Small Drone Field Experiment: Data Collection & Processing

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Motivation

Emerging drone technologies

Current and future ground operations rely on multi-sensing capabilities from UAS assets to provide enhanced persistent wide area coverage. Remote sensing from small UAS can map terrain features of potential conflict areas (e.g., urban areas) and classify & localize target materials to provide enhanced situational awareness

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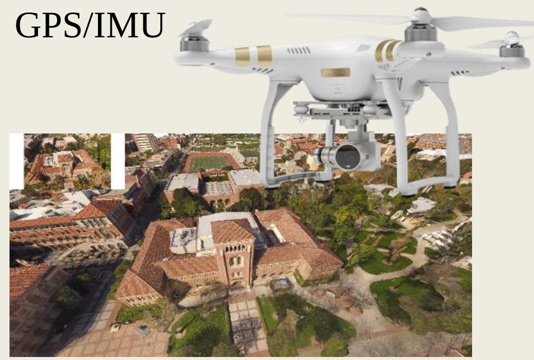
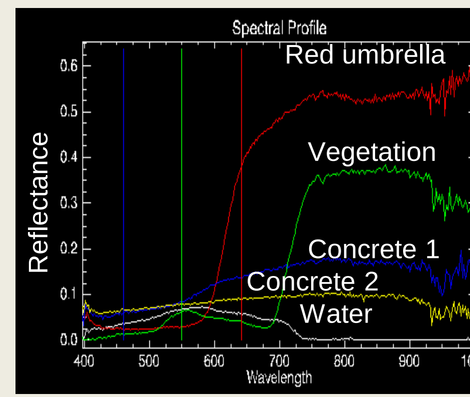
U.S. ARMY RDECOM® Ground & Aerial USC Data Collection ARL

USC Data Supported ARL West Summer Projects

Drone: Phantom 3 quadcopter
Camera: GoPro 3
Gimbal: 3-axis stabilization
GPS/IMU



Drone: Leica Aibotix X6 hexa-rotor
Sensor: Headwall's Nano-Hyperspec
Gimbal: 3-axis stabilization
GPS/IMU



Objective

- Explore the value of COTS drone/sensor system emerging technologies for enhanced Image Understanding
- Develop capability based on fusion of 3D DEMs & spectra for scene segmentation, and adaptive machine learning
- Jointly organize & conduct w/ ICT a data collection at USC main campus, consisting of ground-based and drone-based hyperspectral remote sensing, and drone based sensing for 3D point clouds from photogrammetry

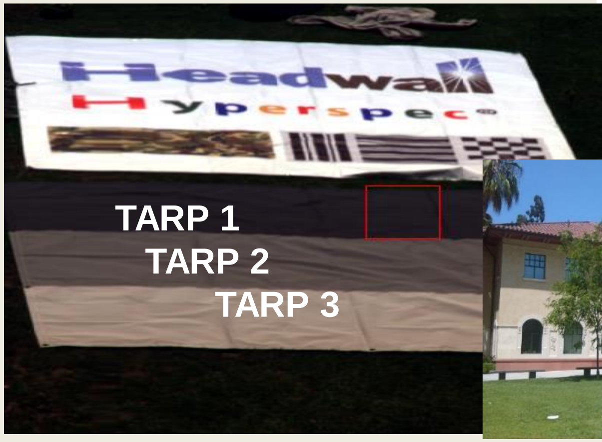
Impact

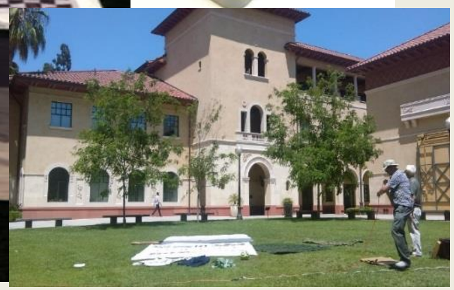
- Adaptive, Aerial Situational Awareness
  - Material classification map for Common Operating Picture (COP)
  - Adaptive semi-supervised machine learning

