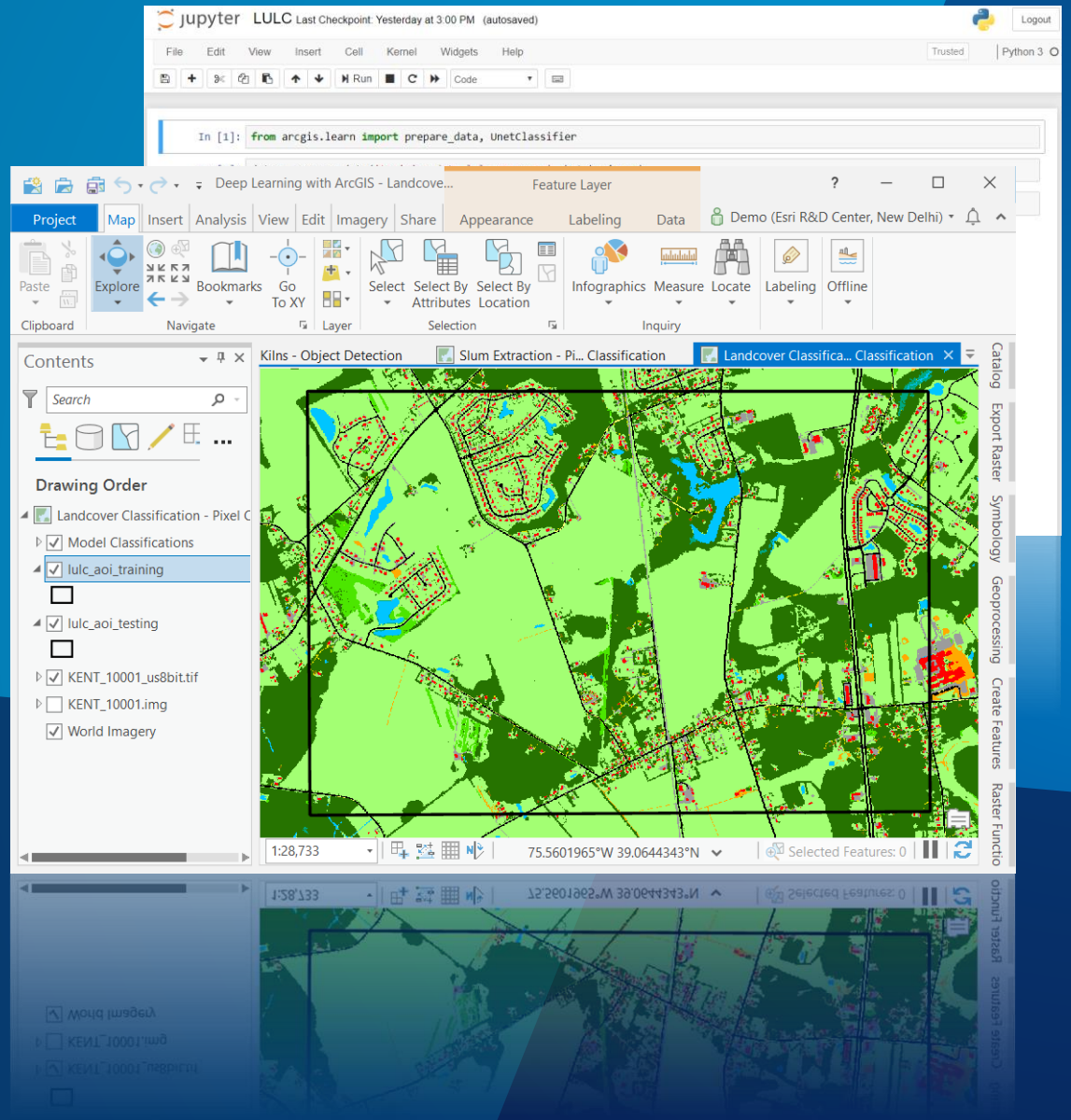
Refugee Camps

Sinkholes



Training Model using arcgis.learn

Rohit



Demo

Landcover Classification

ArcGIS Pro, Jupyter Notebook

Types of Deep Learning Models & their applications in GIS

Image Classification

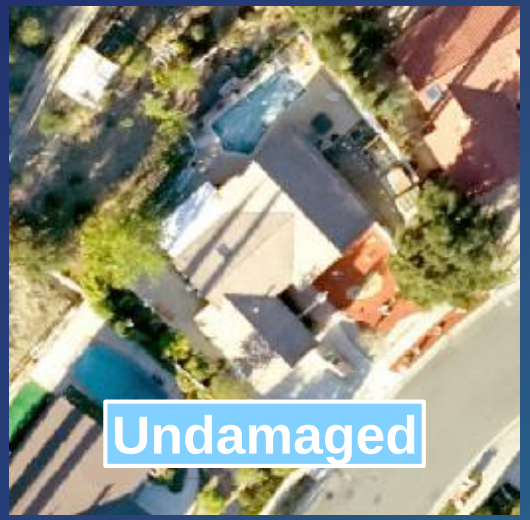
Assign a label to a given image

Models (from torchvision):

