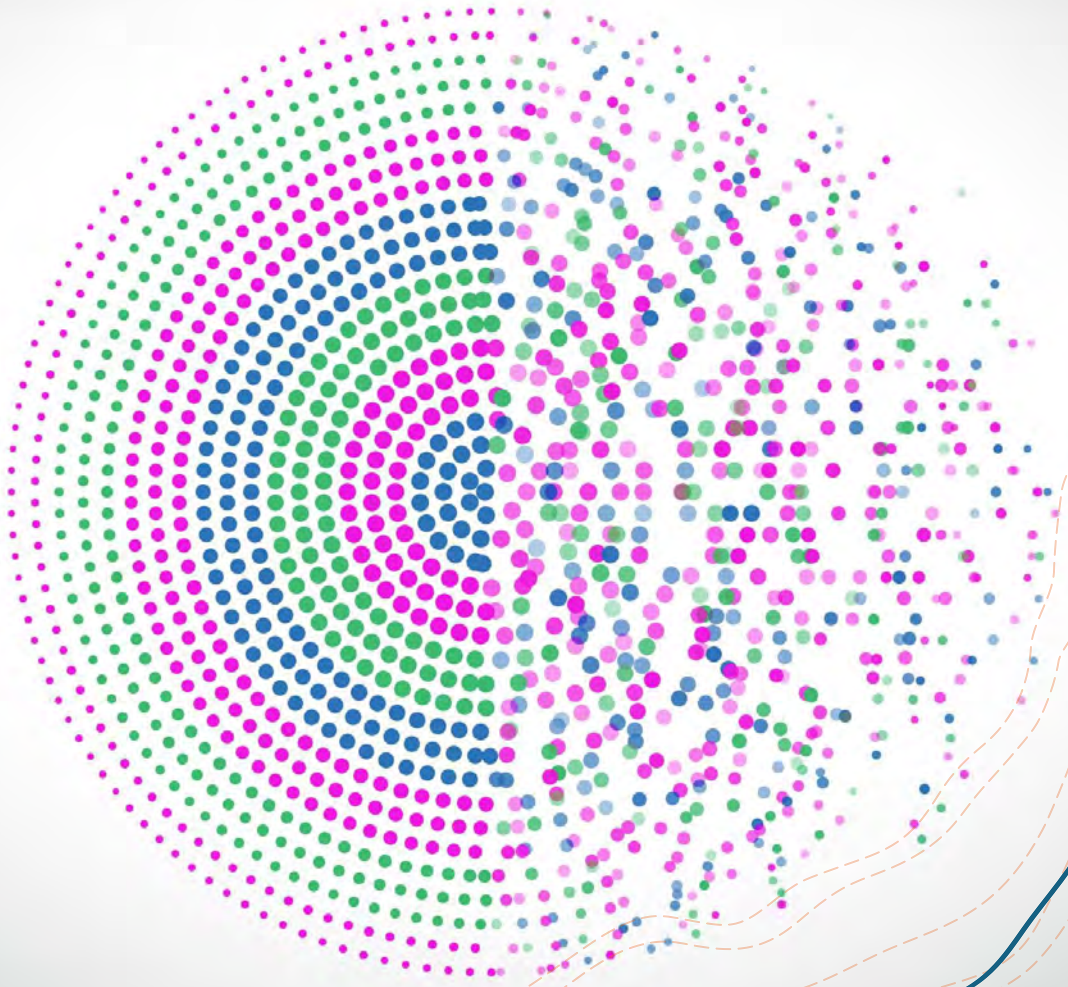
CGIA
CALIFORNIA GEOGRAPHIC INFORMATION ASSOCIATION

Integrating GIS and AI Technologies

Dr. Kostas Alexandridis, GISP
Spatial Data Scientist



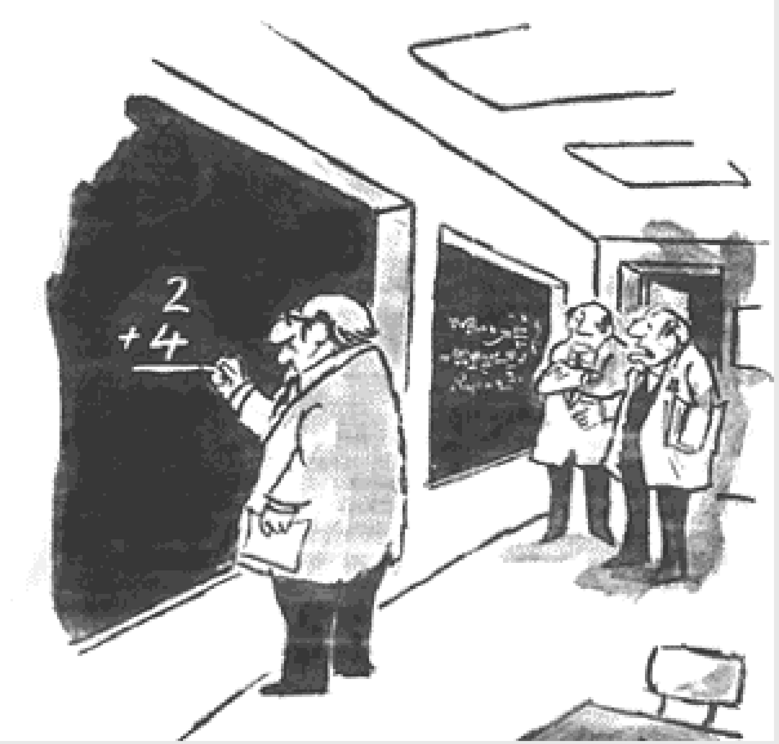
COUNTY OF ORANGE CALIFORNIA
OC Public Works
Geospatial Services

digital twin CONSORTIUM

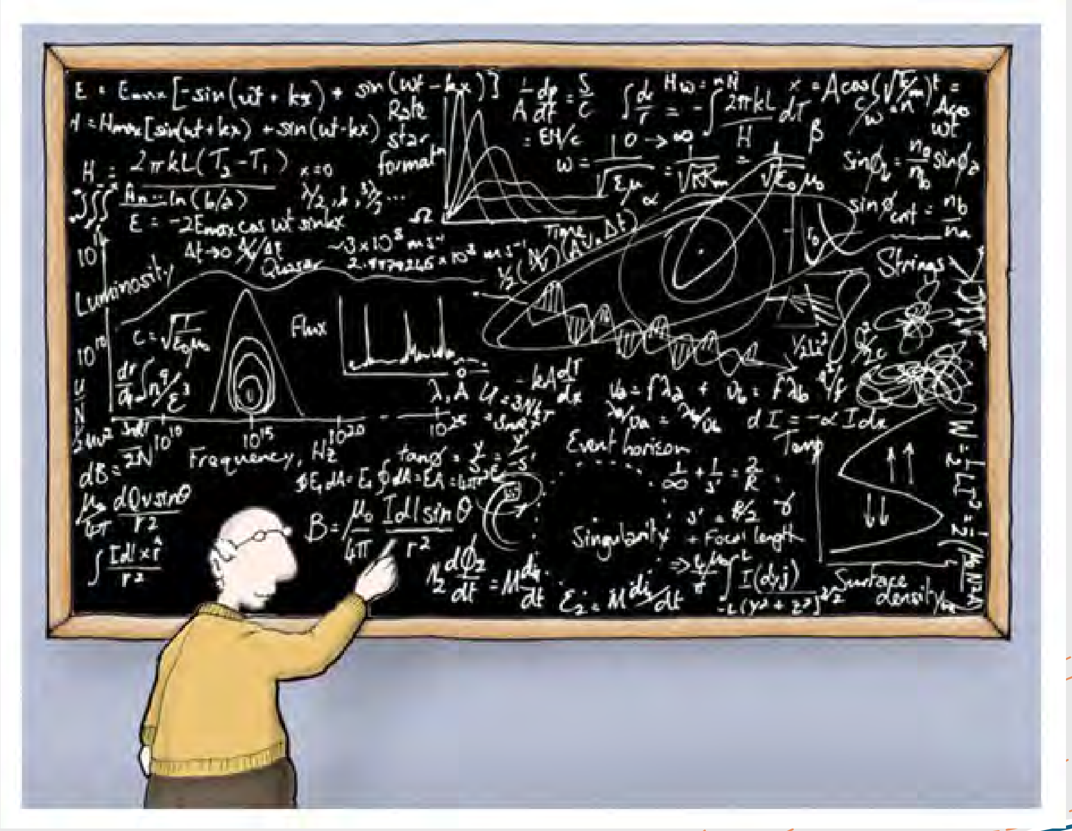
MindScribble
Spatial Intelligence

Often, we fail to realize the complexities of our contemporary world

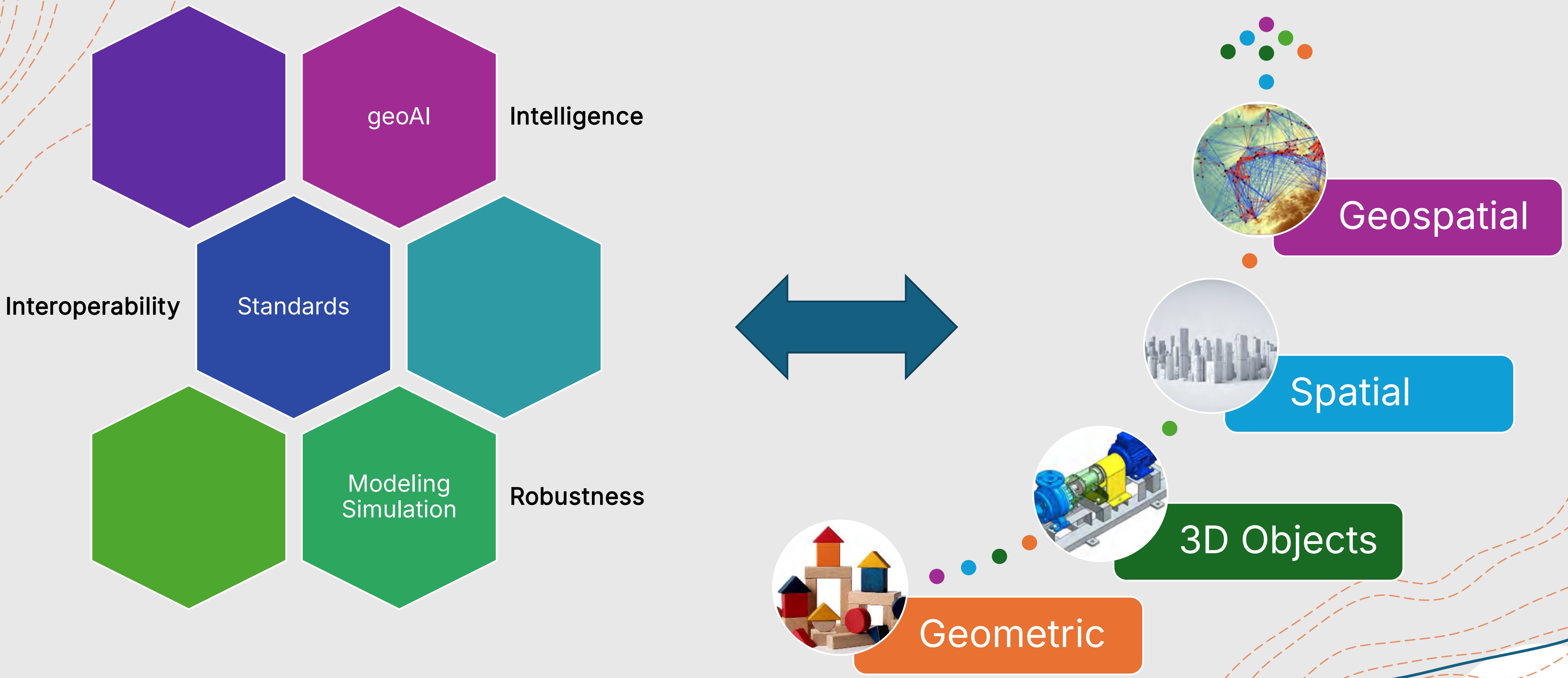
How do we value the simple?



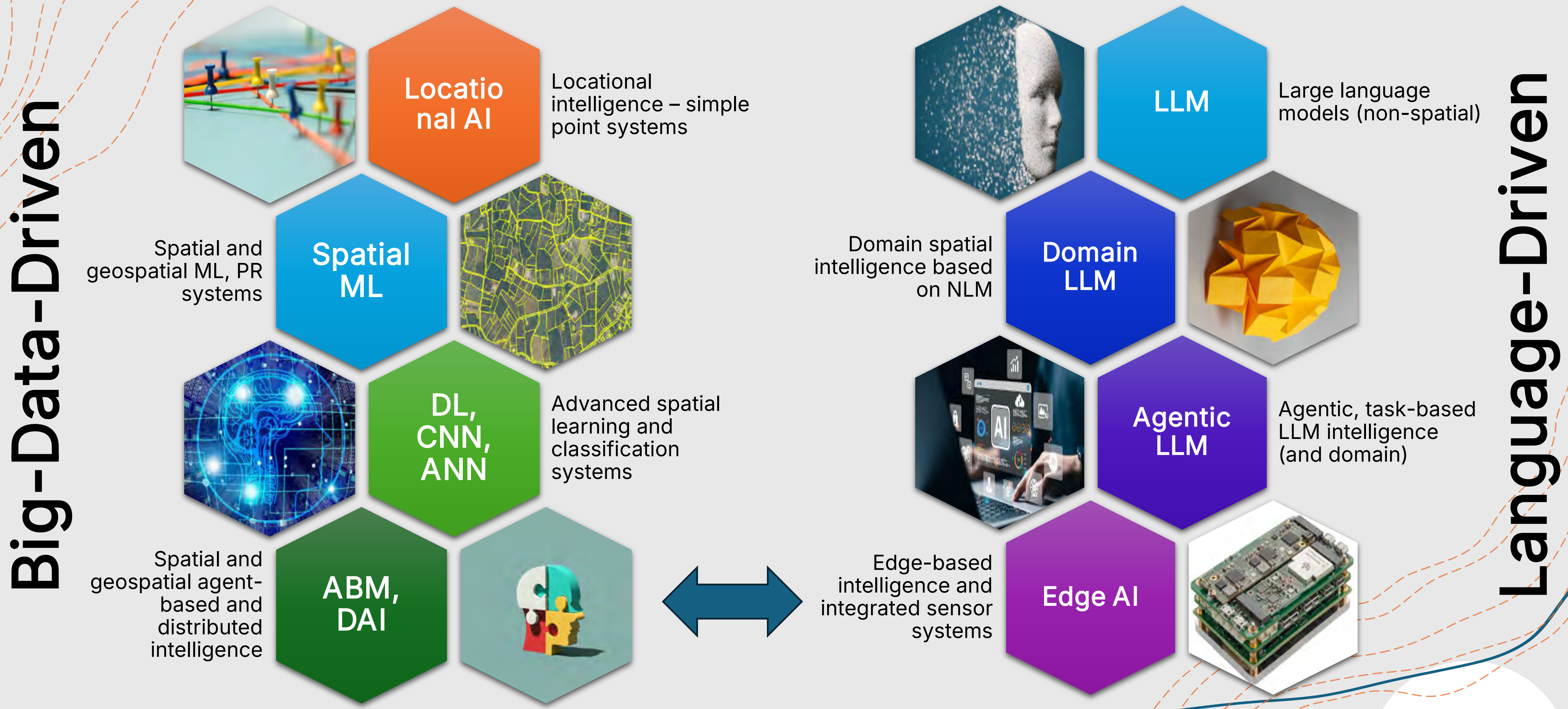
Or complex?