ARL, ARL West
USC/ ICT
Headwall Photonics
Leica Geosystems

USC Data Post-processing

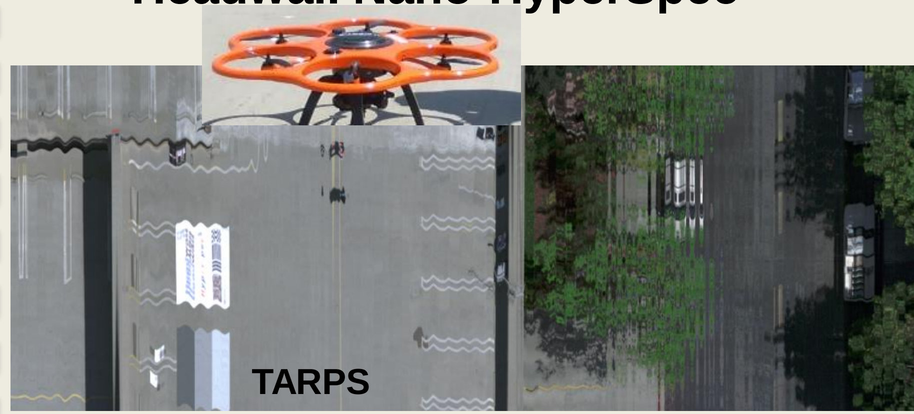
Ground Data Acquisition



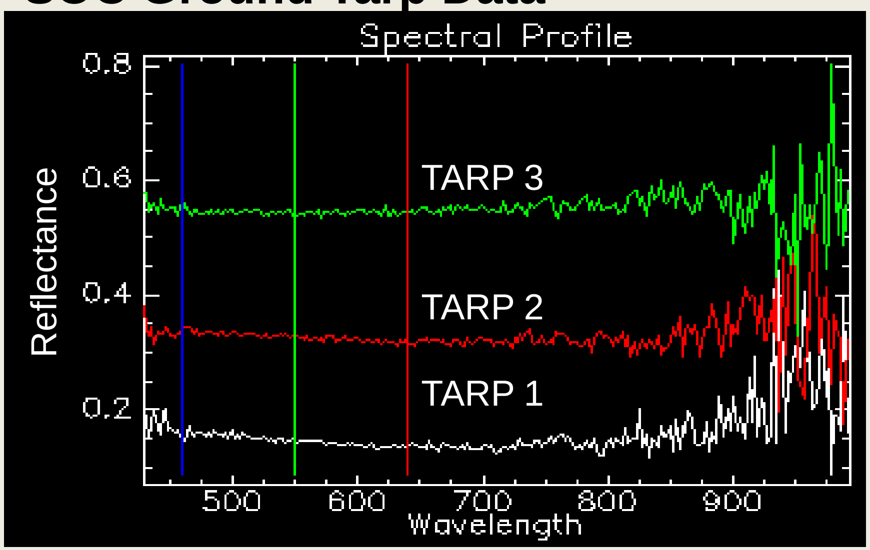


Aerial Data Acquisition

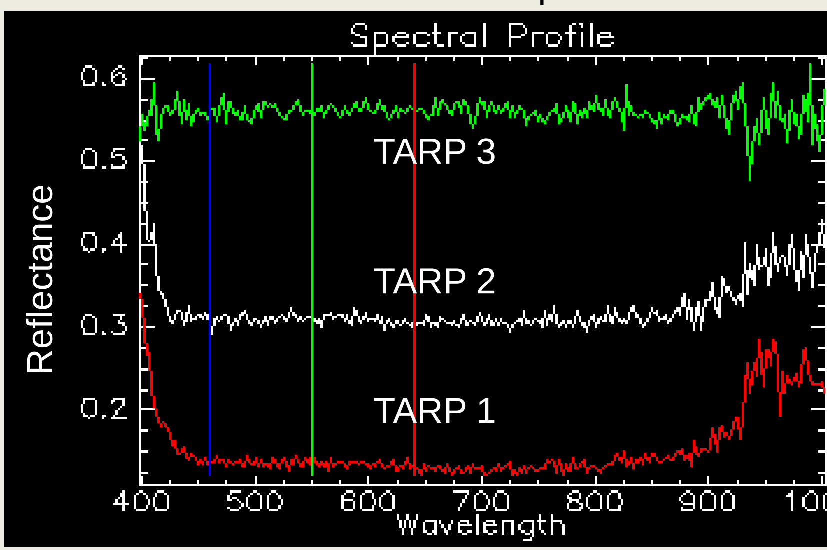
Headwall Nano-HyperSpec



SOC Ground Tarp Data



Headwall Aerial Tarp Data



U.S. ARMY RDECOM