- Inception
- ResNet
- VGG…

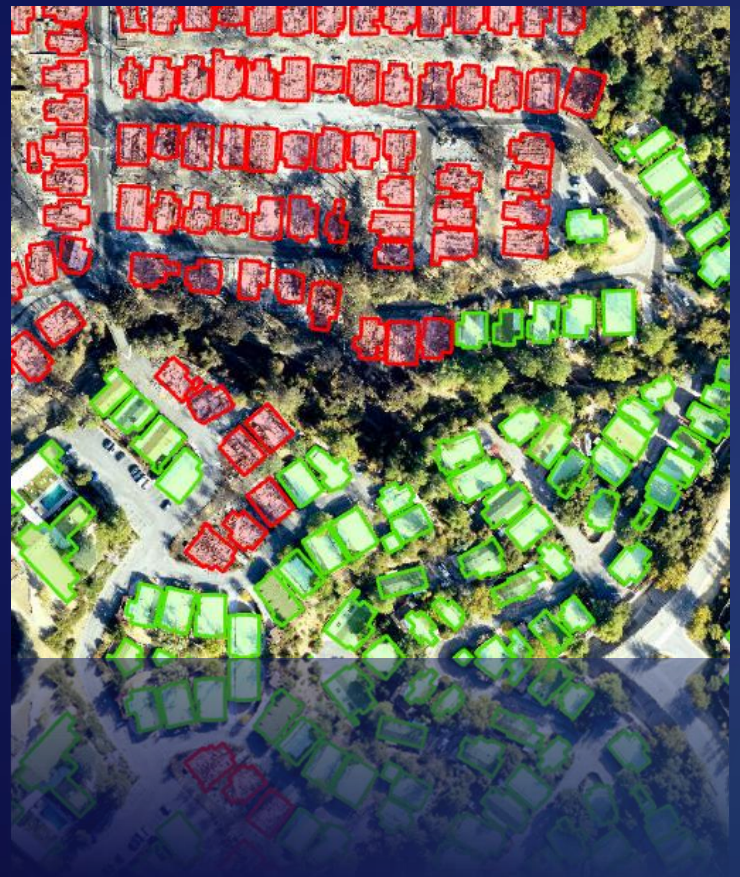
Object Classification

Assign a label to a given feature



Applications:

- Damaged building classification
- Clean or ‘green’ pools…



Demo

Damage classification using ArcGIS Pro

Vinay

Semantic Segmentation

Assign a label to each pixel

Cat

Ground

Sky

Models:

- UNetClassifier
- PSPNetClassifier

Pixel Classification

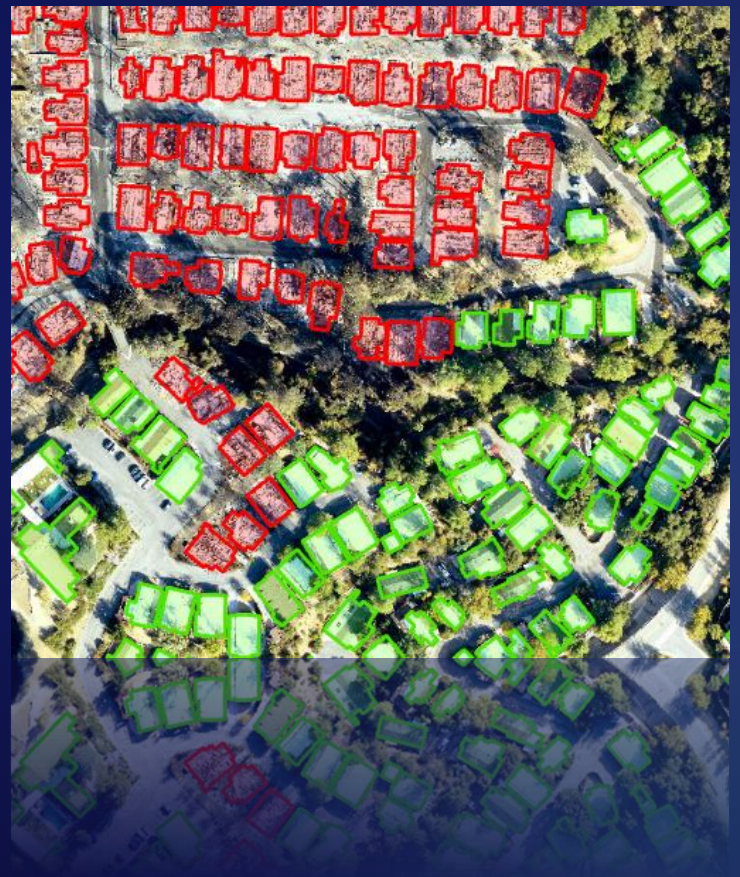
Turf/Grass

Building

Water

Applications:

- Land Cover Classification
- Pervious/Impervious mapping…



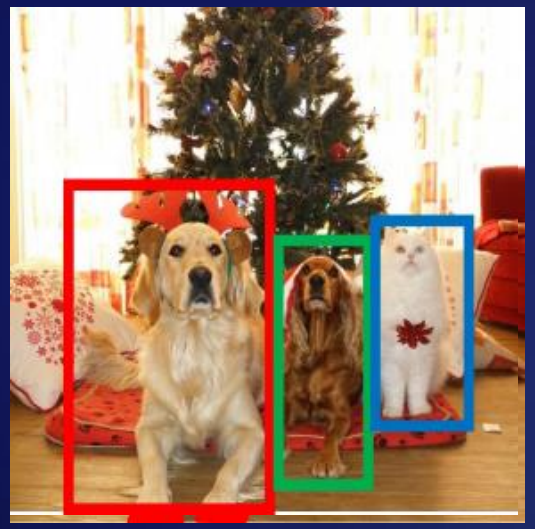
Demo

Building Footprint extraction

Vinay

Object Detection

Find objects and their location (bounding boxes)



Models:

- SingleShotDetector
- RetinaNet

Applications:

- Detect trees, cars, airplanes, …

Instance Segmentation

Find objects and their *precise* locations (masks or polygonal features)

Models:

- MaskRCNN

Applications:

- Building footprint extraction

Demo

Building footprints

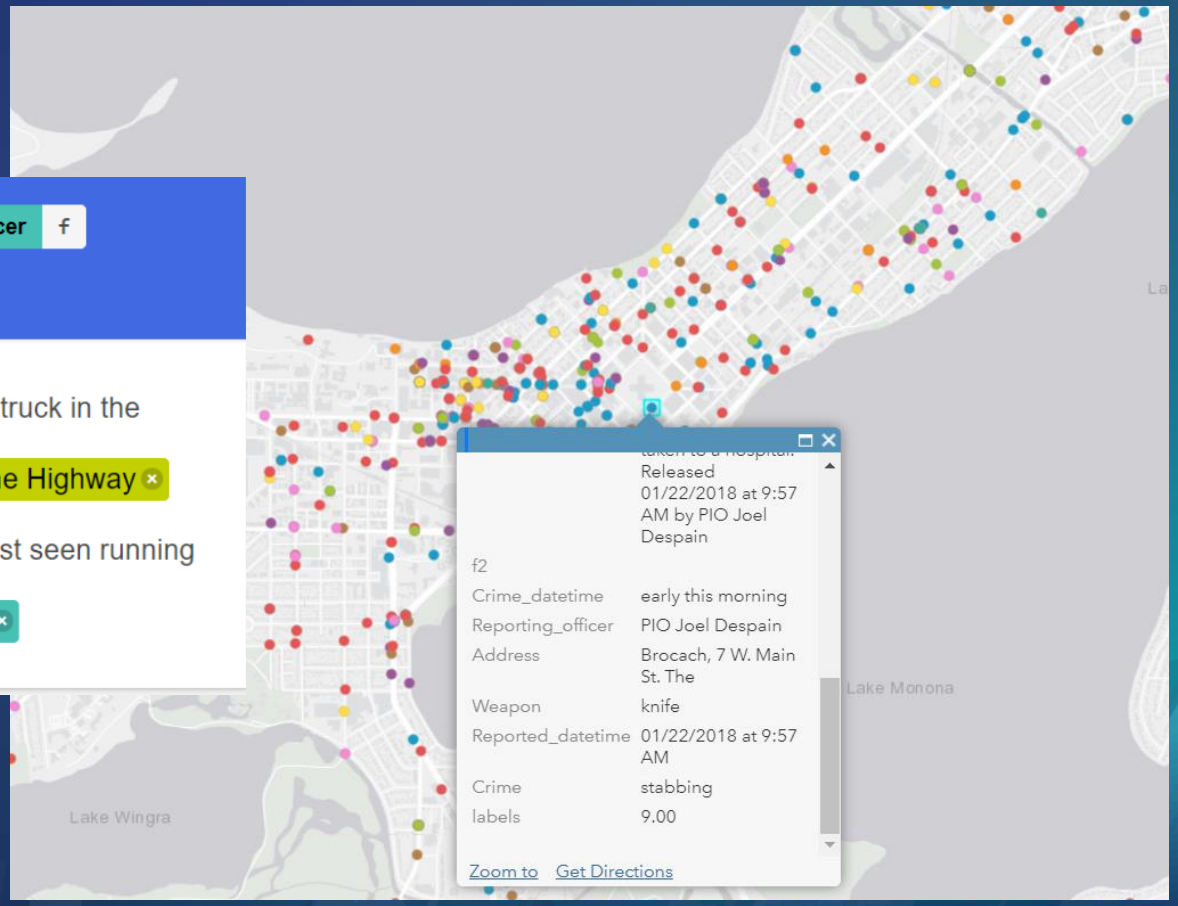
Rohit

Text / NLP

- arcgis.learn – model for extracting location and other entities
  - EntityExtractor model

Crime c | Address a | Crime_datetime d | Reported_datetime r | Reporting_officer f | Weapon w

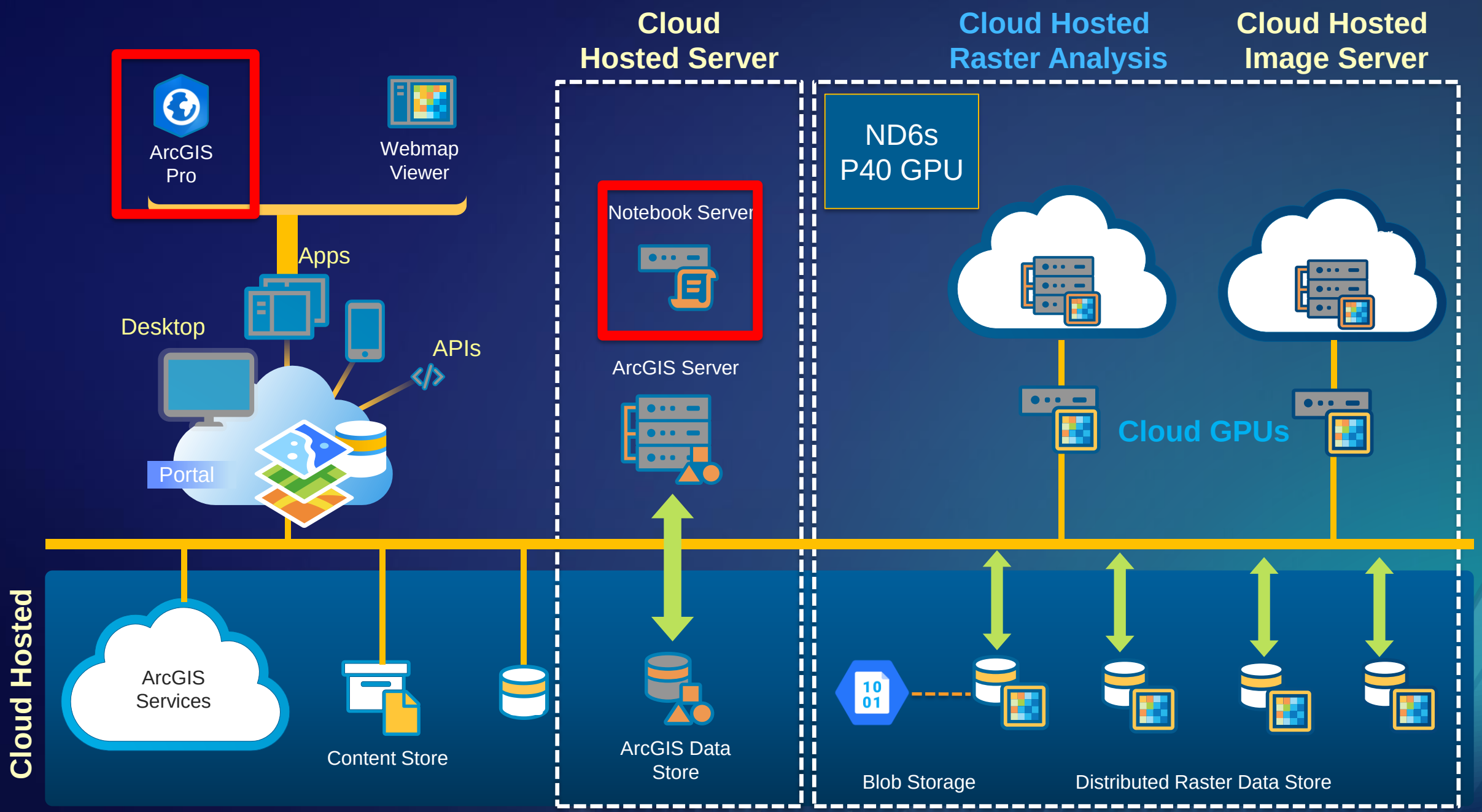
A convenience store clerk was robbed at gunpoint Wednesday night, and struck in the shoulder with the weapon. The holdup took place at the 7-Eleven, 2703 W. Beltline Highway just before 11:00 p.m. The victim was shaken but not injured. The crook was last seen running south on Todd Dr. Released 12/14/2017 at 9:28 AM by PIO Joel Despain