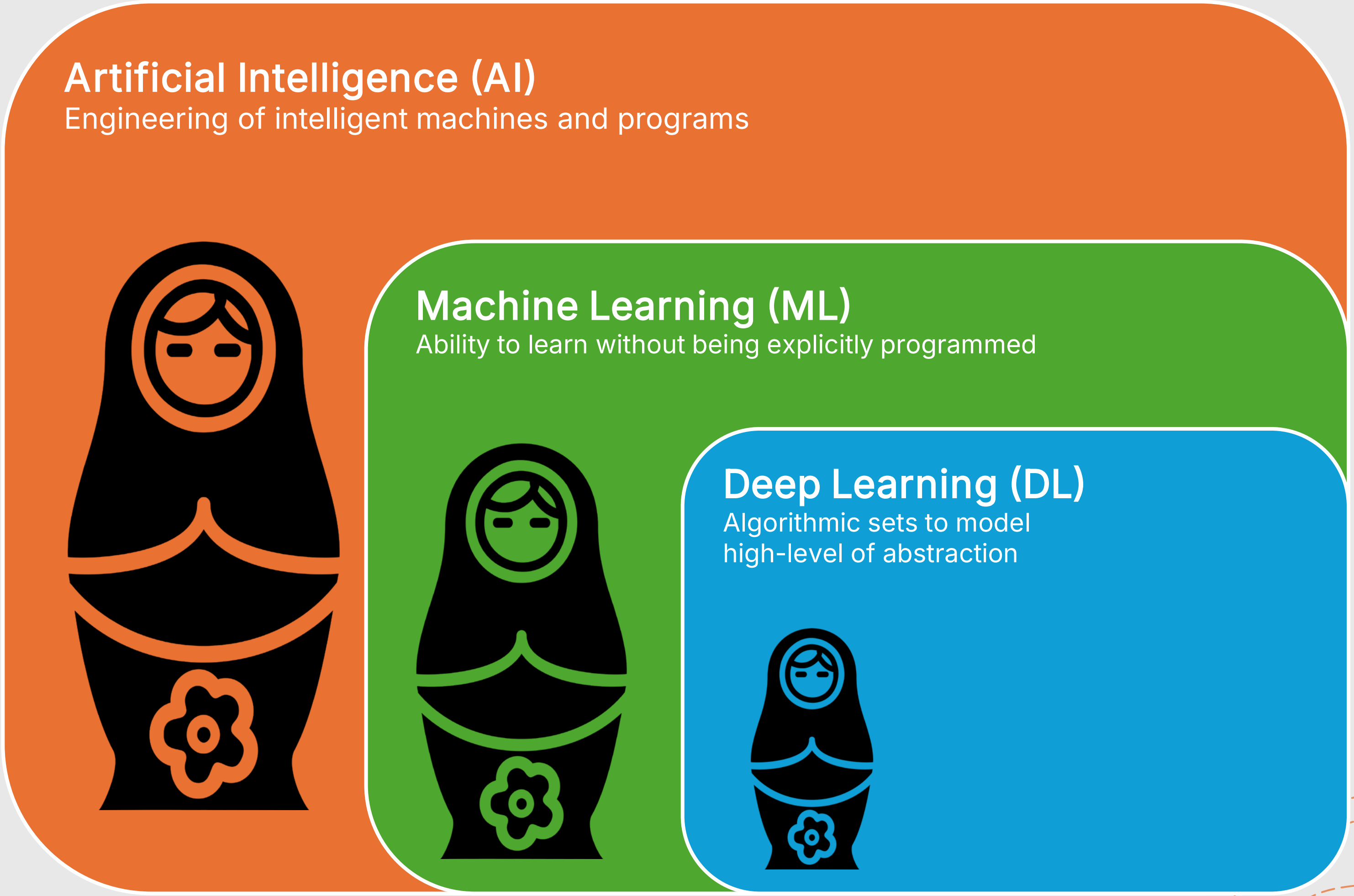
Geospatial Composability



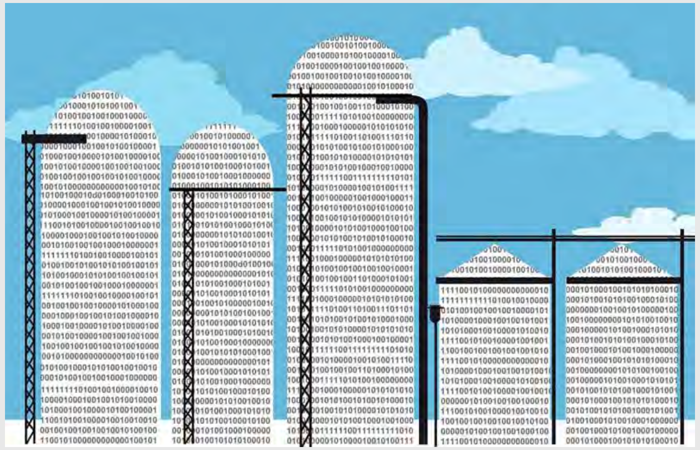
Typology of GeoAI Methods



Methodology in Perspective



Data Challenges



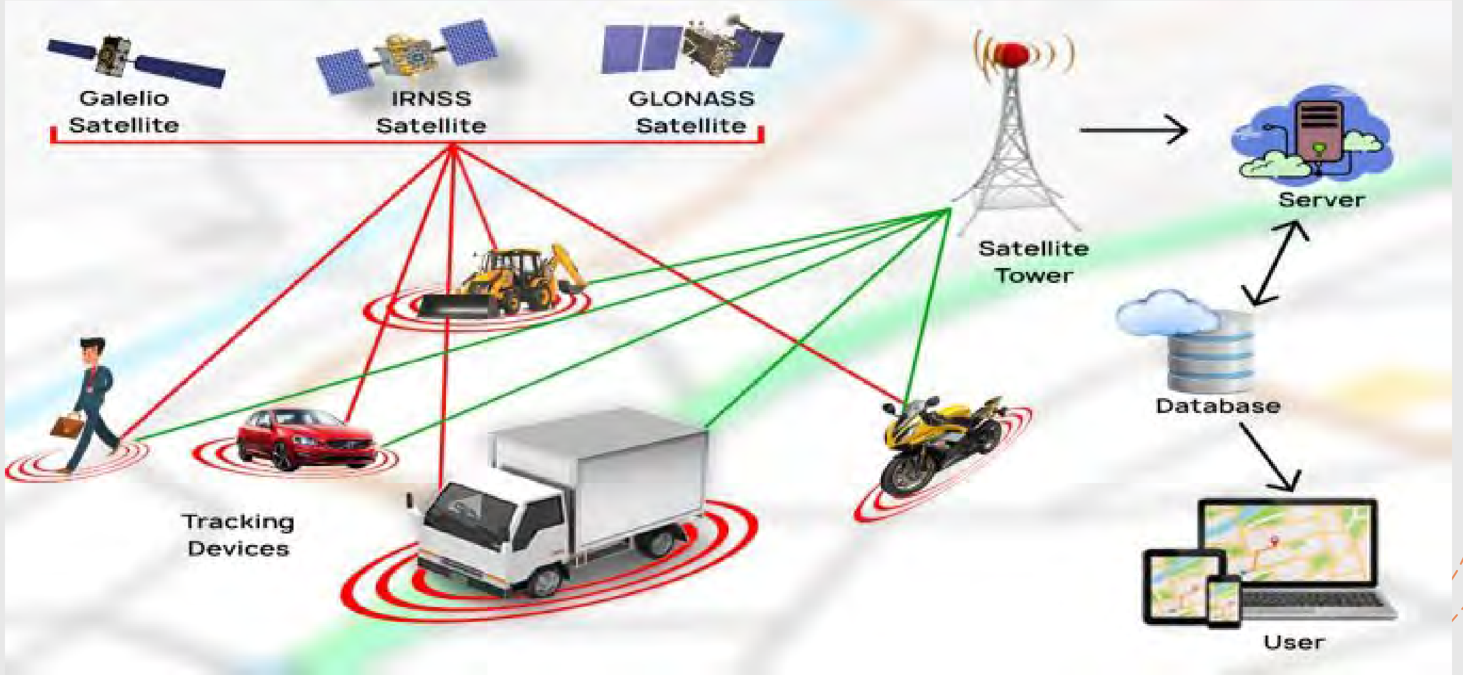
DATA SILOS

TOO MUCH DATA

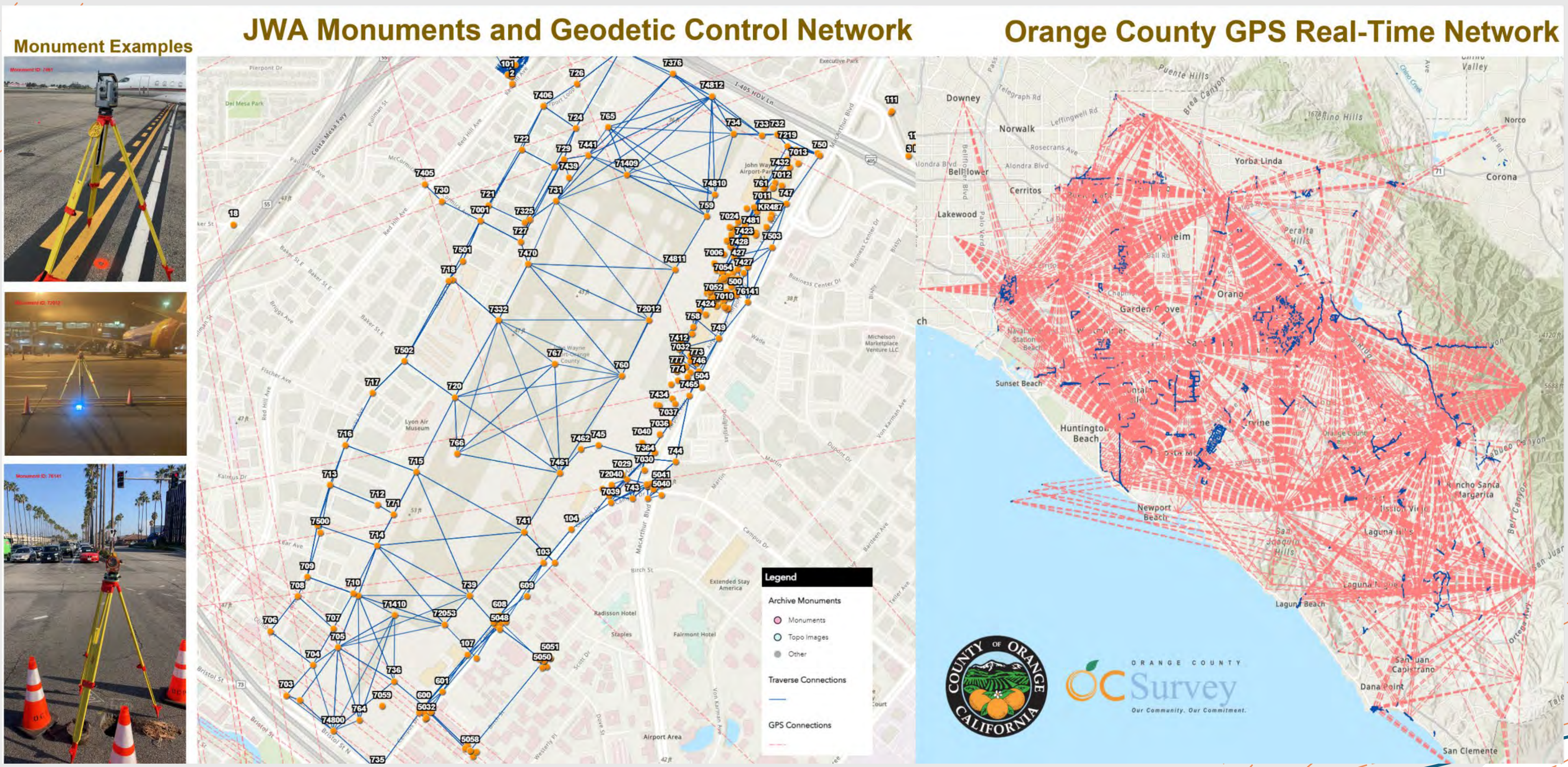
SINGLE SOURCE OF DATA

Multi-Sensor Systems

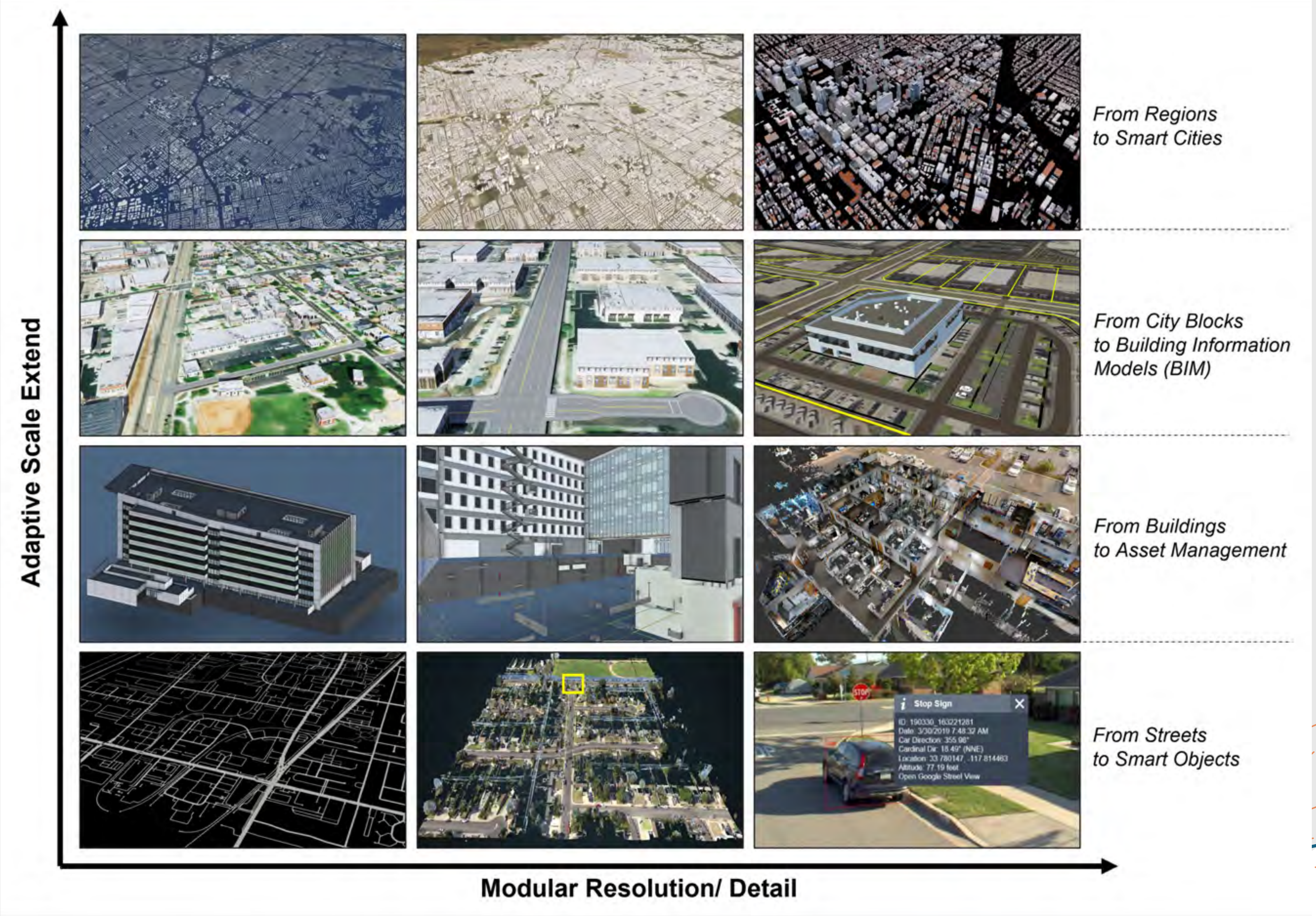
- Global Navigation Satellite System (GNSS)
- Global Positioning System (GPS)
- Uses satellites to Position on the Earth
- Time and Orbit to Calculate Positioning
- Data Use Cases:
- Precise Positioning (Dams, Post-Earthquake)
- Navigation Systems (your phone)