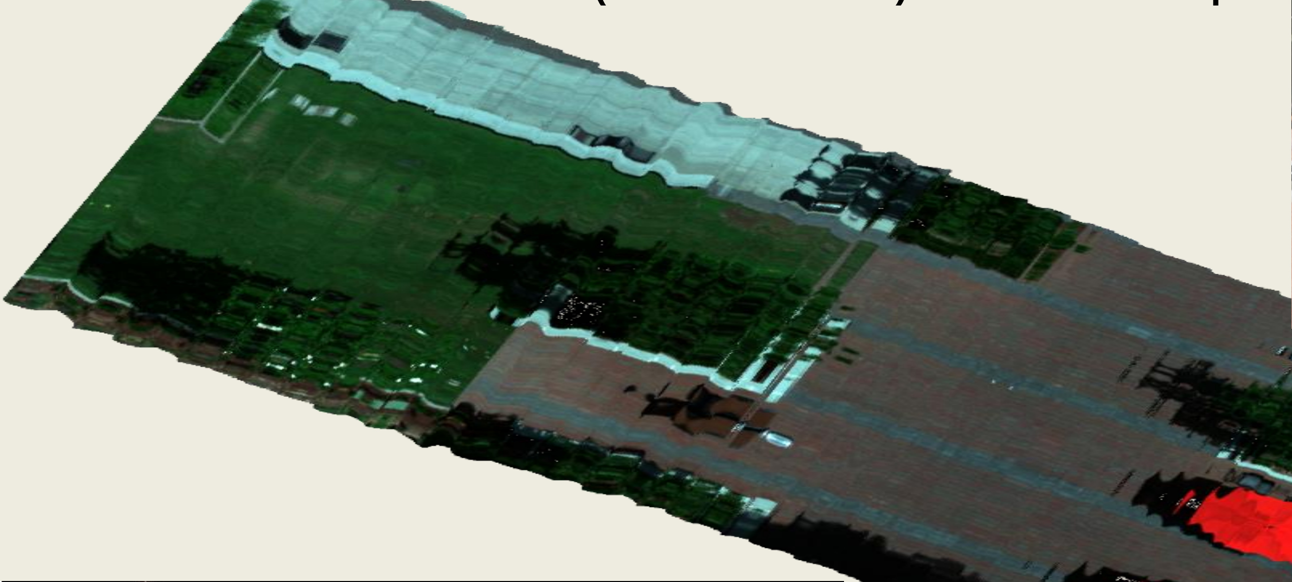
USC Data Post-processing

ARL

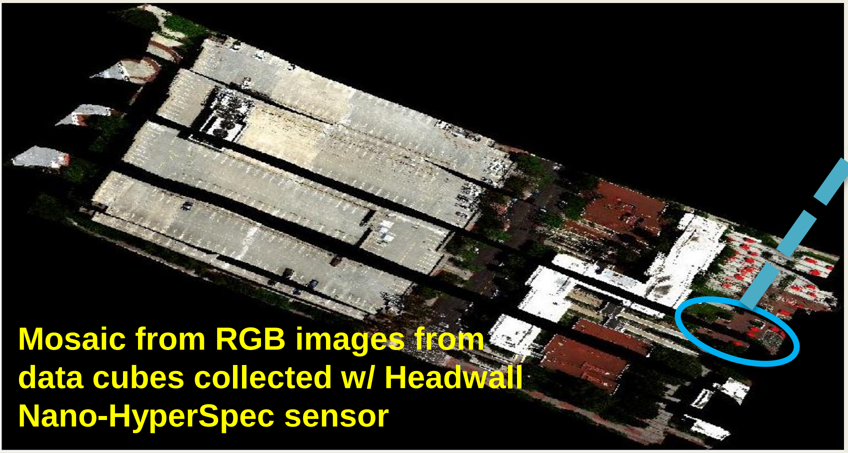
Low resolution Mosaic (17000x13000x272) from RGB image patches using all data cubes collected w/ Headwall Nano-hyperSpec sensor

USC Data Post-processing

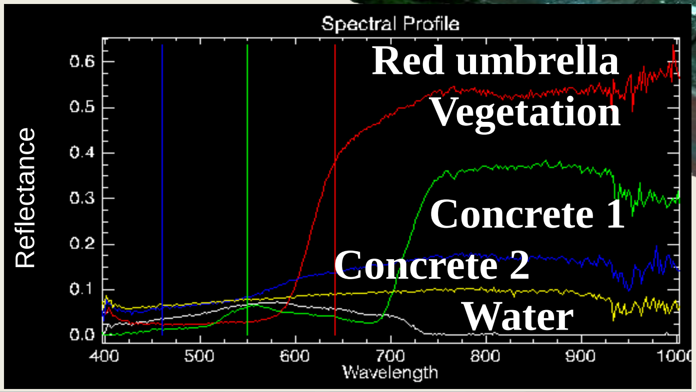
RGB image from a Headwall Nano-hyperspec data cube (640 x 1000 x 272) – USC main campus