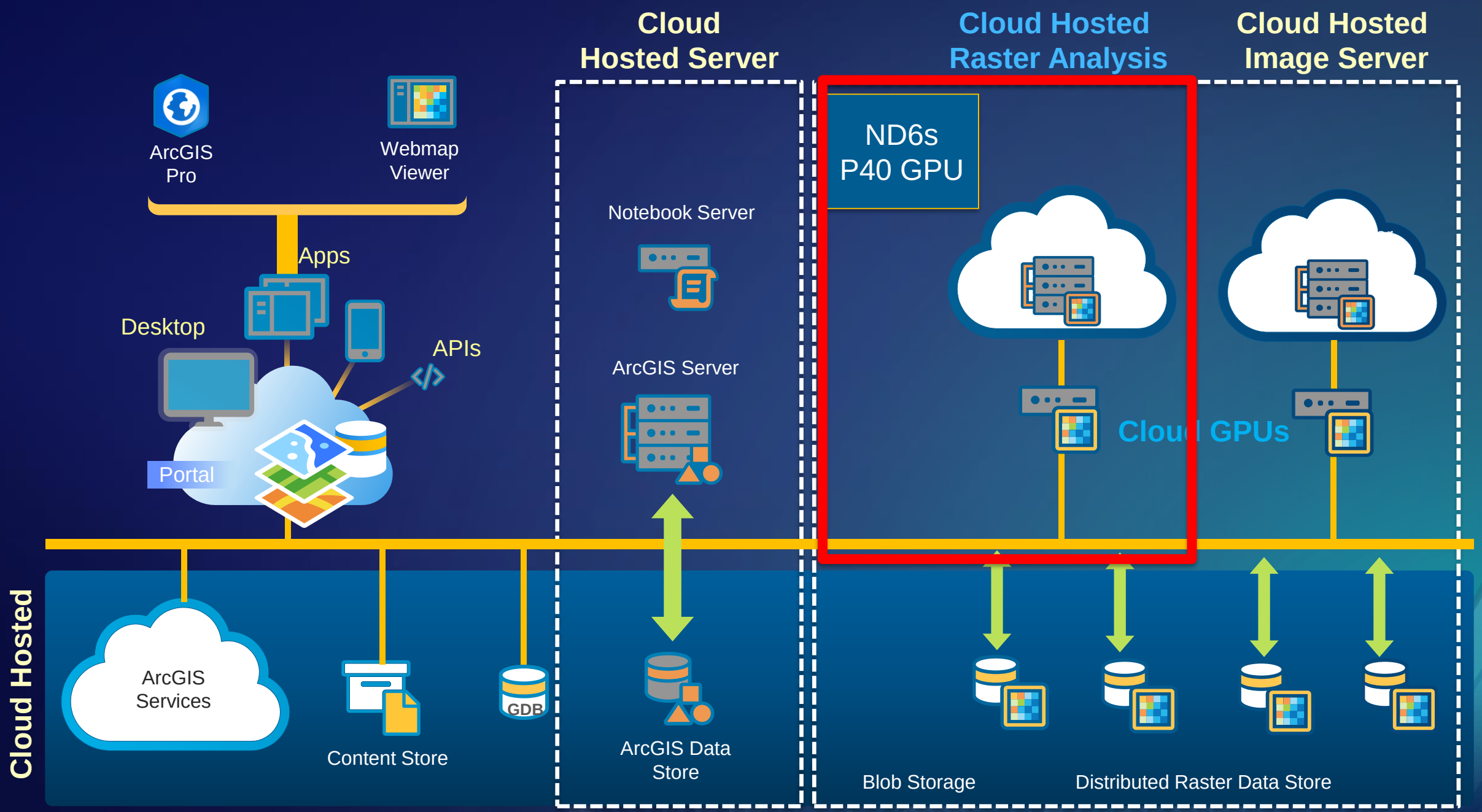


ArcGIS Enterprise for Scaling Deep Learning

- Leverage Raster Analytics to scale inferencing
- All desktop inferencing tools are accessible through enterprise
- Clients to invoke distributed inferencing – map viewer, pro, notebooks
- Requires the ArcGIS Image Server license

ArcGIS Enterprise Deep Learning – System Architecture


Cloud Hosted Server
Cloud Hosted Raster Analysis
Cloud Hosted Image Server
ArcGIS Pro
Webmap Viewer
Apps
Desktop
APIs
Portal
Notebook Server
ArcGIS Server
ND6s P40 GPU
Cloud GPUs
Cloud Hosted
ArcGIS Services
Content Store
ArcGIS Data Store
Blob Storage
Distributed Raster Data Store