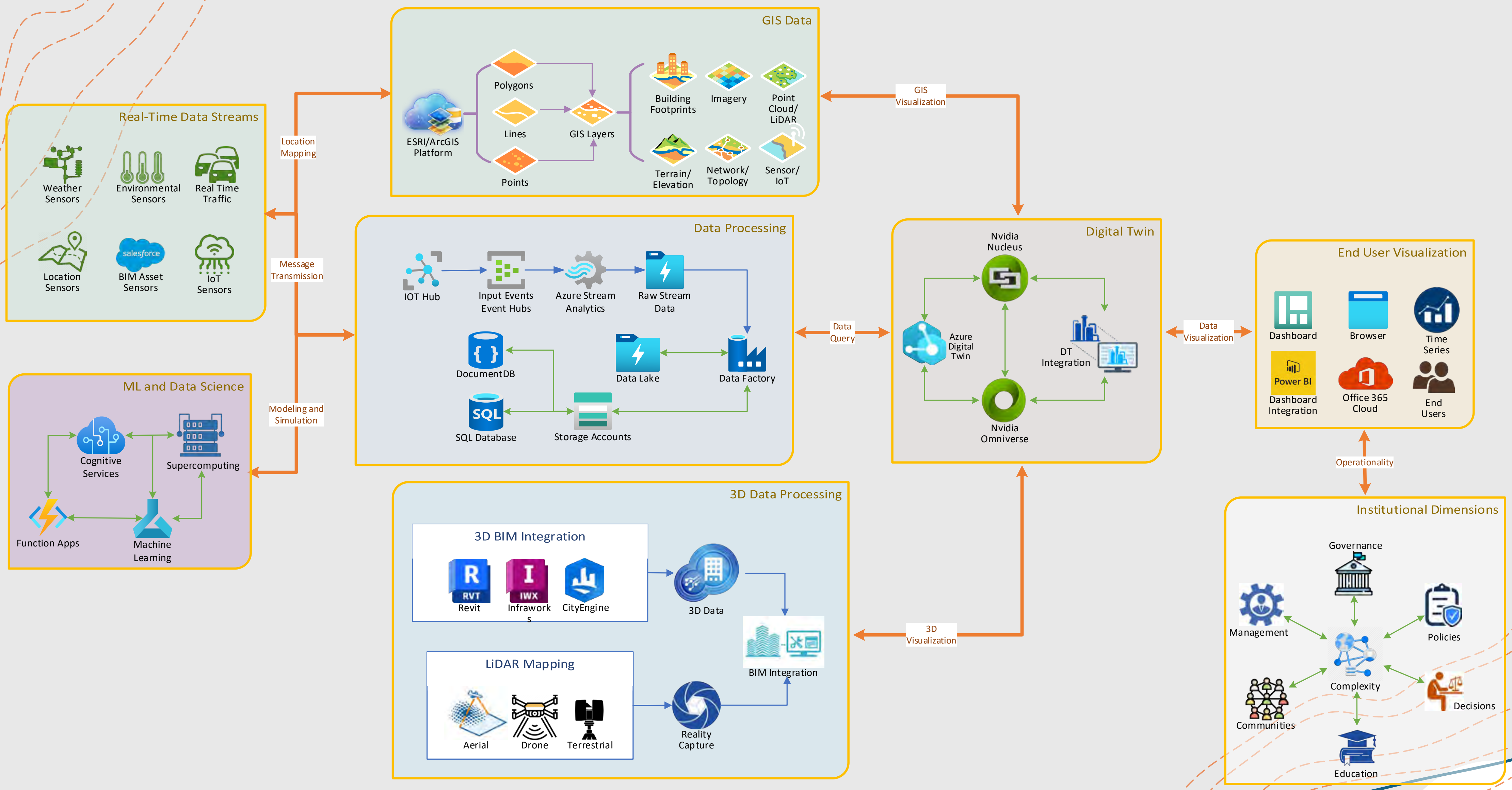
Example: JWA Tied Geodetic Control



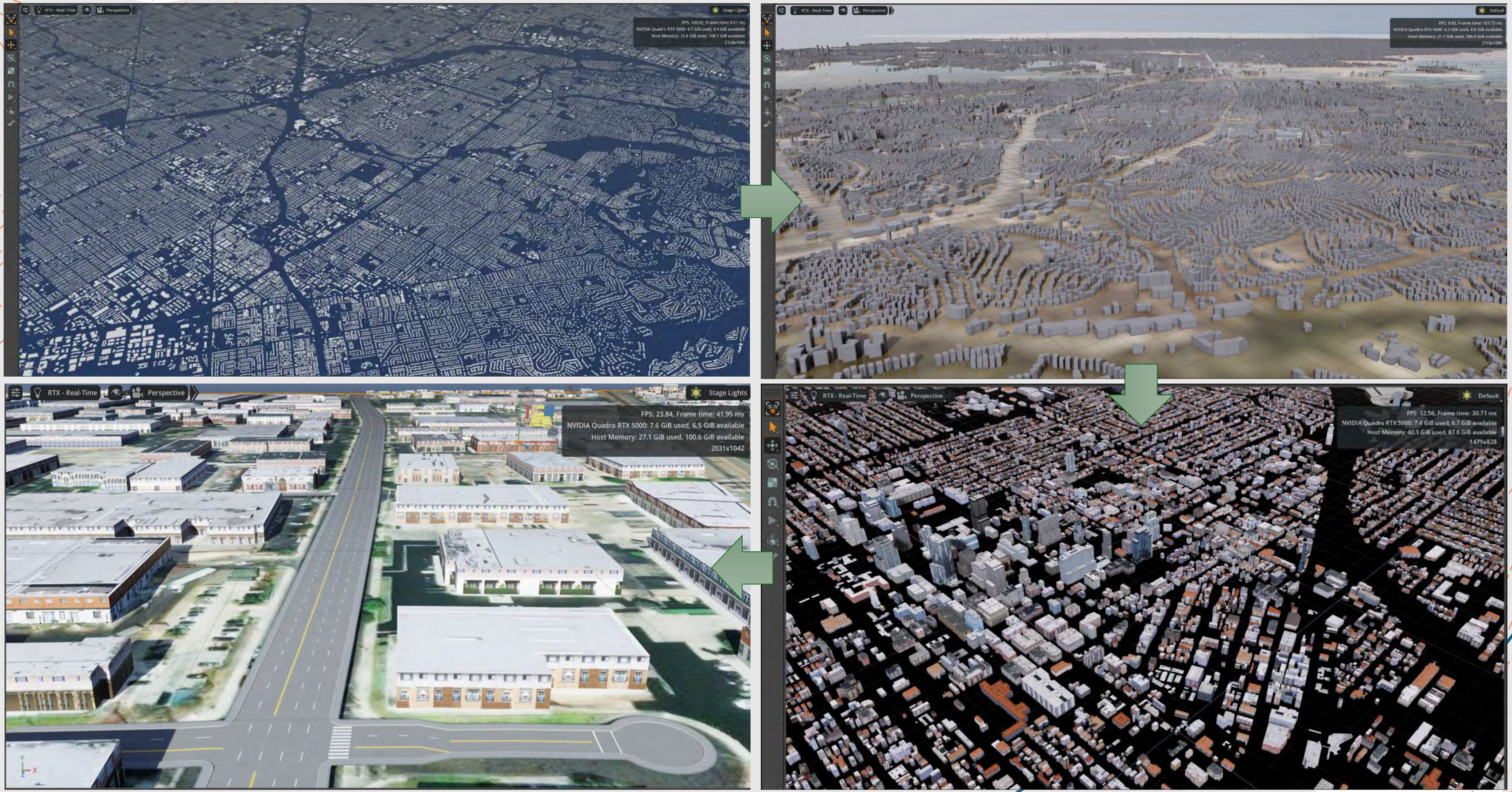
Cross-Scalability Approach



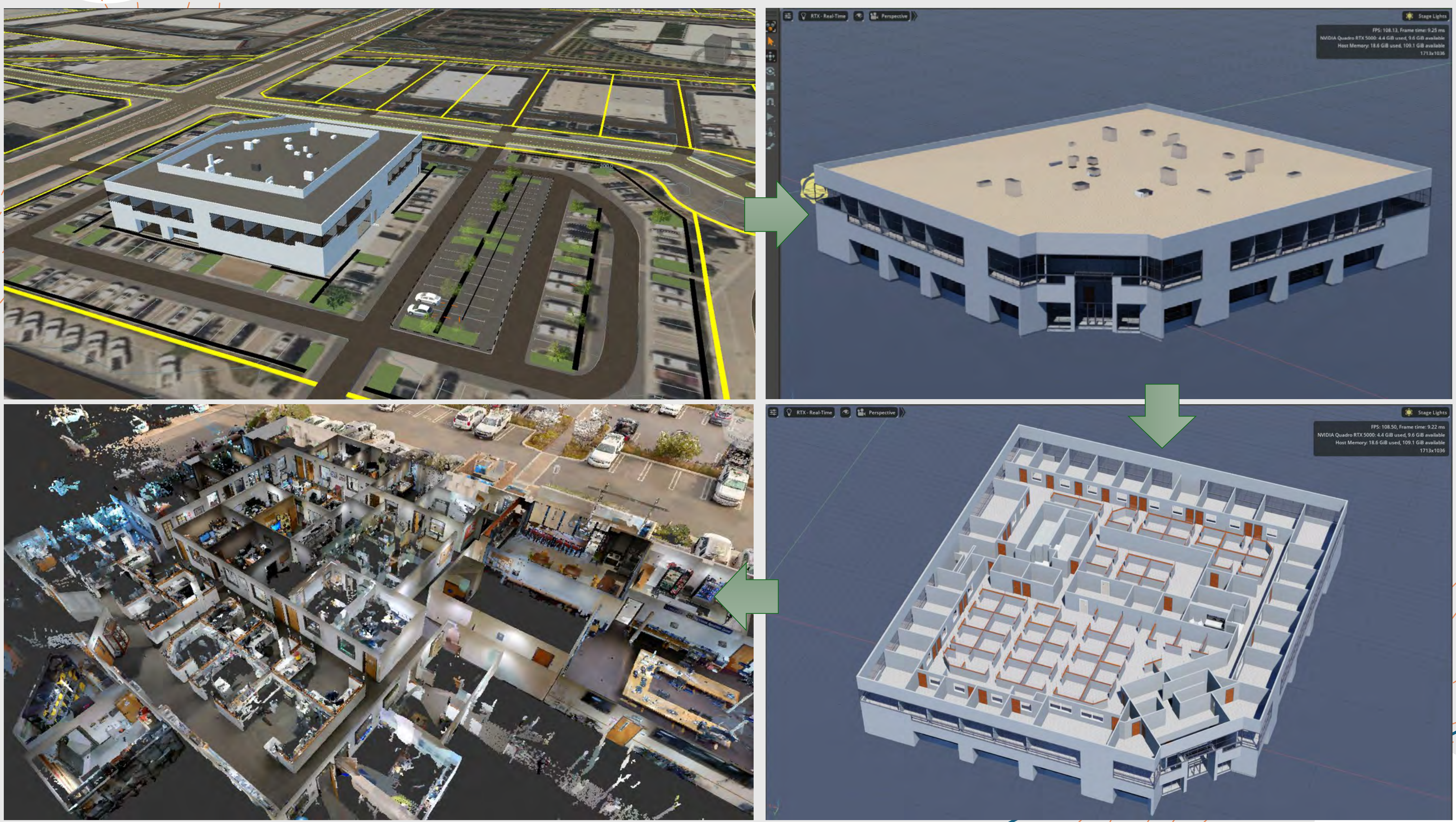
Example Framework Overview

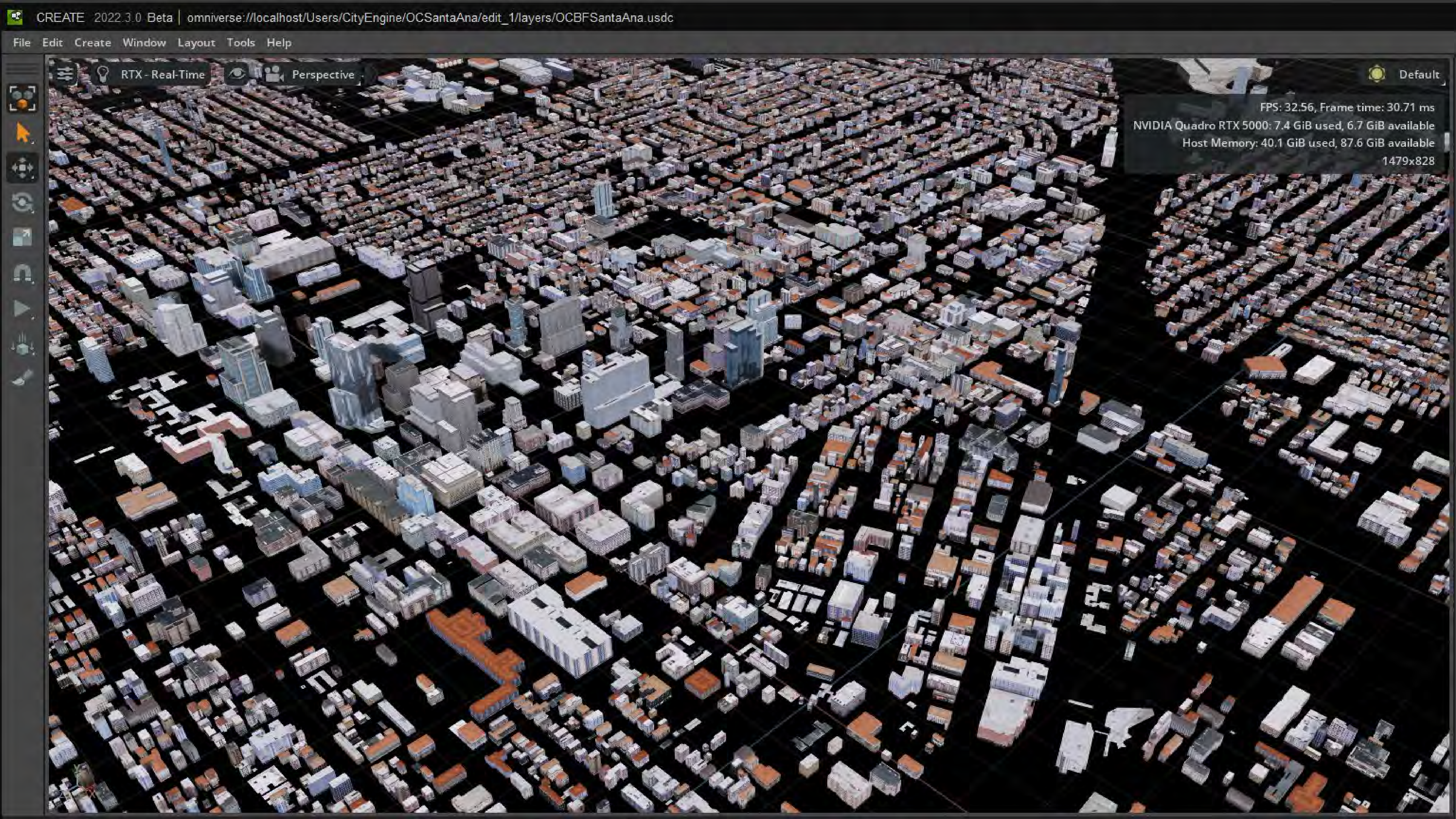


Scalability, Robustness and Interoperability: From Cities to Buildings



Scalability, Robustness and Interoperability: From Cities to Buildings

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RTX - Real-Time
Perspective
Default
FPS: 32.56, Frame time: 30.71 ms
NVIDIA Quadro RTX 5000: 7.4 GiB used, 6.7 GiB available
Host Memory: 40.1 GiB used, 87.6 GiB available
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LIVE
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FPS: 23.66, Frame time: 42.27 ms
NVIDIA Quadro RTX 5000: 7.4 GiB used, 6.7 GiB available
Host Memory: 27.0 GiB used, 100.7 GiB available
2031x1042
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Transform
This prim has no transforms
Add Transforms
Materials on selected models
Prim
/OCGlassell52/Terrain_Imagery!
/OCGlassell52/Terrain_Imager
Strength
Weaker than Descendants
Geometry
Content
NVIDIA Assets
Asset Stores (beta)
Samples
Environments
Materials
Console
Import
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Search
Bookmarks
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Library
NVIDIA
assets
layers
OCGlassell52
OCGlassell52.usdc
Date Modified
Created by kostas.alexandridis@oc
Modified bykostas.alexandridis@oc
File size