Fountain at Epstein Family Plaza - USC main campus



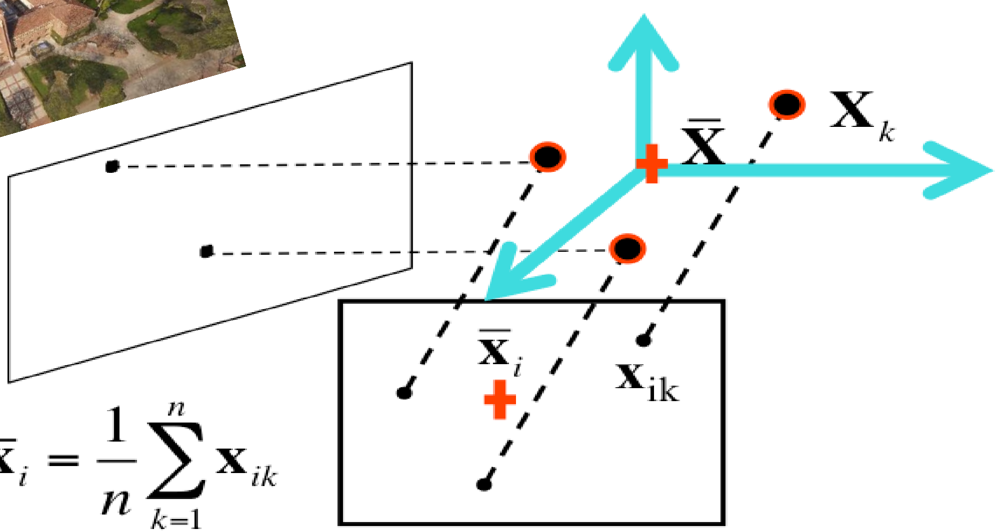
Mosaic from RGB images from data cubes collected w/ Headwall Nano-HyperSpec sensor



A factorization method - Centering the data

If the centroid of points in 3D = center of the world reference system

$$\hat{\mathbf{x}}_{ij} = \mathbf{A}_i \hat{\mathbf{X}}_j = \mathbf{A}_i \mathbf{X}_j$$