Cloud Hosted Server
Cloud Hosted Raster Analysis
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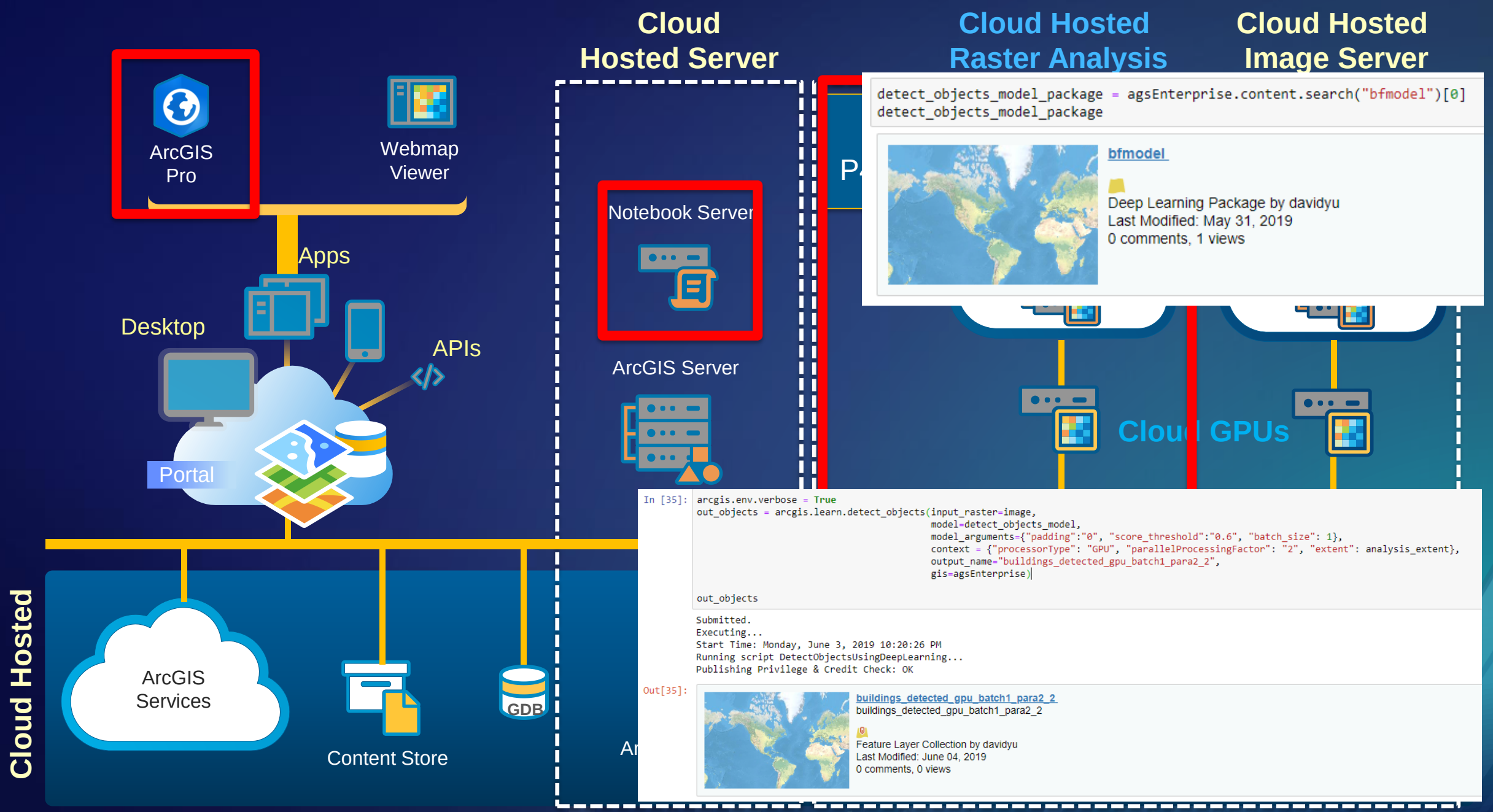
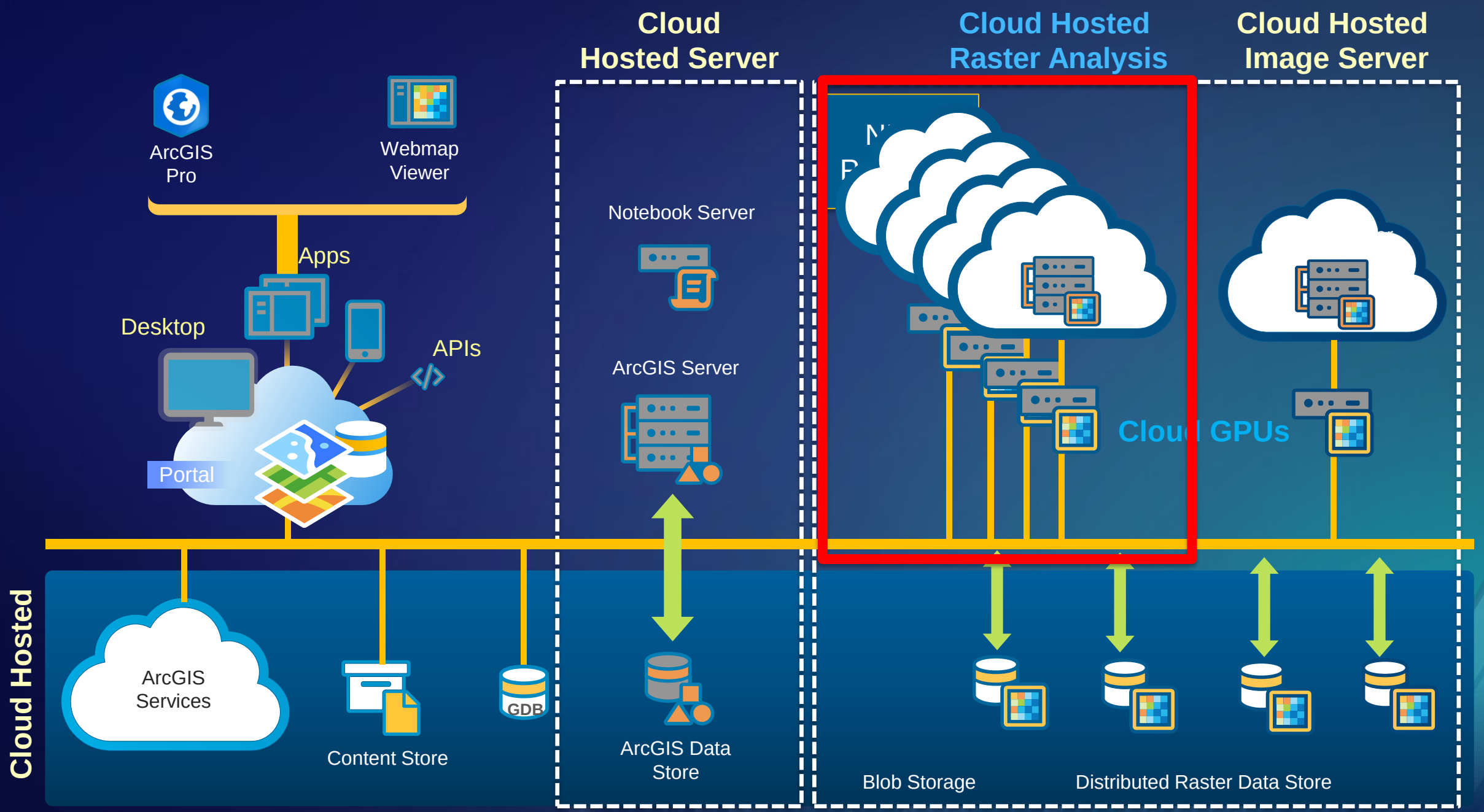
ArcGIS Pro
Webmap Viewer
Apps
Desktop
APIs
Portal
Notebook Server
ArcGIS Server
ND6s P40 GPU
Cloud GPUs
Cloud Hosted
ArcGIS Services
Content Store
GDB
ArcGIS Data Store
Blob Storage
Distributed Raster Data Store