CREATE 2022.3.0 Beta | omniverse://9ea69715-b84f-49fc-af9a-79ae08fad7d0.cne.ngc.nvidia.com/Projects/CityEngine/OCGlassellv52/OCGlassell52.usdc*
File Edit Create Window Layout Tools Help
LIVE
CACHE: ON
RTX - Real-Time
Perspective
Stage Lights
FPS: 23.84, Frame time: 41.95 ms
NVIDIA Quadro RTX 5000: 7.6 GiB used, 6.5 GiB available
Host Memory: 27.1 GiB used, 100.6 GiB available
2031x1042
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way_1101816212_91bc1 Xform
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Property
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Omniverse
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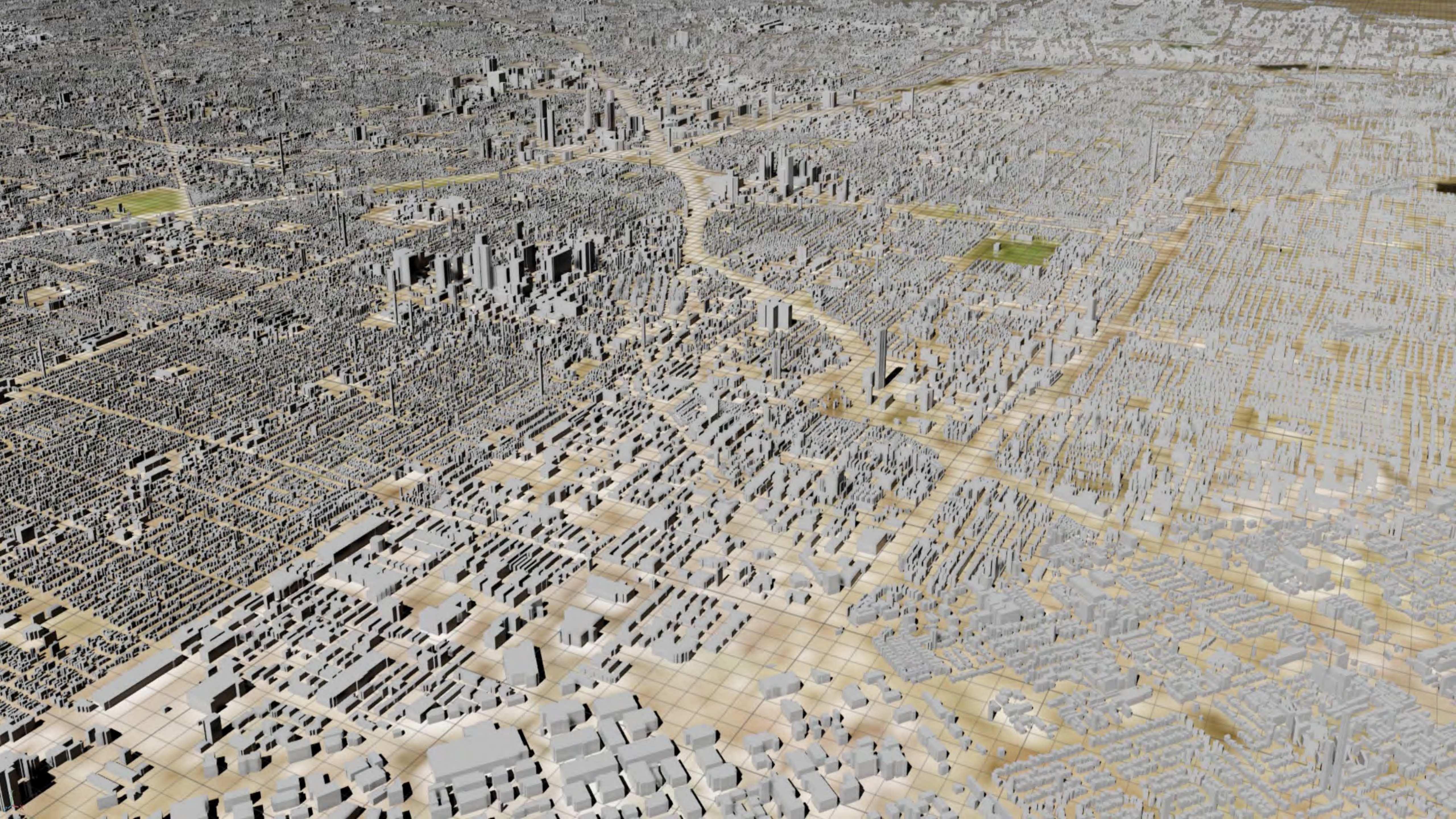
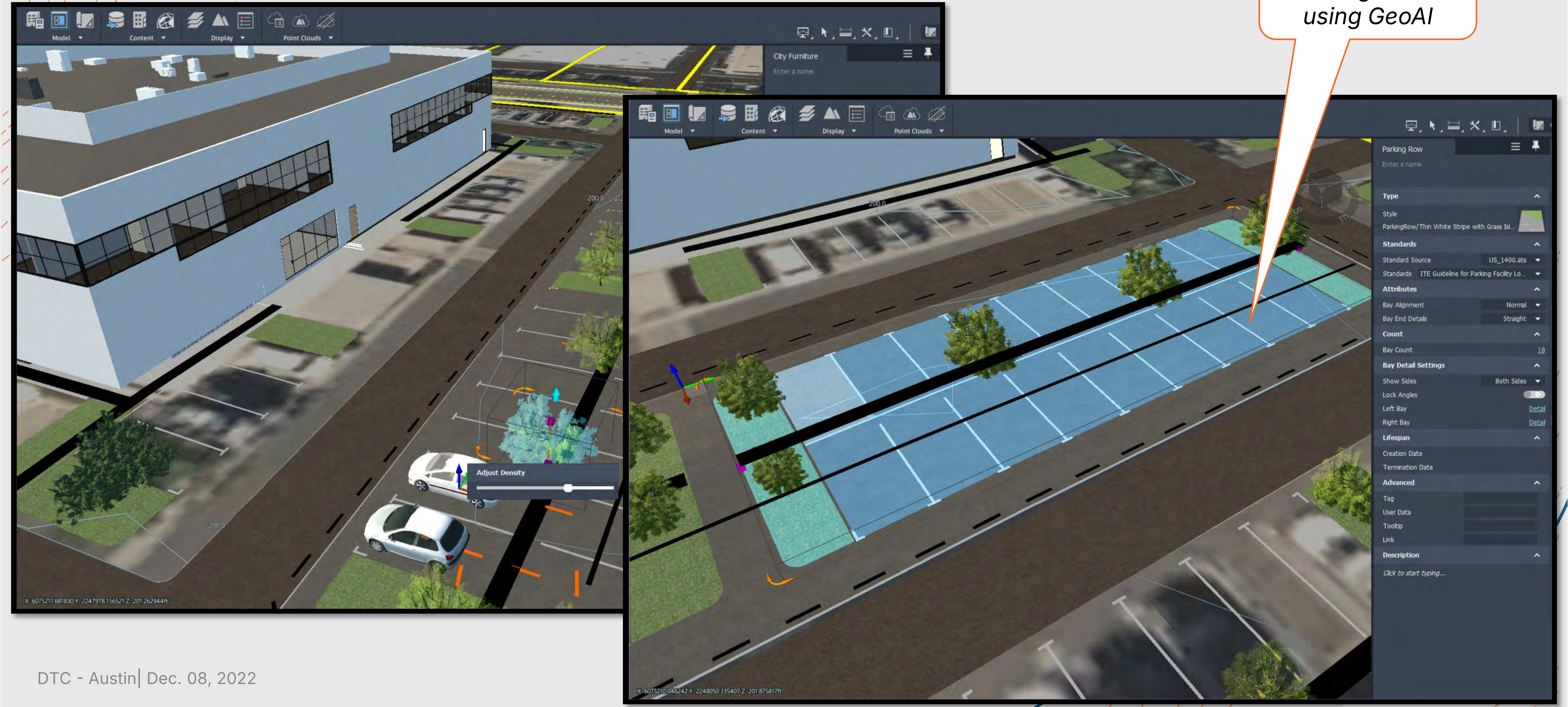
Modified by kostas.alexandridis@oc
File size



Digital 3D Object Generation from Reality Capture

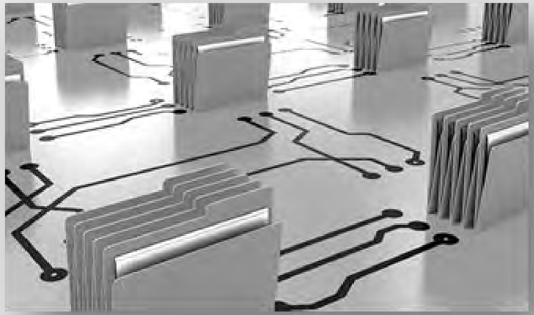
Digital Object Recognition using GeoAI



Data-Centric Approach to AI Development

DATA AGGREGATION

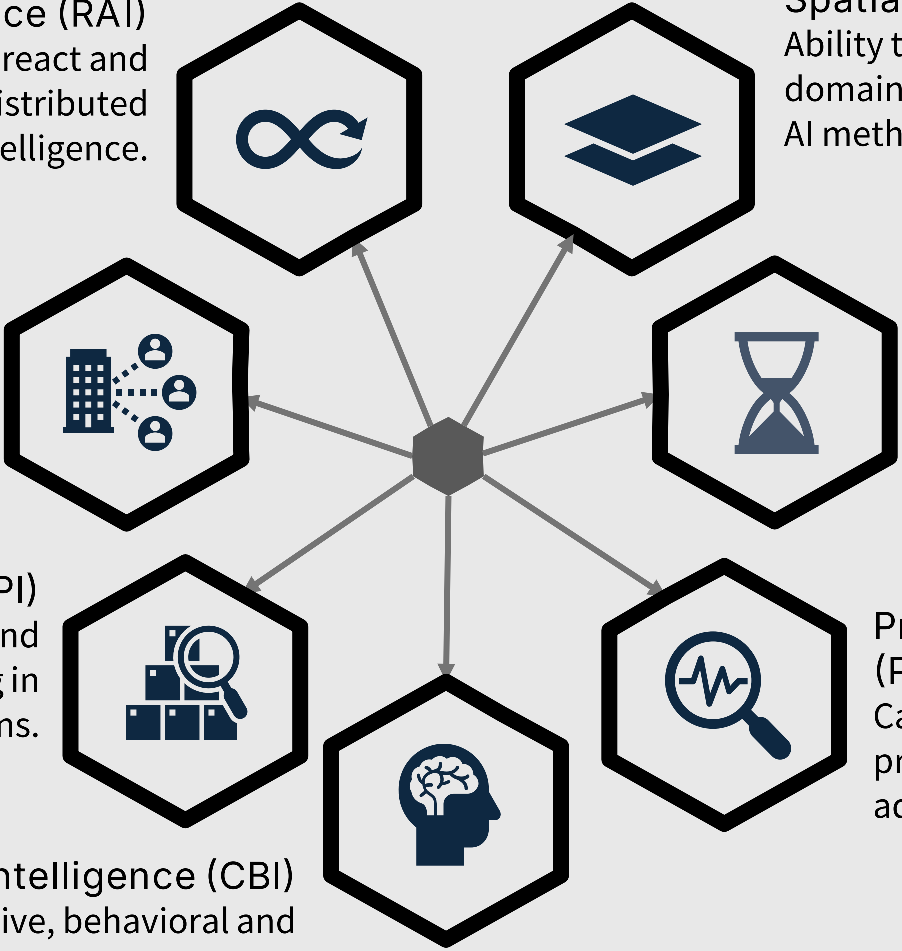
DATA VALIDATION



DATA STANDARDIZATION

DATA PIPELINES

Intelligent Digital Transformation Approach



Reactive – Adaptive Intelligence (RAI)
Ability of systems, components and elements to react and adapt to changes dynamically or use distributed intelligence.

Spatial – Geospatial Intelligence (SGI)
Ability to understand and respond across spatial domains and scales and use advance geospatial AI methods and approaches.

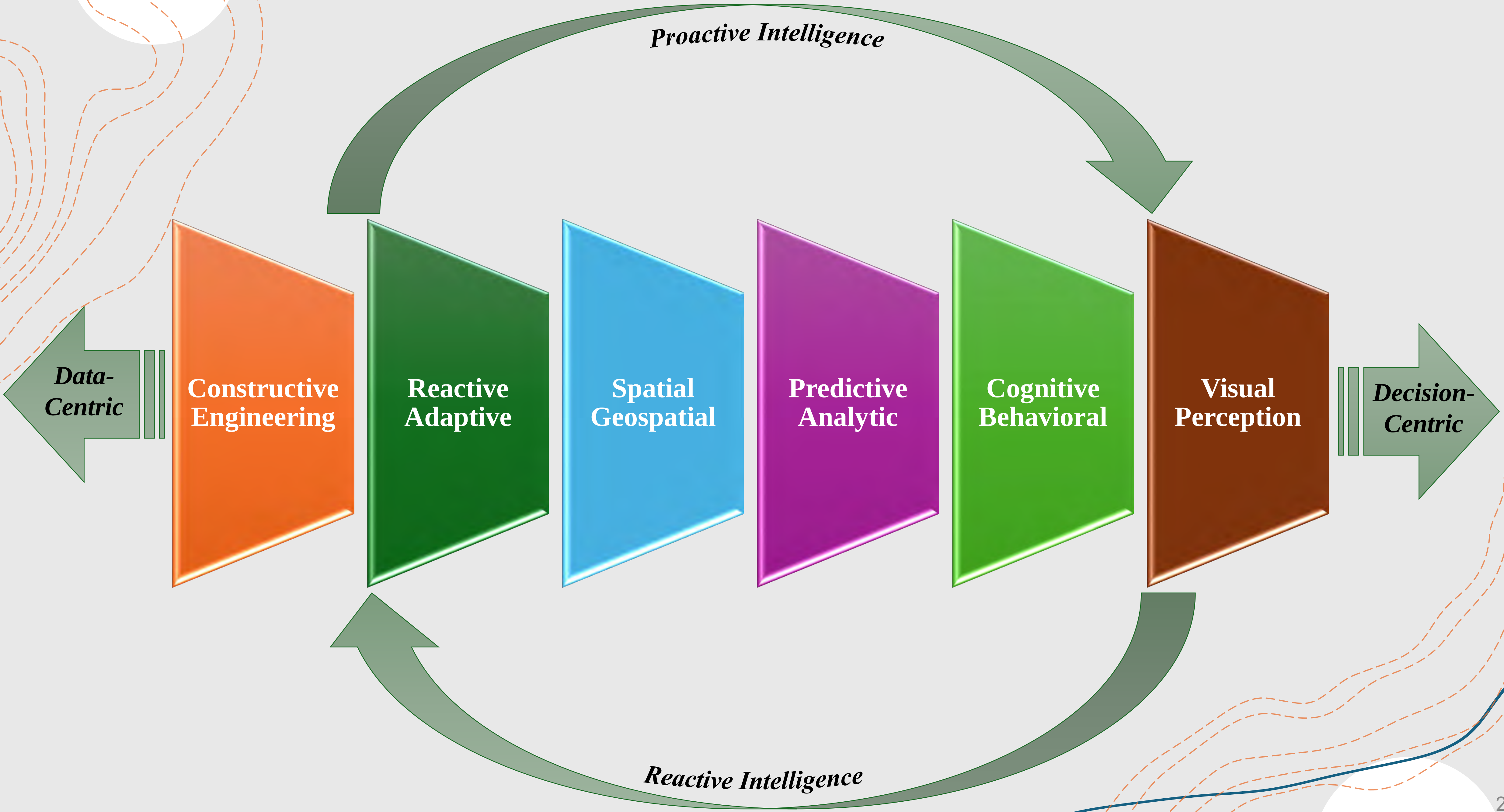
Constructive – Engineering Intelligence (CEI)
Intelligence related to physical systems and built structural environment and related systems including stationary, non-stationary, stochastic and dynamic physical systems.

Temporal – Transient Intelligence (TTI)
Intelligent abilities and emergence of patterns at multiple temporal scales from historical to real-time, to future predictions.

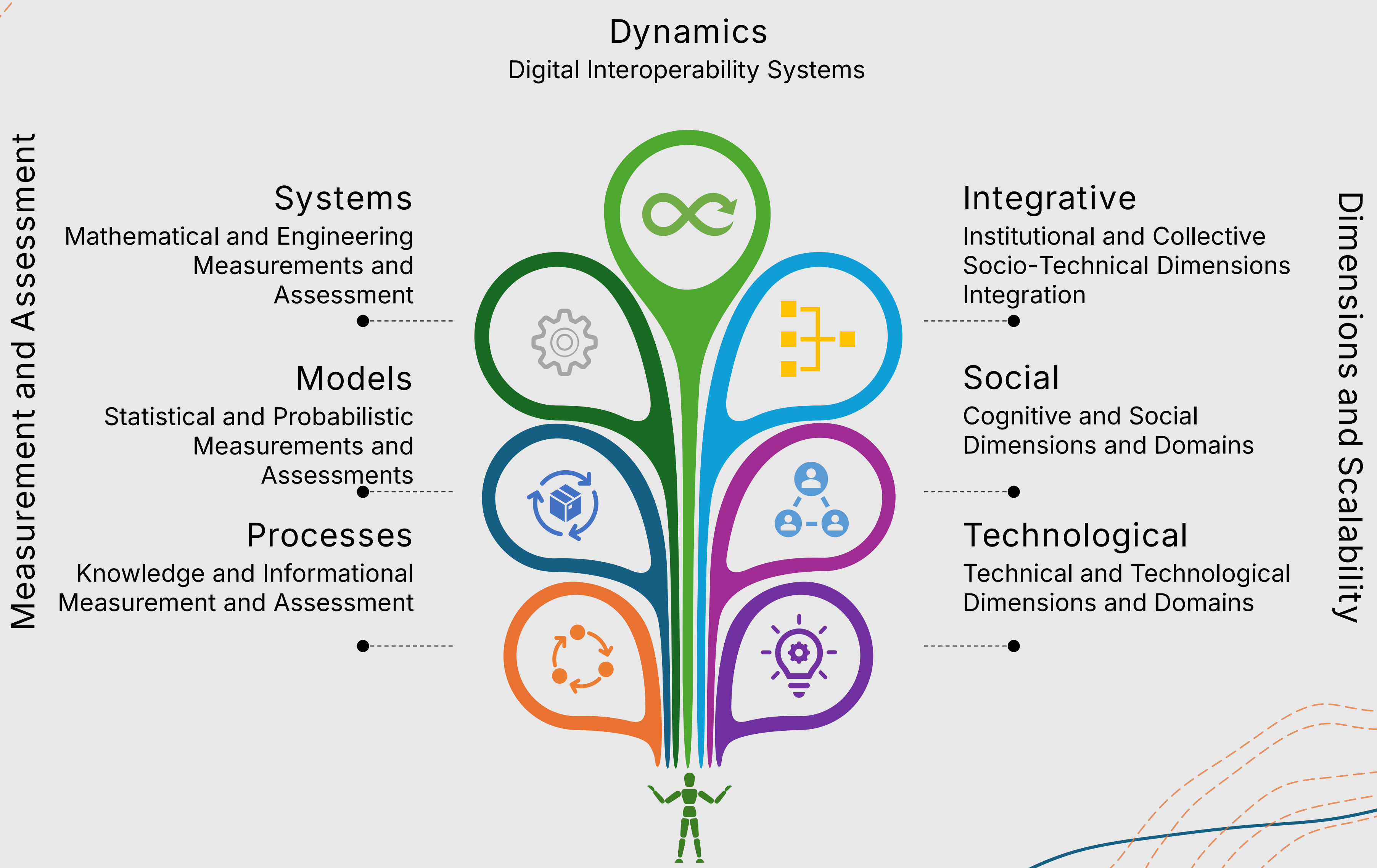
Visual – Perceptional Intelligence (VPI)
Utilizing advanced visual intelligence (VQ) and perceptions related to decision making in complex problem formulations.

Predictive – Analytic Intelligence (PAI)
Capacities and capabilities related to prediction and analytics stemming from advanced AI modeling and simulation.

Cognitive – Behavioral Intelligence (CBI)
Incorporating and integrating cognitive, behavioral and social general approaches of coupled natural-human and socio-technical systems and their dynamics.