$$\bar{\mathbf{x}}_i = \frac{1}{n}\sum_{k=1}^{n}\mathbf{x}_{ik}$$

$$\bar{\mathbf{X}} = \frac{1}{n}\sum_{k=1}^{n}\mathbf{X}_k$$

Centroid of 3D points

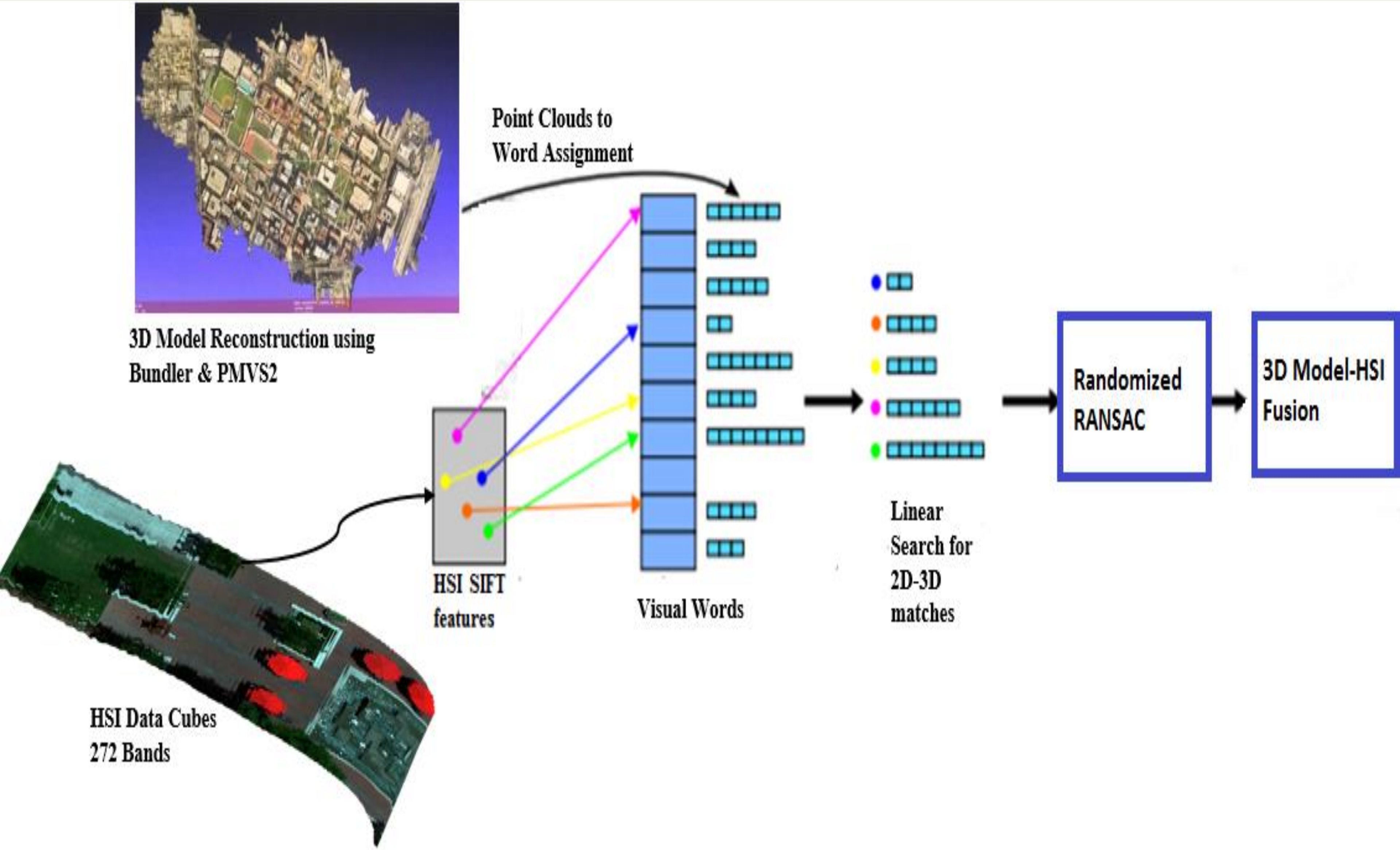
Goal: given spatial features from a query image I, corresponding to 3D point structures, match equivalent spatial features from hyperspectral imagery

Equivalent to: from a collection of derived 3D point clouds, find corresponding landmarks in relevant images that fits invariant spatial features in hyperspectral imagery

Equivalent to a fitting problem!

- Generate hypothesis
- Verify hypothesis
- Select hypothesis with lowest fitting error
- Generate matching results

Fusion Approach

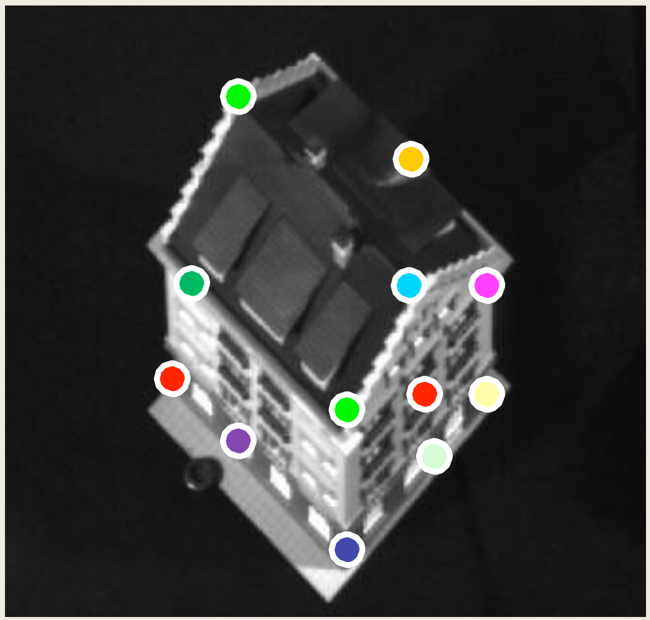


Model Fitting Approach

Goal: Given a query image I, find object model that matches with I

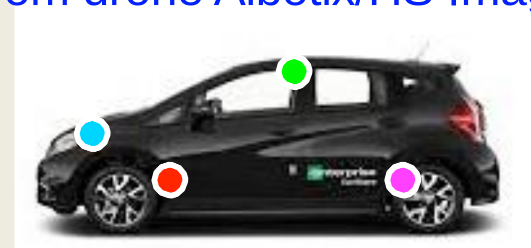
Model: Collection of points on planar surface