Cloud Hosted Server
Cloud Hosted Raster Analysis
Cloud Hosted Image Server
ArcGIS Pro
Webmap Viewer
Apps
Desktop
APIs
Portal
Notebook Server
ArcGIS Server
Cloud GPUs
Cloud Hosted
ArcGIS Services
Content Store
GDB
detect_objects_model_package = agsEnterprise.content.search("bfmodel")[0]
detect_objects_model_package
bfmodel
Deep Learning Package by davidyu
Last Modified: May 31, 2019
0 comments, 1 views
In [35]:
arcgis.env.verbose = True
out_objects = arcgis.learn.detect_objects(input_raster=image,
model=detect_objects_model,
model_arguments={"padding":"0", "score_threshold":"0.6", "batch_size": 1},
context = {"processorType": "GPU", "parallelProcessingFactor": "2", "extent": analysis_extent},
output_name="buildings_detected_gpu_batch1_para2_2",
gis=agsEnterprise)
out_objects
Submitted.
Executing...
Start Time: Monday, June 3, 2019 10:20:26 PM
Running script DetectObjectsUsingDeepLearning...
Publishing Privilege & Credit Check: OK
Out[35]:
buildings_detected_gpu_batch1_para2_2
buildings_detected_gpu_batch1_para2_2
Feature Layer Collection by davidyu
Last Modified: June 04, 2019
0 comments, 0 views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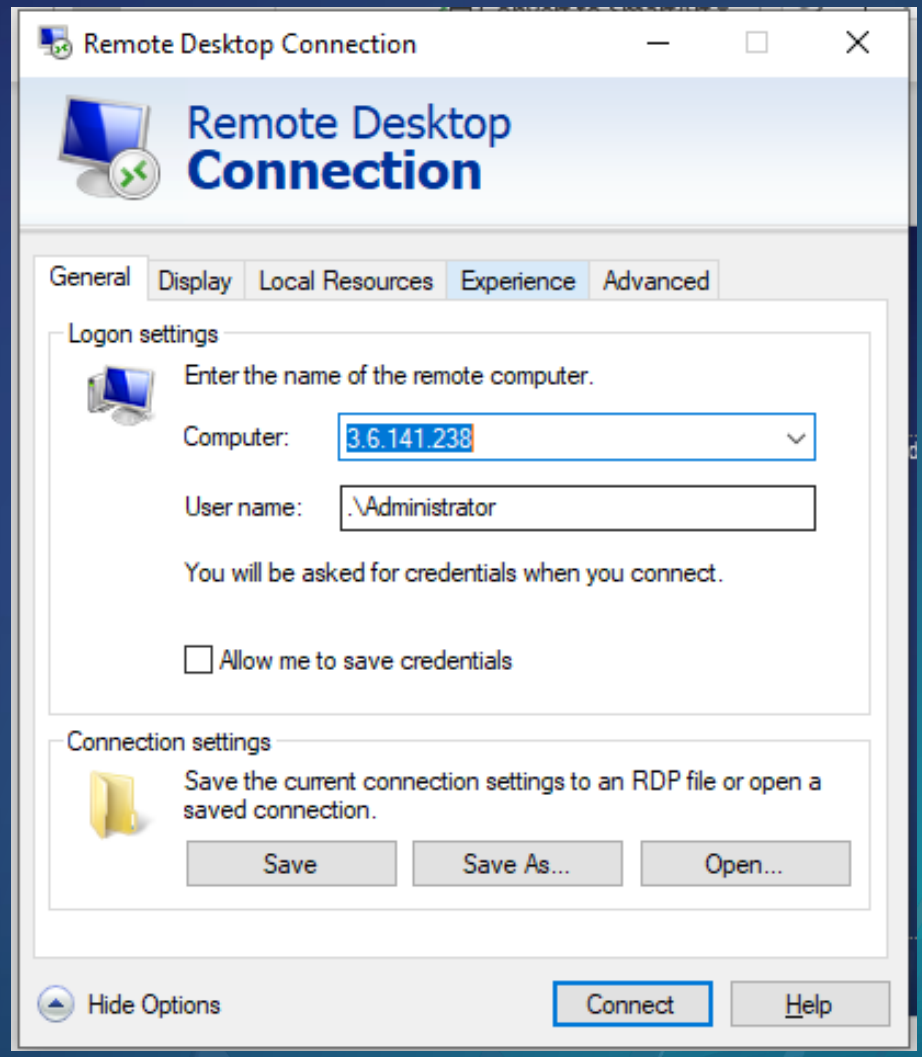
Hands On Exercises