Proactive Intelligence
Data-
Centric
Constructive
Engineering
Reactive
Adaptive
Spatial
Geospatial
Predictive
Analytic
Cognitive
Behavioral
Visual
Perception
Decision-
Centric
Reactive Intelligence

Digital transformations in complex integrated systems context



GeoAI framework’s points of interest

+ Full automation of workflows
+ Achieving near real-time results
+ Towards an augmented reality approach to high-resolution visualizations
+ Real-world production experience and implementation of big-data structures (terra-data workflows)
+ Successful partnering of government and public/community benefits with private/commercial sector (AI & cloud processing)

GeoAI framework’s points of interest

+ Intelligent management and operational processing of critical urban public infrastructure and resources.
+ Preparing and embracing digital transformation and digital innovation technologies in service of communities and citizens.
+ High-value, data-centric and scientific approach to County’s geospatial service provisioning.
+ Reducing uncertainty and subjective interpretations for decision-making
+ Implementing knowledge economies of scale

GeoAI framework's points of interest

+ Utilizing highly-valued skills and competencies
+ Reducing labor costs whilst producing added-value services for the citizens and the community at large (public benefits)
+ Adopting innovation, creative thinking and cutting-edge technologies at the core of the Orange County's geospatial services public service
+ Promoting learning, teaching and outreach for training the next generation of employees and collaborators

Technology trends

- More likely than not **real-time**, **real-world**, and **reality-like-visualization** are dominating the future developments.
- **Cross-disciplinary**, ability to cross professional boundaries and skills are key.
- What can you do to **stand out** of the crowd? How can your skills and training set you apart from others?
- Adopt a **continuous learning** and skill-development attitude.
- Learn to work and thrive in **group environments** and collective work settings.
- **Embrace complexity** and cutting-edge technology. Do not settle with what you already know and feel comfortable with.
- **Challenge yourselves** and others around you. Think outside the box.

Big Data and Open Science

- Technological push towards **big data**.
- Need for integrated solutions tackling pressing issues with **real impact** for our societies.
- Movement towards **open**-data, open-source, open-science.
  - **Fusion and synergism** between science proliferation and technology.
  - **Managing the complex** – embracing complexity, understanding

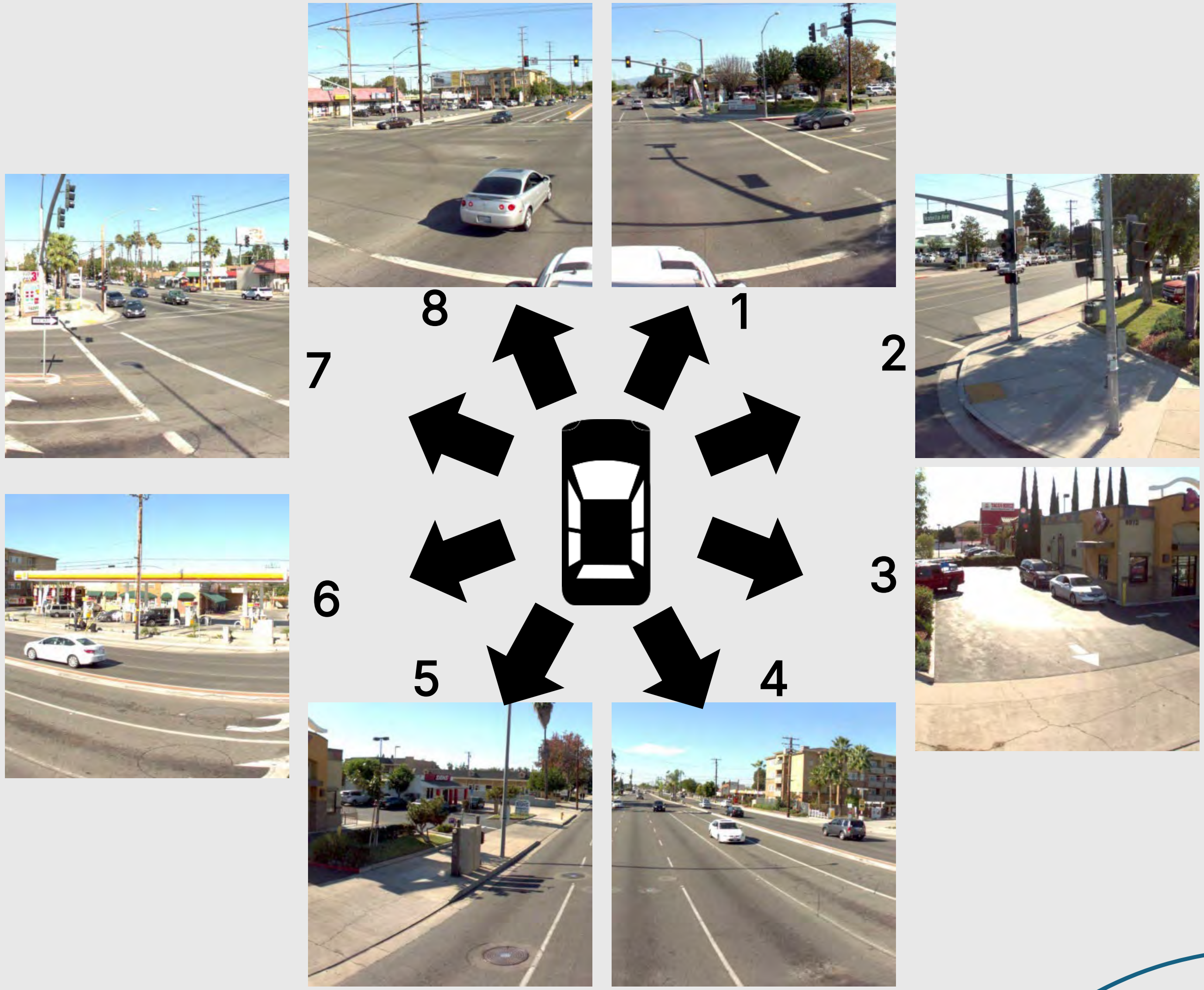
Stage 1: Crop original photosphere (8000 × 8000) to a functional area (1000 × 8000)

Photosphere 360° image segmentation

1000 pixels

1000 pixels

Stage 2:
Separate functional area into 8 cardinal directions (1000×1000) pixels each

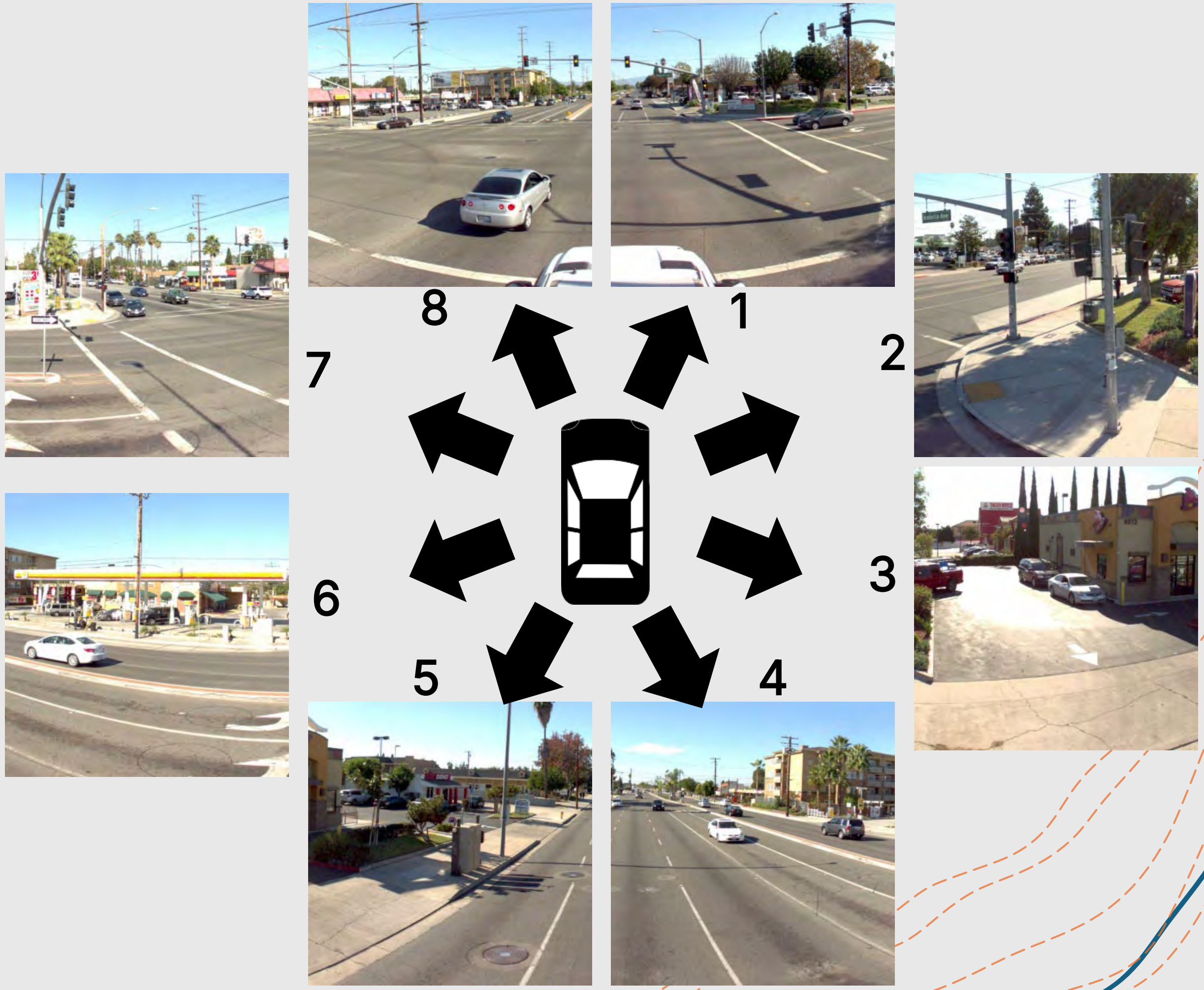


Stage 3:
Perform analysis of each cardinal images using Azure Cognitive Services Computer Vision API

Directional angle detection

Notes:

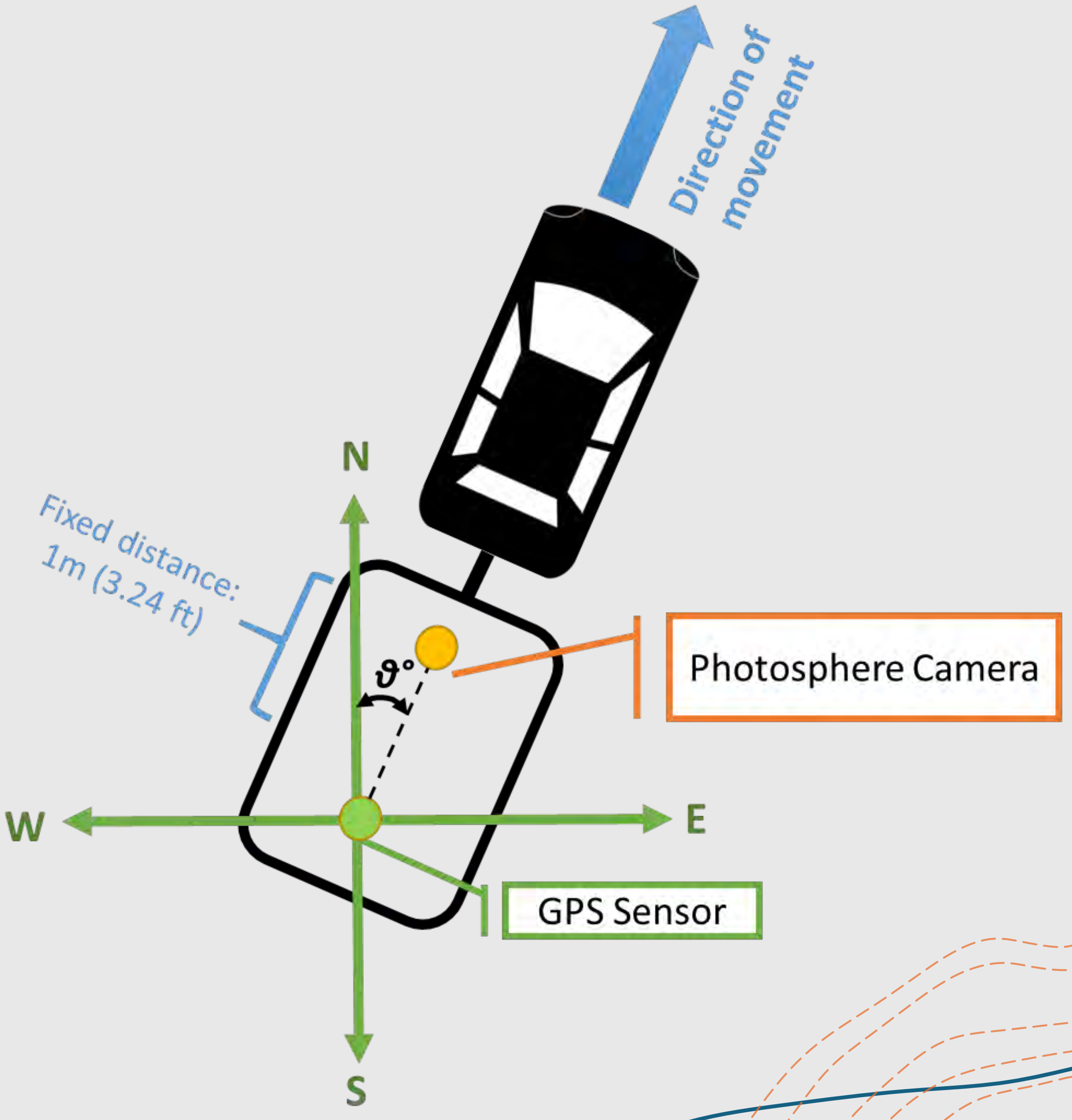
- If we know driving directions, then we know cardinal direction of images. E.g., if vehicle travels N:
  - Dir 1 = NNE (0° - 45°)
  - Dir 2 = ENE (45° - 90 °)
  - Dir 3 = ESE (90° - 135°)
  - Dir 4 = SSE (135° - 180°)
  - Dir 5 = SSW (180° - 225°)
  - Dir 6 = WSW (225° - 270°)
  - Dir 7 = WNW (270° - 315°)
  - Dir 8 = NNW (315° - 360°)
- Each pixel is 0.045° (360°/8000 pixels)
- Cropping original photosphere images reduces noise and helps pinpoint objects more accurately.
- Splitting image into cardinal directions helps object and pattern recognition.