Query

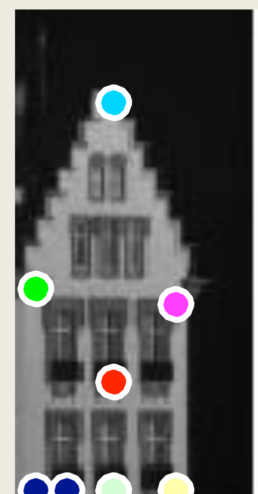


Invariant Spatial Features from Phantom/GoPro Image

Invariant Spatial Features from drone Aibotix/HS Imagery



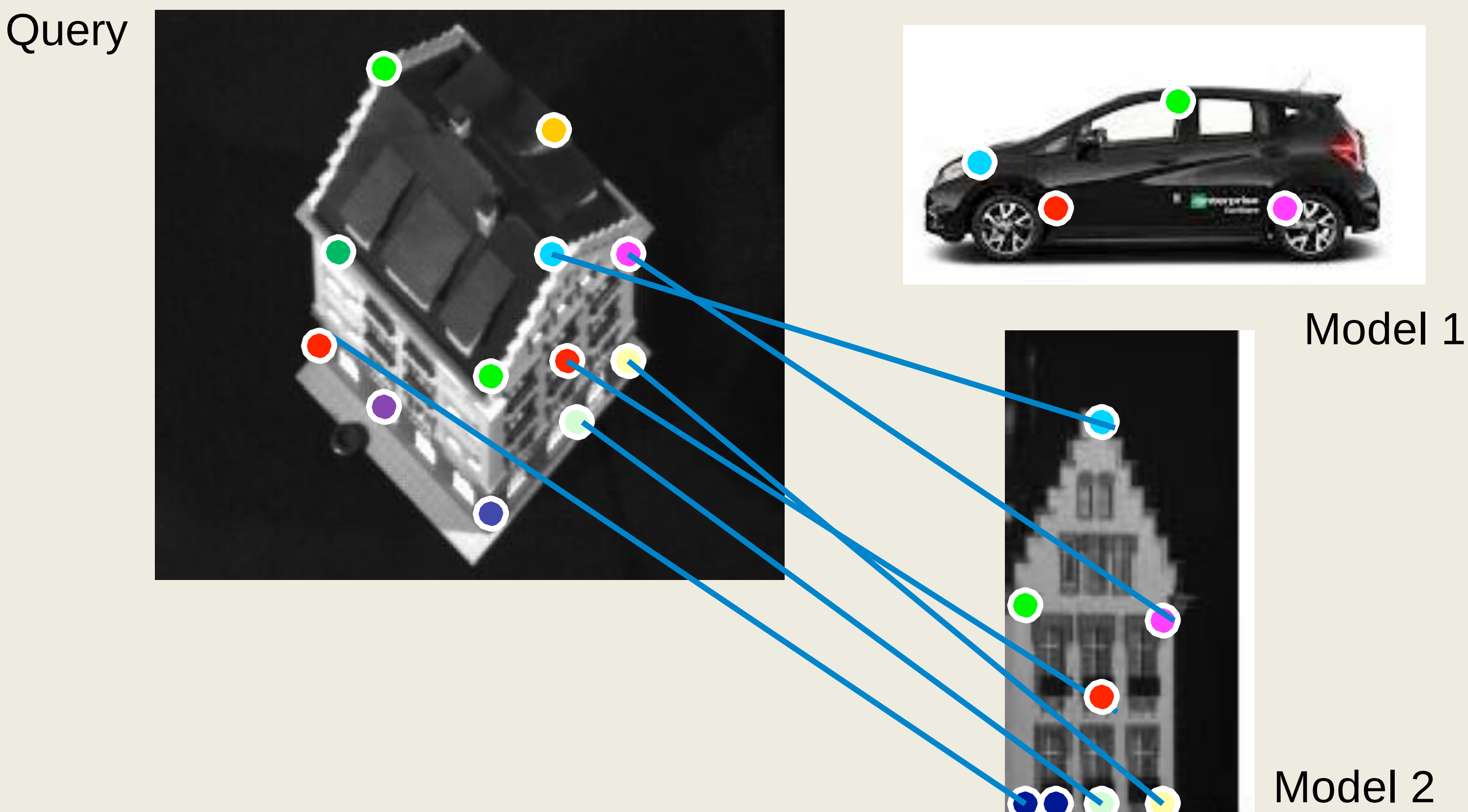
Model 1



Model 2

Model Fitting Approach

- Find matches between “model” points and “query” points
- Using N matches to fit homographic transformation
- If matches and selected model are correct, the fitting error is small