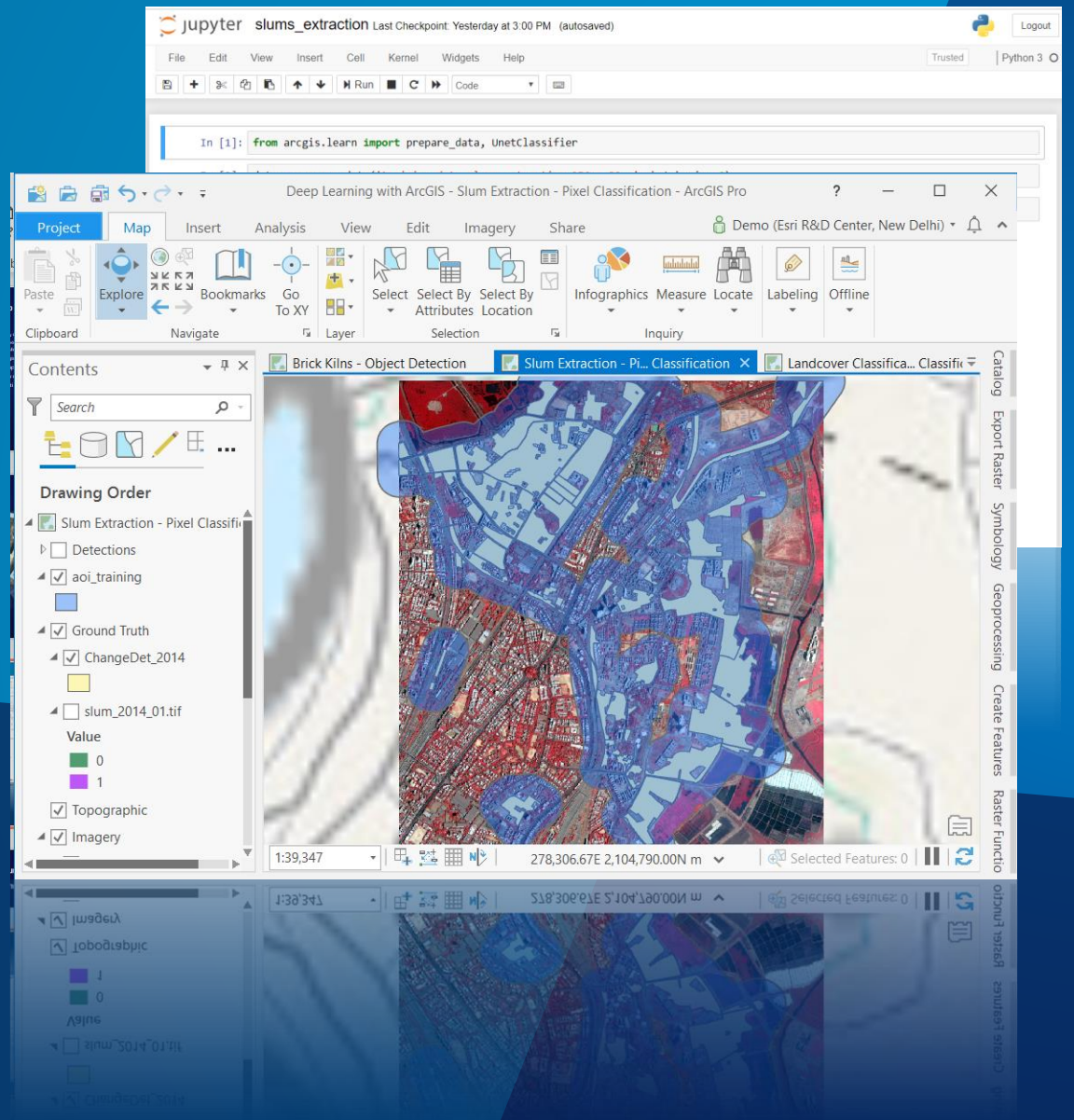
Logging in to the instance

- Login to the local Administrator account of your allotted instance.



Get Required data

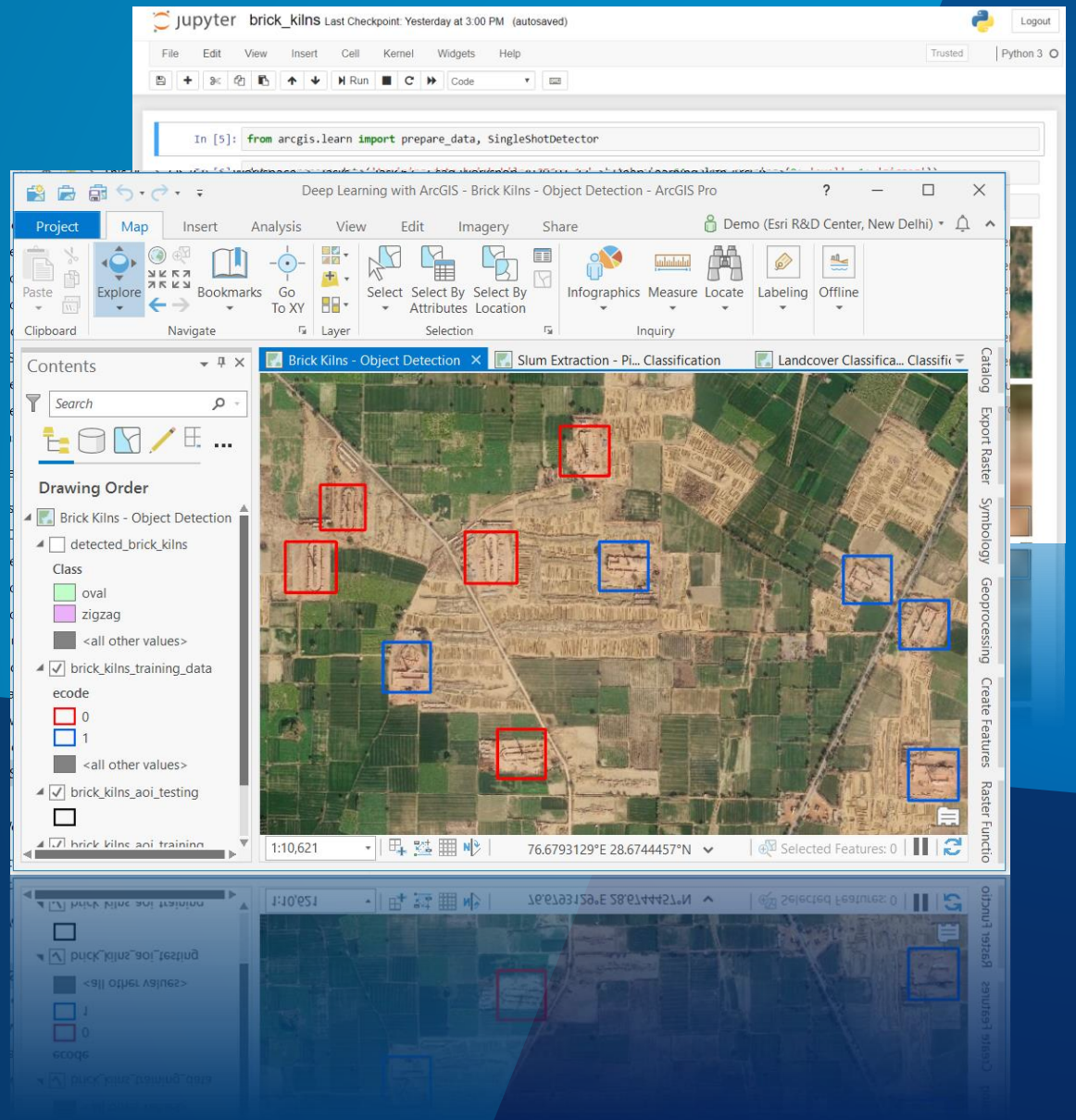
- Open Windows Explorer
- Navigate to Z:\
- Copy the folder “Z:\Deep Learning with ArcGIS” to D drive.
- Open the pro project “Deep Learning with ArcGIS.ppkx” by double clicking on it.
- Extract the contents of “Hands on.zip” file.