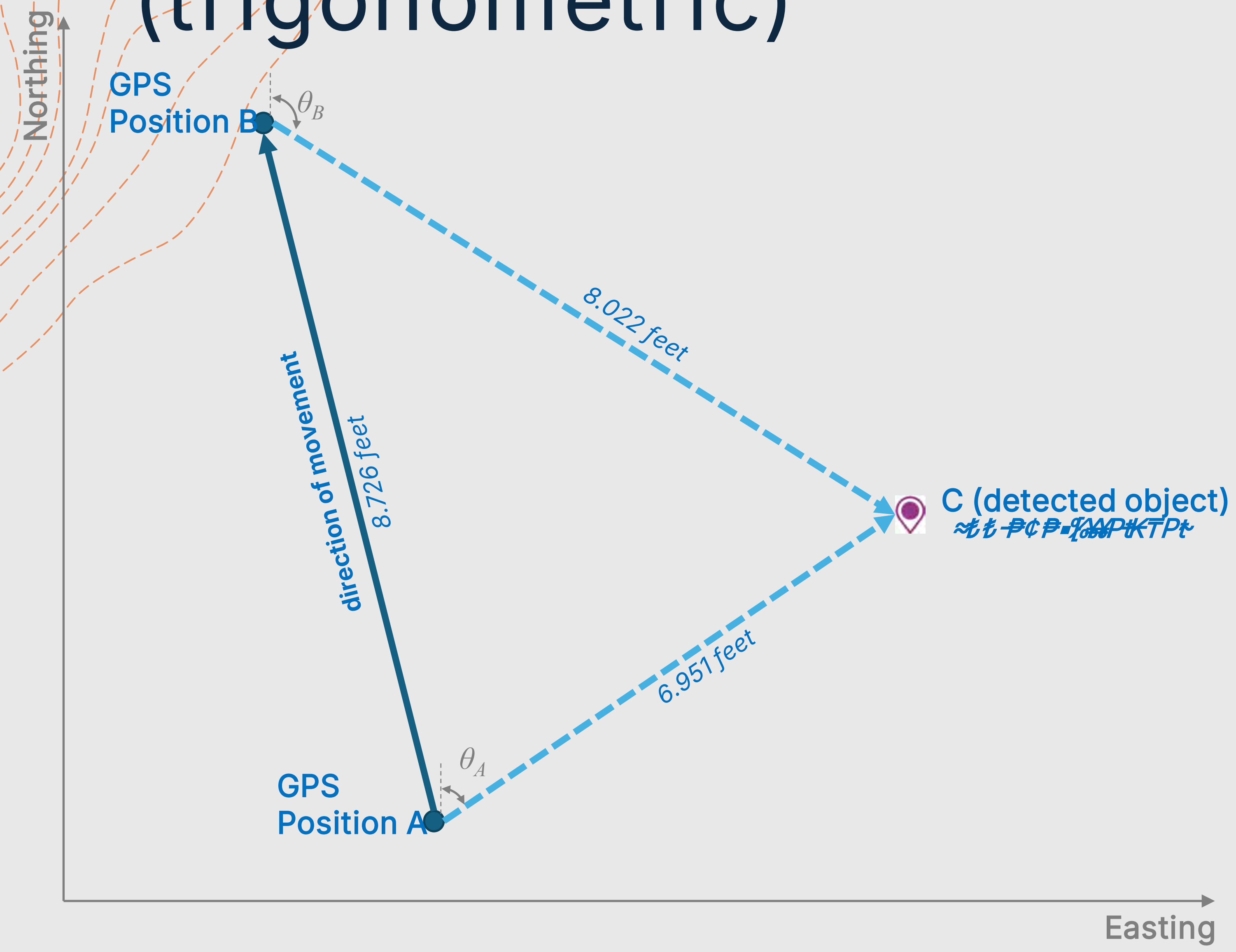
Directional position corrections

Direction (θ):
inverse tangent function expressed in degrees:

θ = degrees(arctan (Easting, Northing)) - 180°
if $\theta < 0$:
$\theta' = (\theta + 360°) \% 360$



Detected object position algorithm (trigonometric)



From directions to slopes:

$$\mu_A = \tan(\theta_A) = \frac{y_A - y_C}{x_A - x_C}$$

$$\mu_B = \tan(\theta_B) = \frac{y_B - y_C}{x_B - x_C}$$

Calculated object coordinates :

$$x_C = \frac{y_B - y_A + \mu_A x_A - \mu_B x_B}{\mu_A - \mu_B}$$

$$y_C = y_A - \mu_A \left(x_A - x_C \right)$$

ML Vision Detection Methods

+ML methods:

Google Cloud Vision

Image Annotator Client:

- label detection
- object localization (multiple)

Azure Cognitive Services Computer Vision

Analyze Visual Features:

- Categories
- Tags
- Description
- Image Type
- Color
- Objects (multiple)

AI can be trained to detect any visible object

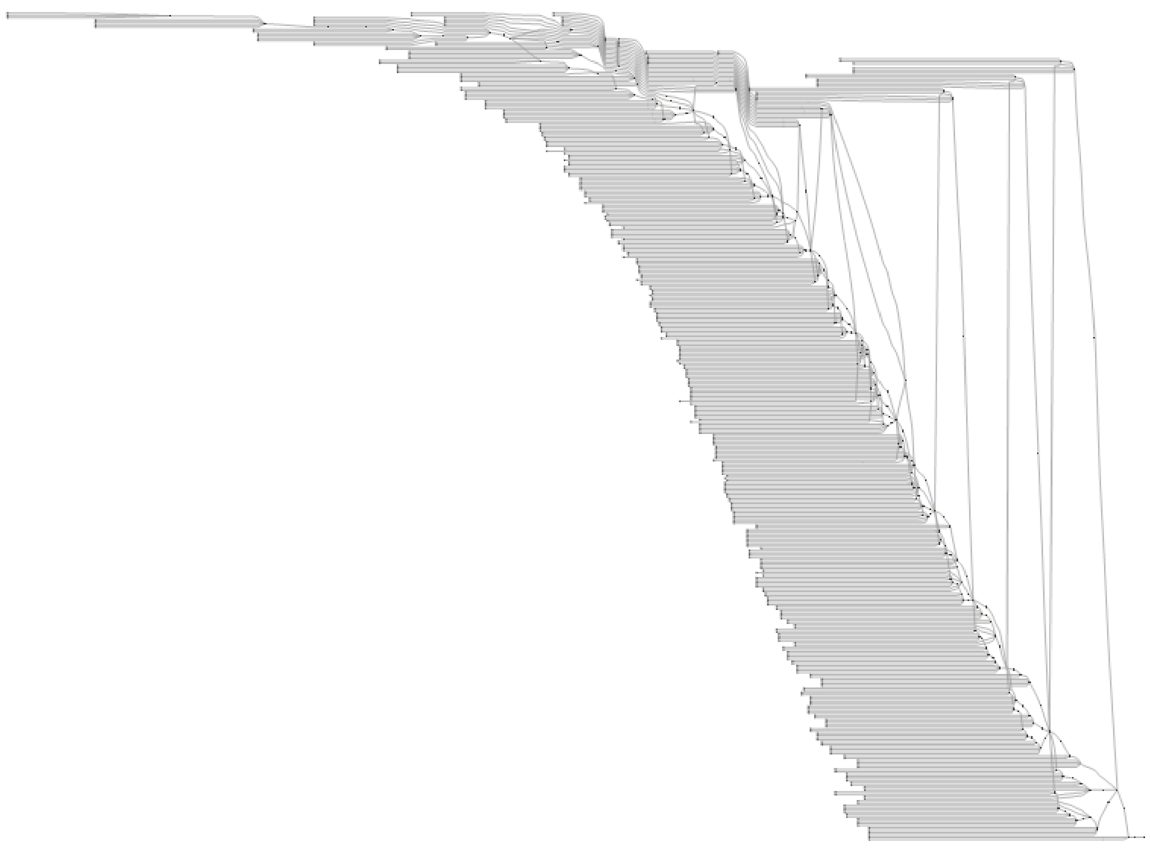
- As ML and AI tools improve, the number of features and the accuracy with which we can detect them will improve
- Can expand AI to look for cracks in pavement/potholes
- Manholes, signs, other road assets
- Real Time processing of 360 photos

GeoAI: Deep Learning Convolutional ANN Model

+ Network Configuration

+ Network Topology

		image
	Input	array (size: 3 × 224 × 224)
conv_1	ConvolutionLayer	array (size: 64 × 112 × 112)
bn_1	BatchNormalizationLayer	array (size: 64 × 112 × 112)
relu_1	Ramp	array (size: 64 × 112 × 112)
pool_1	PoolingLayer	array (size: 64 × 55 × 55)
conv_2_red	ConvolutionLayer	array (size: 64 × 55 × 55)
bn_2_red	BatchNormalizationLayer	array (size: 64 × 55 × 55)
relu_2_red	Ramp	array (size: 64 × 55 × 55)
conv_2	ConvolutionLayer	array (size: 192 × 55 × 55)
bn_2	BatchNormalizationLayer	array (size: 192 × 55 × 55)
relu_2	Ramp	array (size: 192 × 55 × 55)
pool_2	PoolingLayer	array (size: 192 × 27 × 27)
3a	NetGraph (23 nodes)	array (size: 256 × 27 × 27)
3b	NetGraph (23 nodes)	array (size: 320 × 27 × 27)
3c	NetGraph (17 nodes)	array (size: 576 × 14 × 14)
4a	NetGraph (23 nodes)	array (size: 576 × 14 × 14)
4b	NetGraph (23 nodes)	array (size: 576 × 14 × 14)
4c	NetGraph (23 nodes)	array (size: 608 × 14 × 14)
4d	NetGraph (23 nodes)	array (size: 608 × 14 × 14)
4e	NetGraph (17 nodes)	array (size: 1056 × 7 × 7)
5a	NetGraph (23 nodes)	array (size: 1024 × 7 × 7)
5b	NetGraph (23 nodes)	array (size: 1024 × 7 × 7)
global_pool	PoolingLayer	array (size: 1024 × 1 × 1)
linear	LinearLayer	vector (size: 4315)
softmax	SoftmaxLayer	vector (size: 4315)
	Output	class



Example: Stop Sign detections

Image	Concept	BoundingBox	Probability
	stop sign	Rectangle[{635.781, 362.607}, {732.331, 466.488}]	0.846811

tagged and labeled

Alternative display output configurations

Focused with darkened background

Multiple object type detections

Image	Concept	BoundingBox	Probability
	stop sign	Rectangle[{635.781, 362.607}, {732.331, 466.488}]	0.846811

Image	Concept	BoundingBox	Probability
	person	Rectangle[{372.419, 60.3142}, {455.796, 215.575}]	0.713712
	automobile	Rectangle[{480.086, 339.012}, {650.738, 390.345}]	0.600908
	automobile	Rectangle[{640.382, 326.726}, {785.321, 383.847}]	0.523947

Image	Concept	BoundingBox	Probability
	automobile	Rectangle[{379.327, 205.512}, {570.379, 337.324}]	0.594767

Missing[NotRecognized]

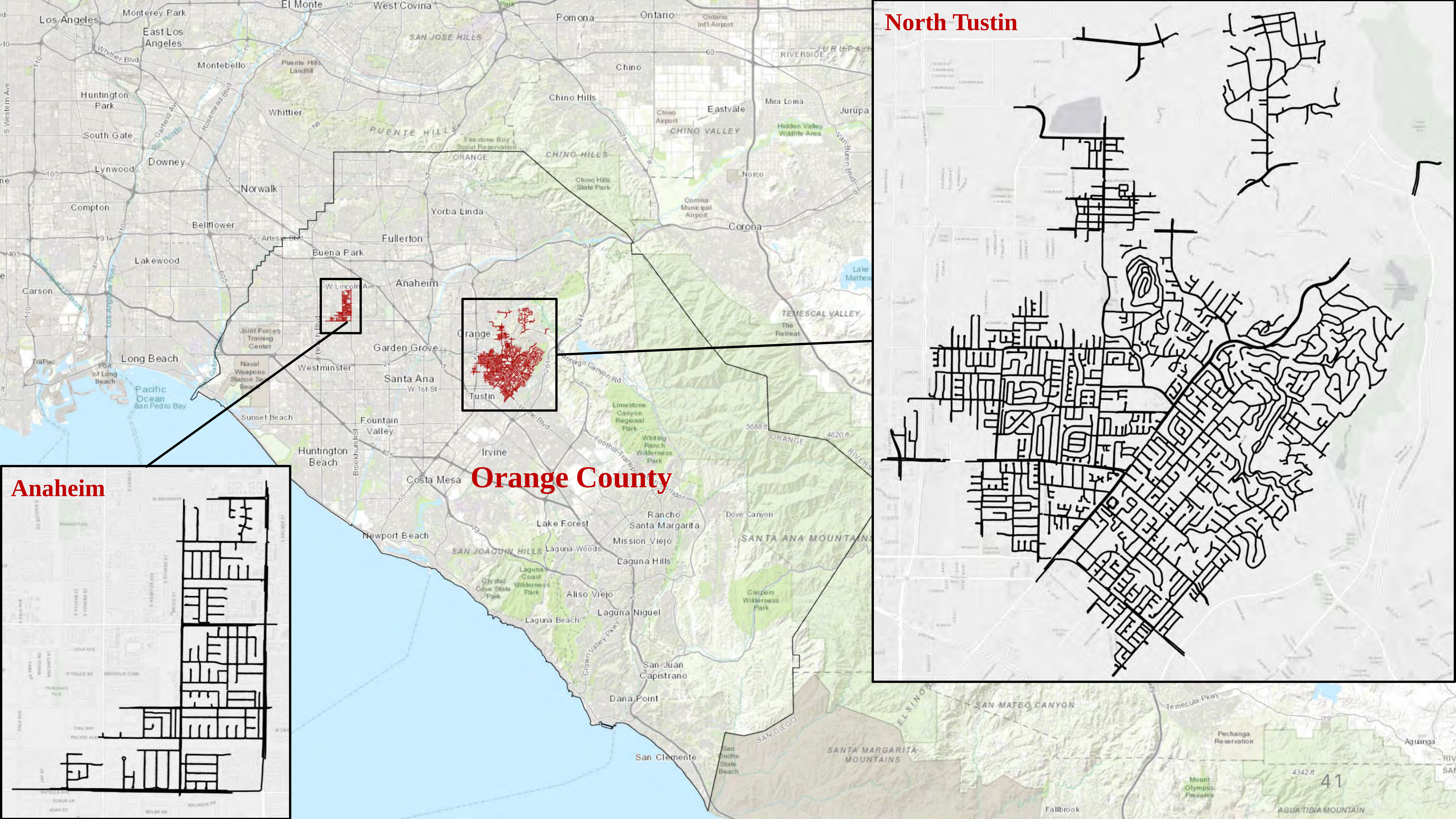
Image	Concept	BoundingBox	Probability
	automobile	Rectangle[{245.991, 288.577}, {465.887, 365.635}]	0.727035
	automobile	Rectangle[{958.4, 384.183}, {1000, 428.596}]	0.557257

Multiple object type detections

Photosphere Sensor configurations

+ Sensor measurements approximately 10 feet apart (speed invariant).

Example Application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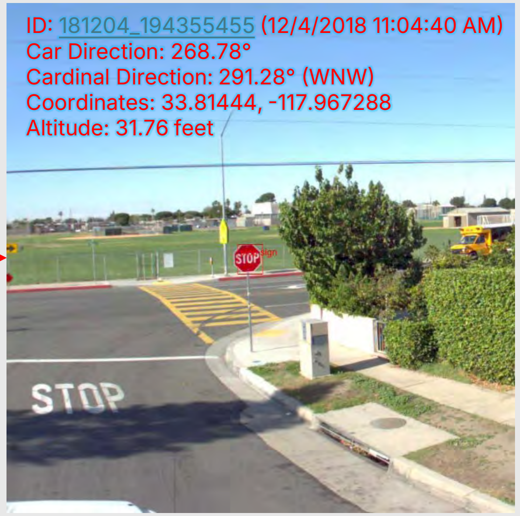
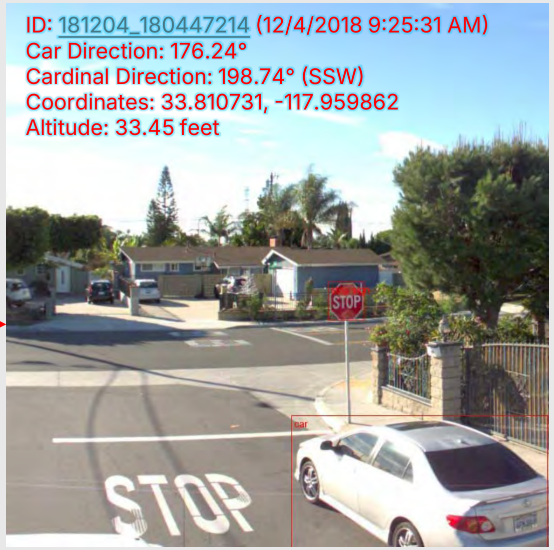
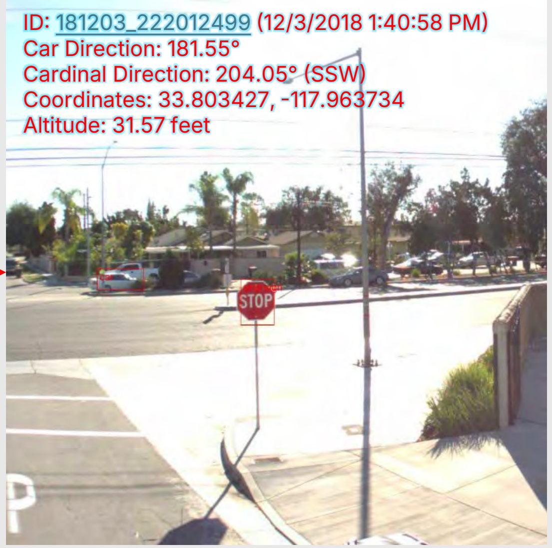
Anaheim
Orange County
Los Angeles
Monterey Park
El Monte
West Covina
Pomona
Ontario
East Los Angeles
Montebello
Huntington Park
Whittier
South Gate
Downey
Lynwood
Norwalk
Compton
Bellflower
Lakewood
Carson
Long Beach
Pacific Ocean
San Pedro Bay
Chino
Chino Hills
Eastvale
Mira Loma
Jurupa
Riverside
Norco
Corona
Yorba Linda
Fullerton
Buena Park
Garden Grove
Westminster
Santa Ana
Orange
Tustin
Seal Beach
Sunset Beach
Fountain Valley
Huntington Beach
Irvine
Costa Mesa
Newport Beach
Lake Forest
Rancho Santa Margarita
Mission Viejo
Laguna Hills
Laguna Woods
Aliso Viejo
Laguna Niguel
Laguna Beach
San Juan Capistrano
Dana Point
San Clemente
PUENTE HILLS
CHINO HILLS
CHINO VALLEY
SAN JOSE HILLS
TEMESCAL VALLEY
SANTA ANA MOUNTAINS
SAN JOAQUIN HILLS
SANTA MARGARITA MOUNTAINS
SAN MATEO CANYON
Dove Canyon
Fallbrook
Aguanga
Santiago Canyon Rd