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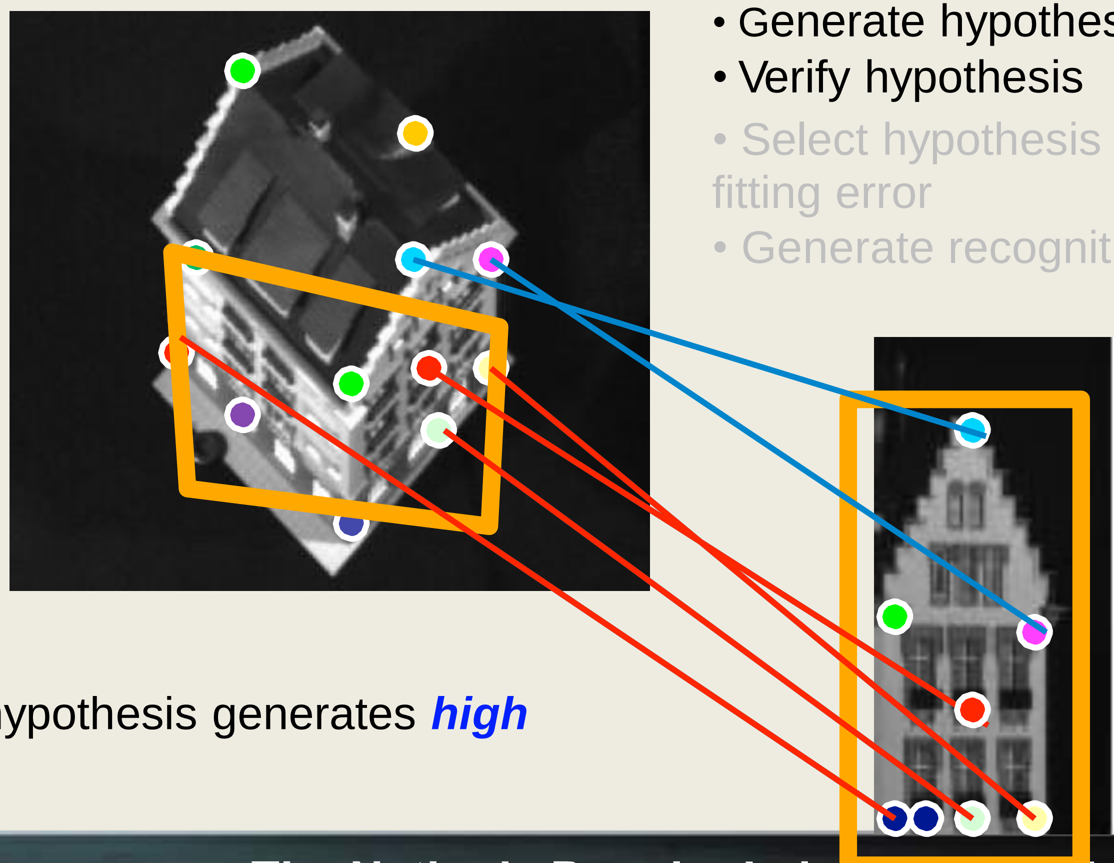