Hands On Exercise

Slums Extraction

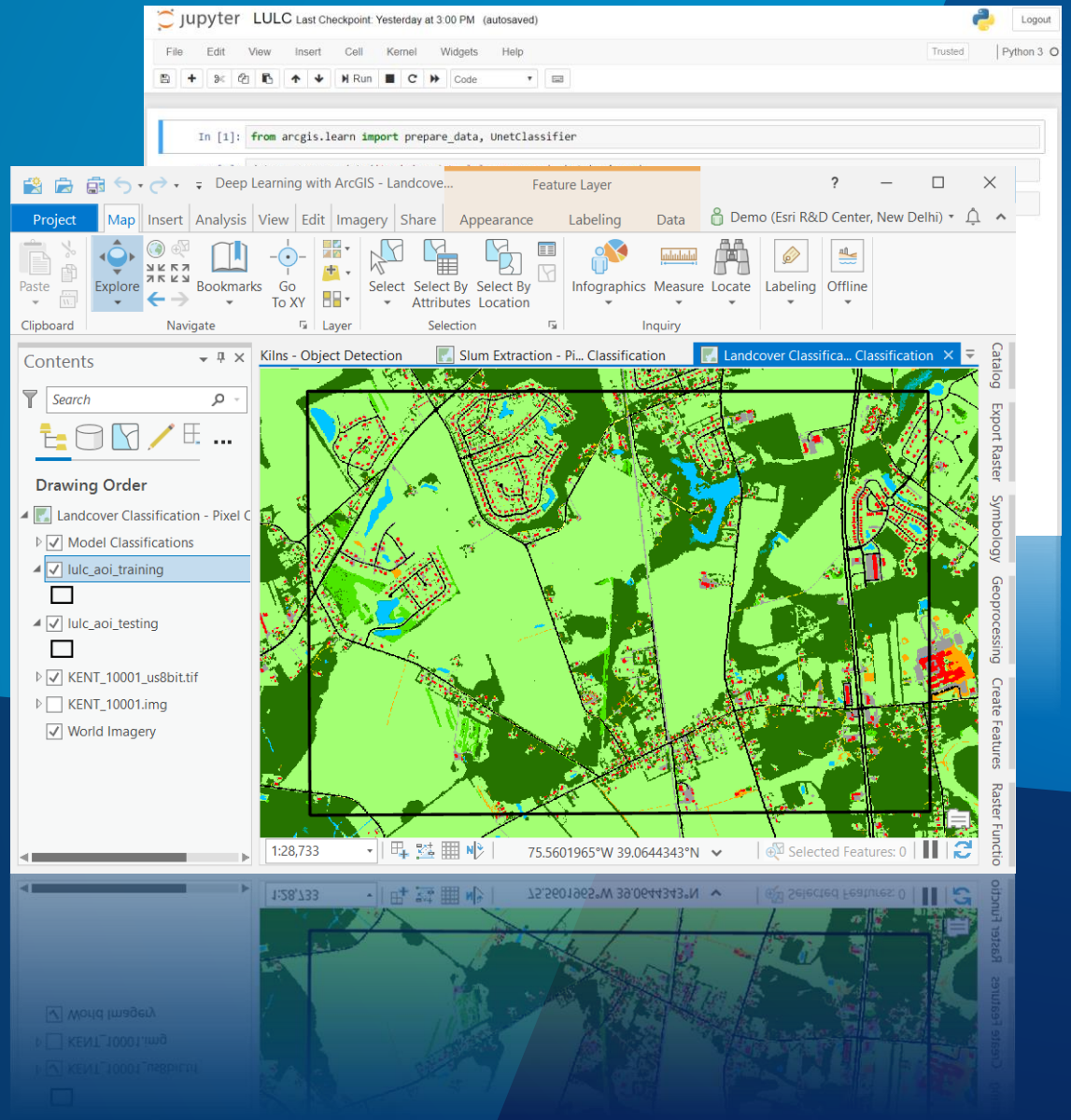
ArcGIS Pro, Jupyter Notebook



Hands On Exercise

Brick Kilns Detection

ArcGIS Pro, Jupyter Notebook



Hands On Exercise

Landcover Classification

ArcGIS Pro, Jupyter Notebook

Resources

- **Geonet Community** https://community.esri.com/groups/arcgis-python-api/pages/overview
- **ArcGIS API for Python** https://developers.arcgis.com/python/
- **API Reference** https://developers.arcgis.com/python/api-reference/
- **GitHub Repo** https://github.com/Esri/arcgis-python-api
- **Sample Notebooks** https://developers.arcgis.com/python/sample-notebooks/
- **GeoAI blogs** https://medium.com/geoai

Practical deep learning for coders:

- https://course.fast.ai/

- **Resources of this workshop on GitHub** https://github.com/sandeepgadhwal/csag-workshop2020
- **Try it out on collab** https://drive.google.com/open?id=1qhFkvZiT4a9uzinisVI0ugHmUeA43Afd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