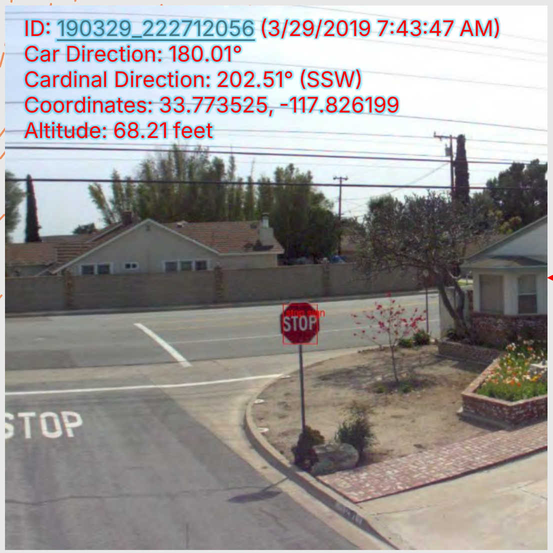
Anaheim Stop Signs

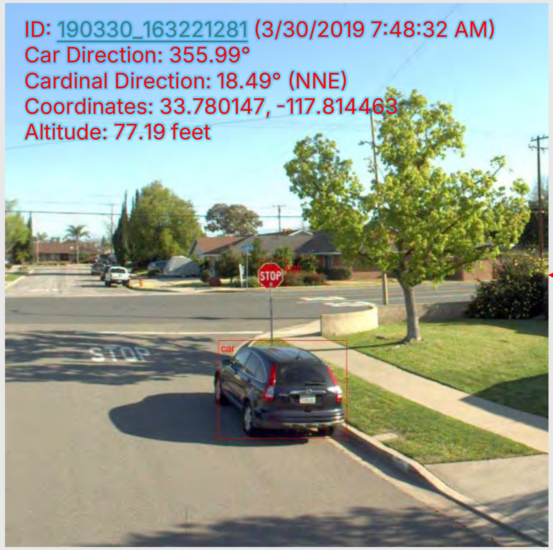


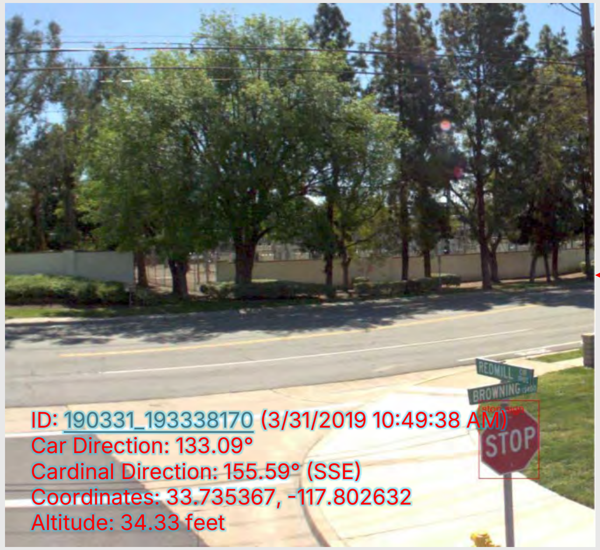


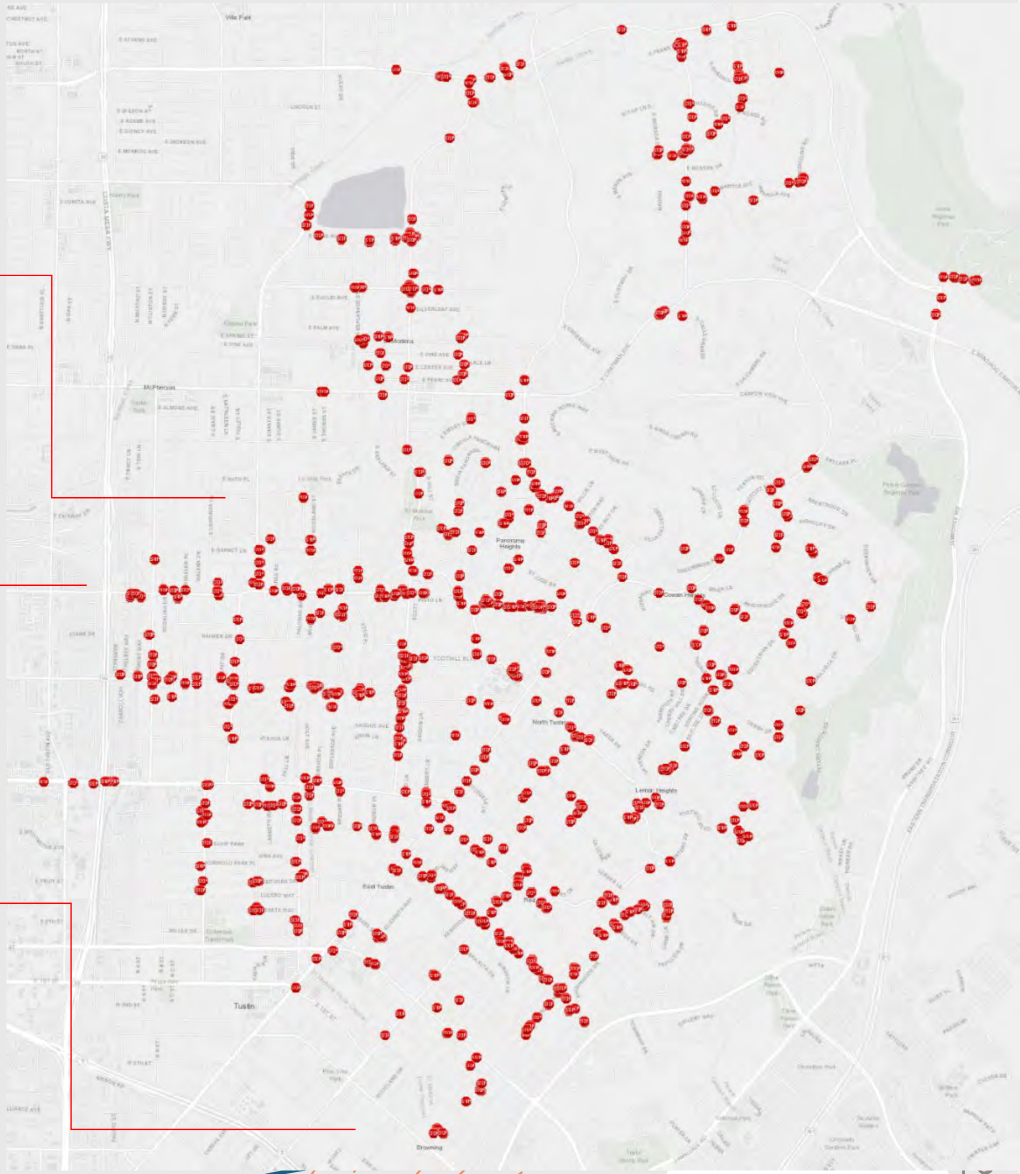


North Tustin Stop Signs







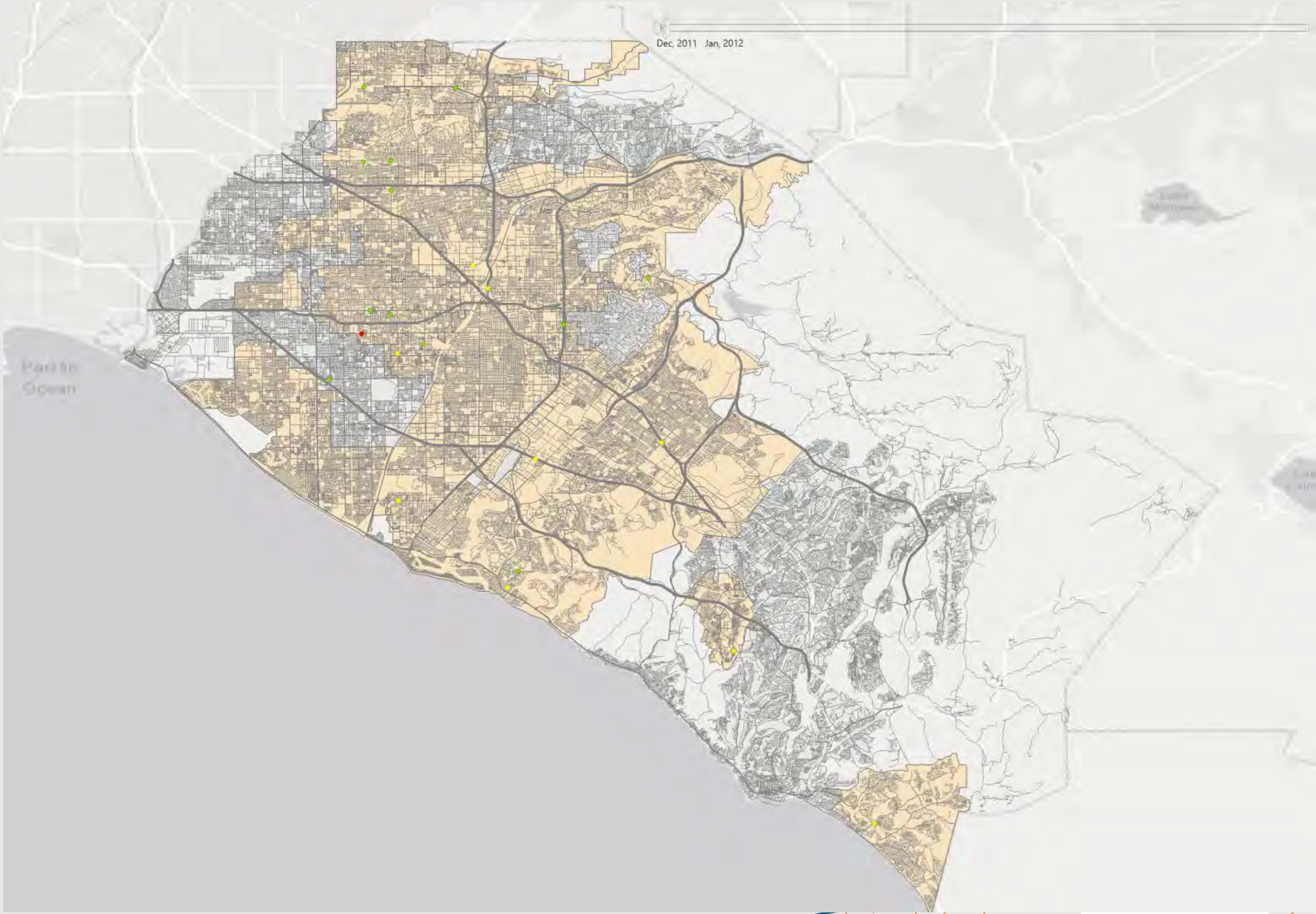


Traffic Incidents and Aggregation

SWITRS Incidents (2012-2025)
Crash Reports by Time
Aggregated by City
and Unincorporated Area

Parameters:
- Time Step: 1 Month
- Aggregated by City and Area (Raw Date and Time of Incident)

[Web App]

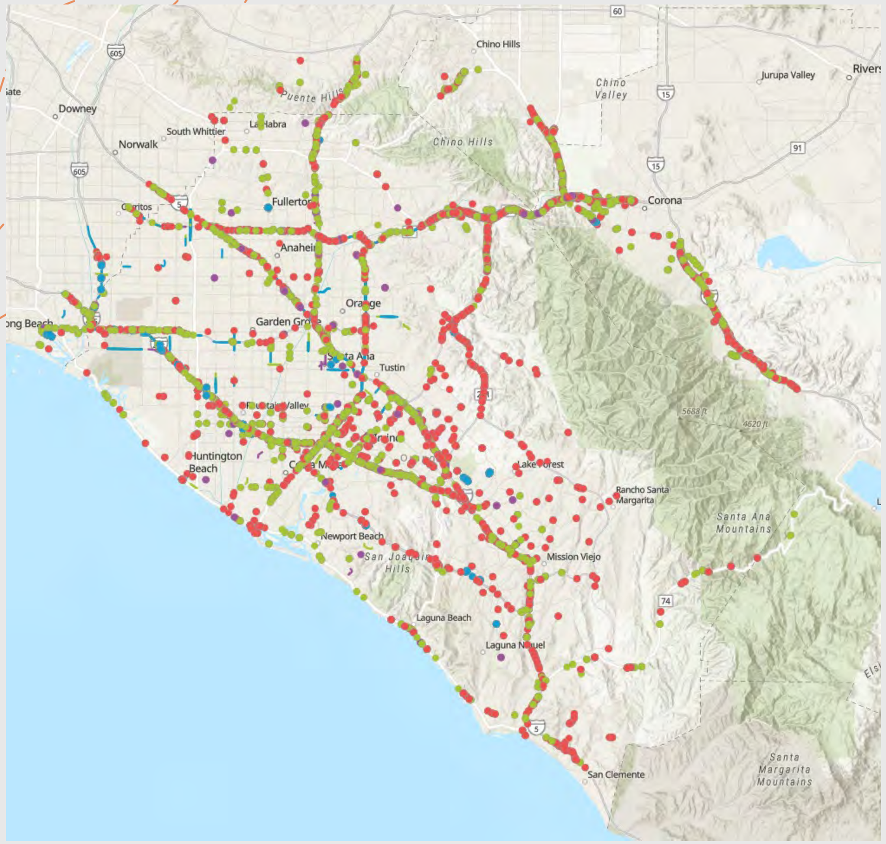


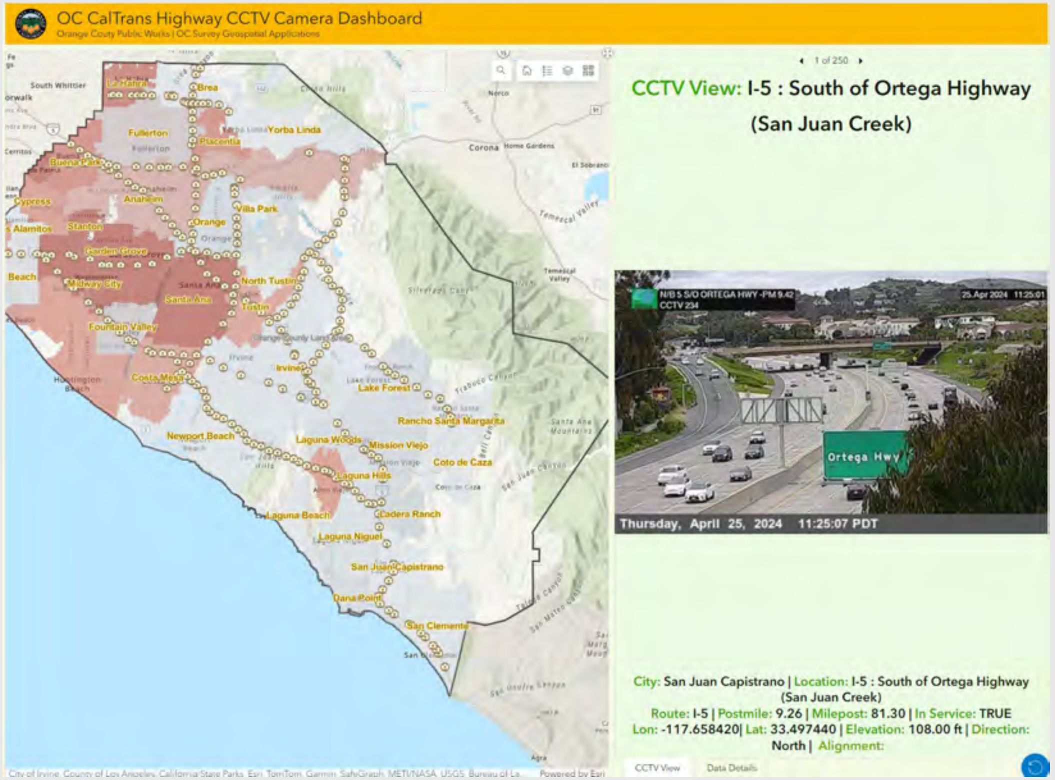
Collision Severity
- Fatal
- Injury (Severe)
- Injury (Other Visible)
- Injury (Complaint of Pain)
- Property Damage Only (PDO)

SWITRS: Total Incidents
- 164 - 259
- 103 - 163
- 50 - 102
- 20 - 49
- 1 - 19

Road Category
- Primary
- Secondary
- Local

Other Traffic Data

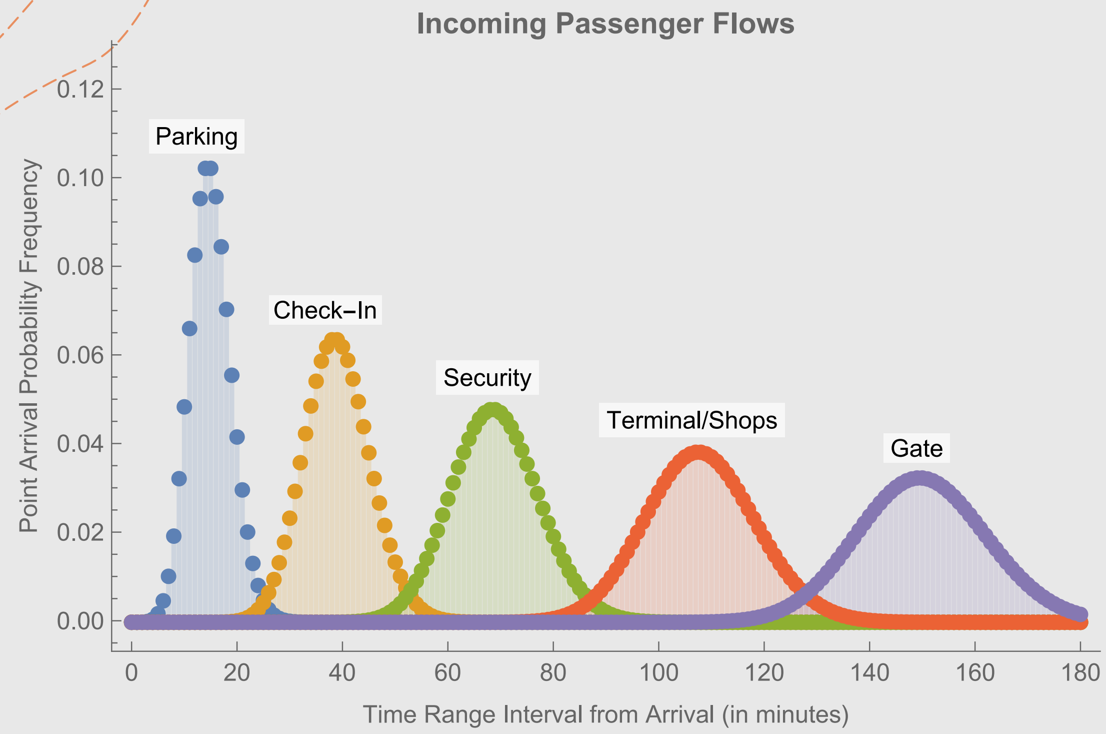


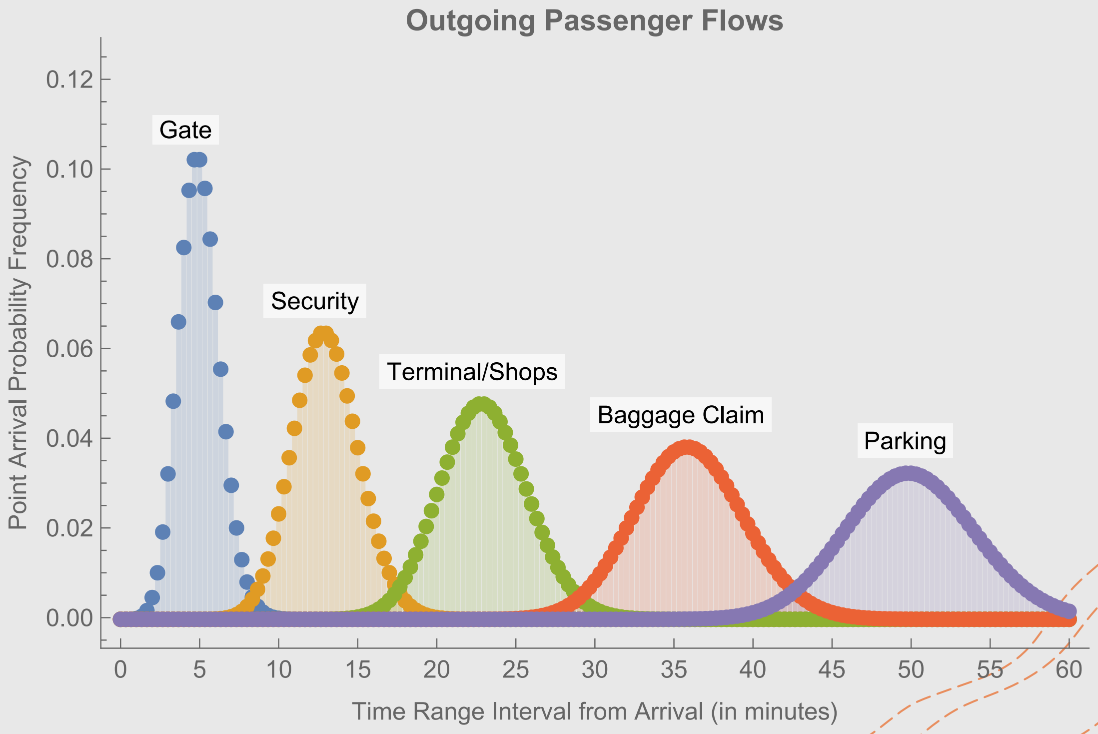


[OC Waze Partnership Data]

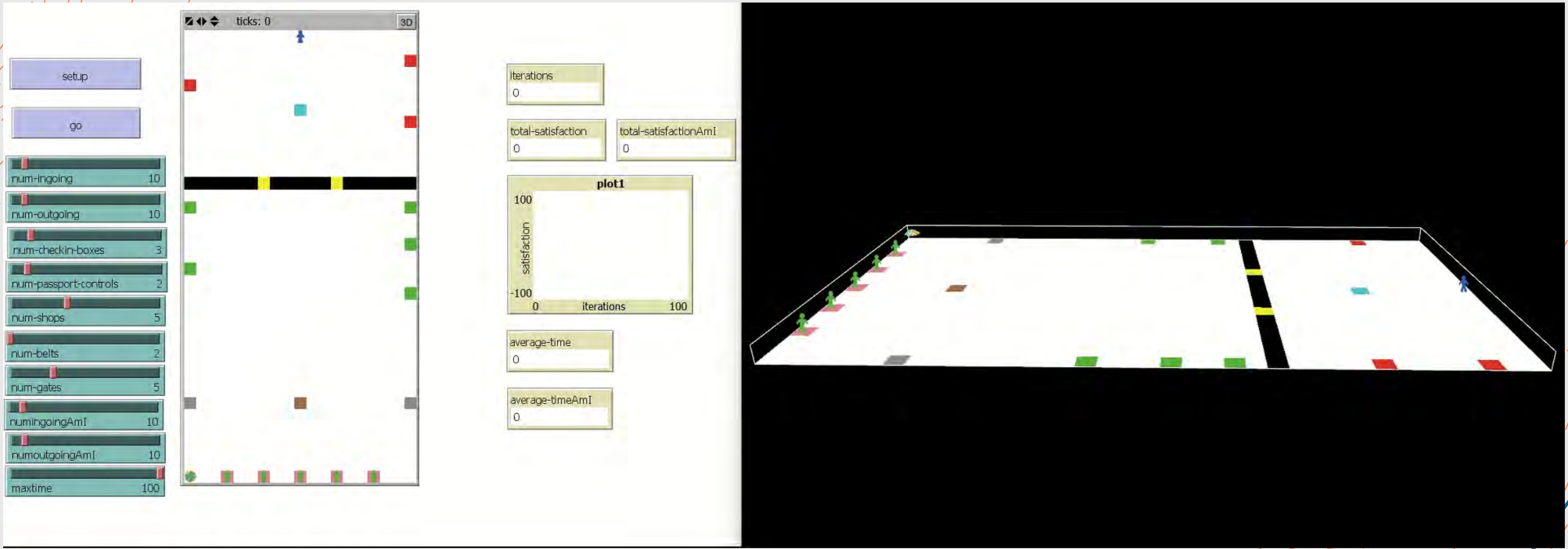
[Real-Time Camera Dashboards]

Smart Airport DT: Example passenger arrival distributions

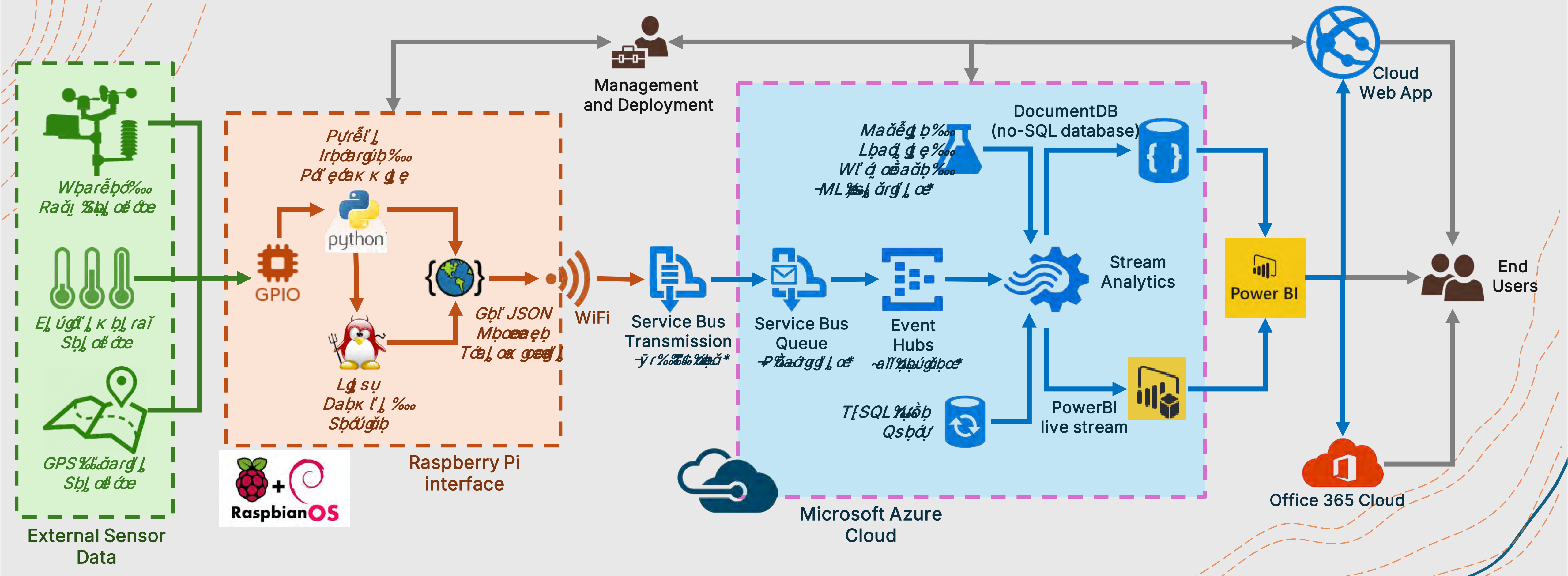




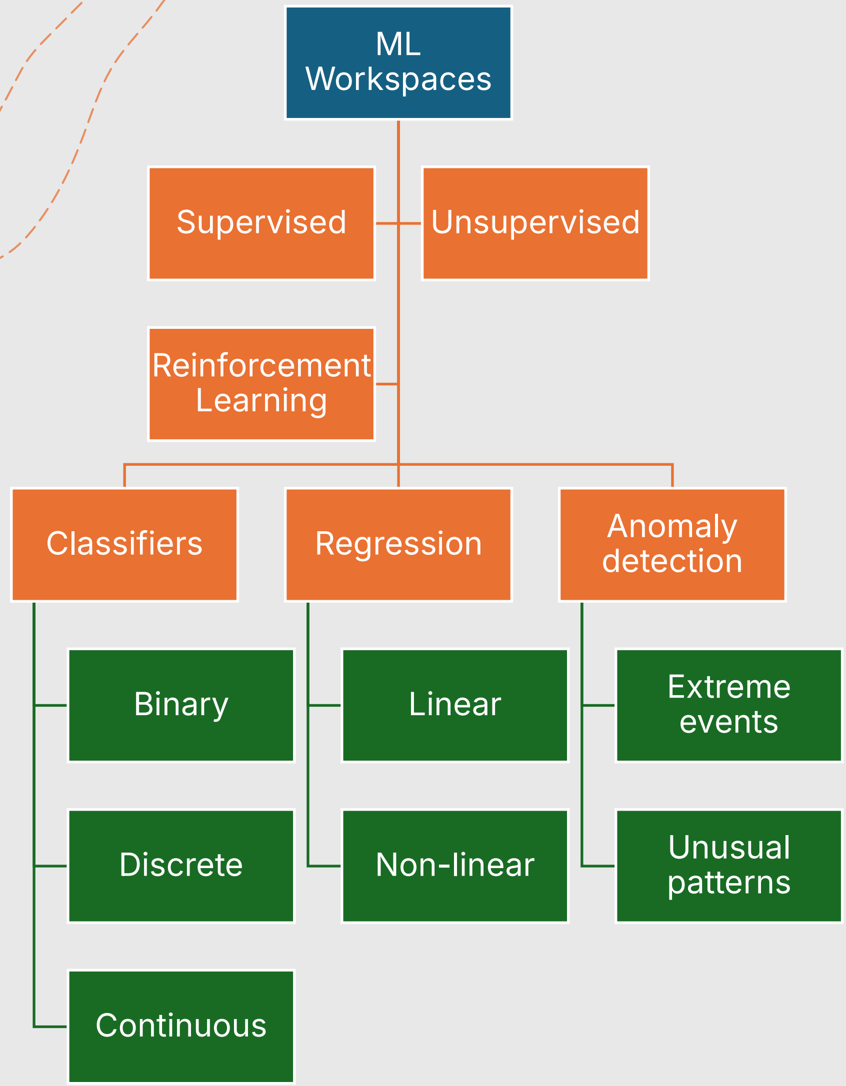
Smart Airport Agent-Based Modeling



Integrated IoT development



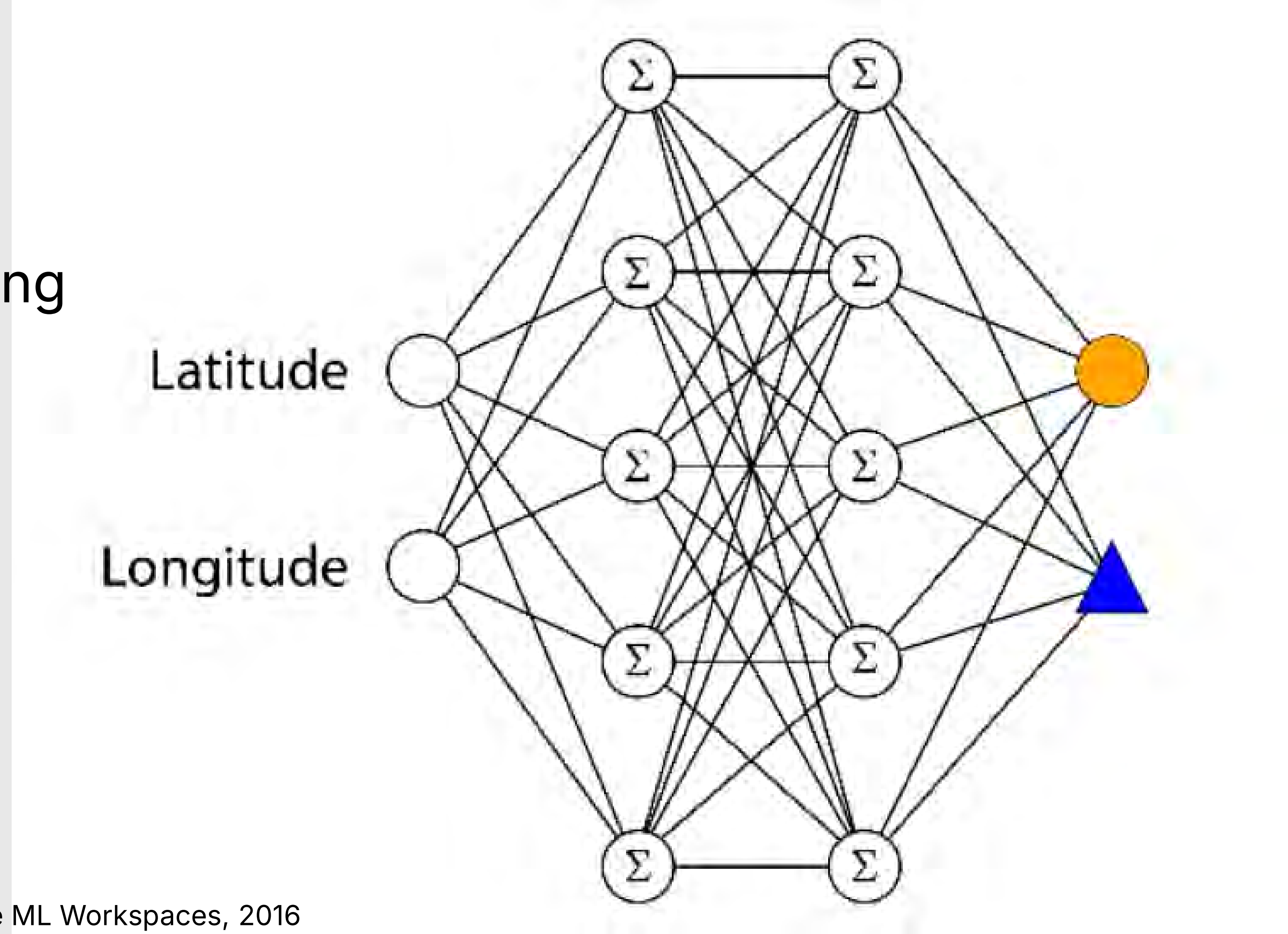
Big Data Machine Learning



- Example Algorithms:
  - Neural Networks
    - Averaged perceptron
    - Support Vector Machines
  - Bayesian (probabilistic)
    - Naïve Bayes
    - Bayes Point Machines
  - Regression-based
    - Linear
    - Logistic
    - Random Forests
  - Tree/Search-based
    - Decision trees
    - Boosted trees
    - PCA-based

Machine Learning Experiments

Example:
Spatial Boundary Prediction using 2-layer ANN Classifier



Source: Microsoft Azure ML Workspaces, 2016