Model 2

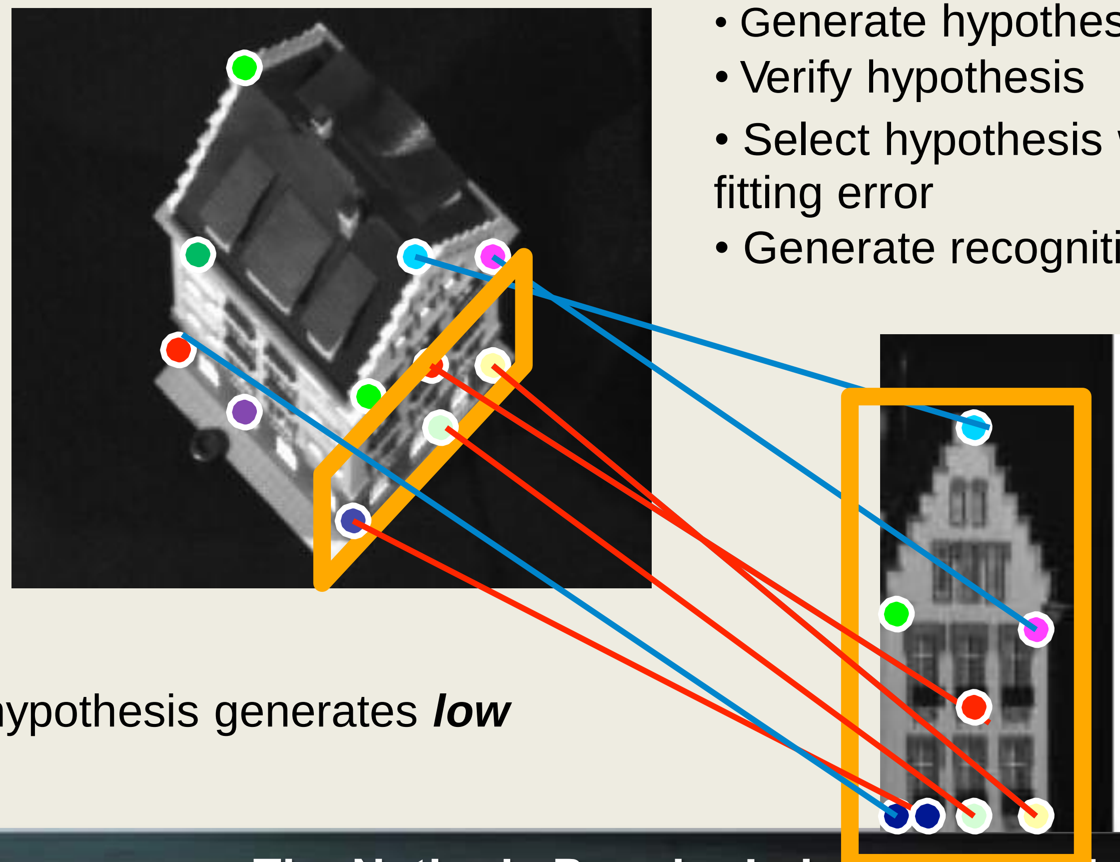
- Generate hypothesis
- Verify hypothesis
- Select hypothesis with lowest fitting error
- Generate recognition results

Verification: The hypothesis generates ***high*** fitting error

Model Fitting Approach

- Find matches between “model” points and “query” points
- Using N matches to fit homographic transformation
- If matches and selected model are correct, the fitting error is small

Query



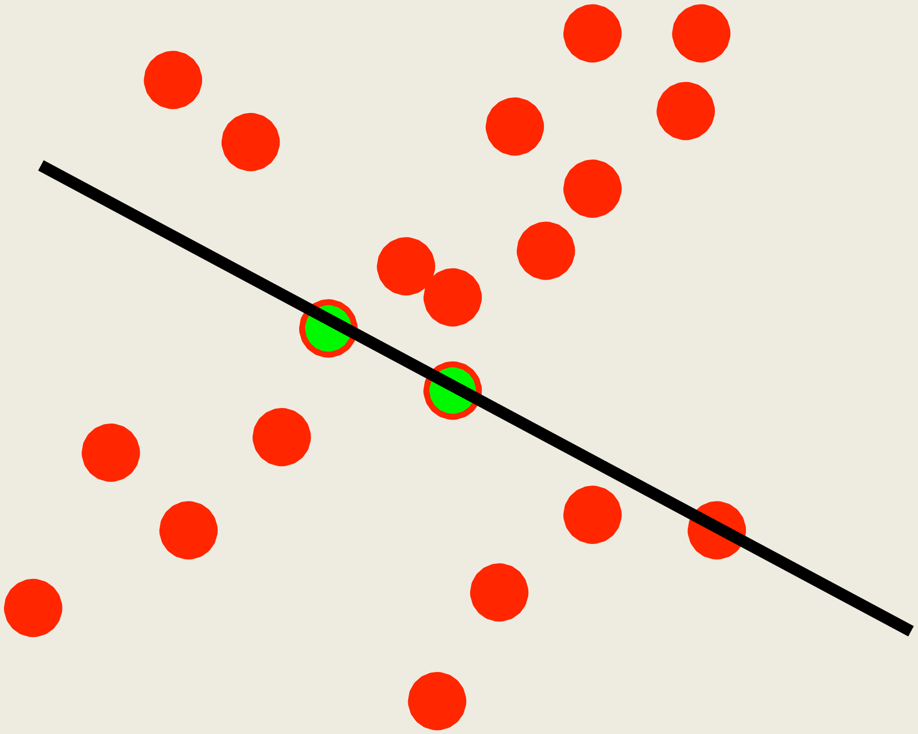
Model 2

- Generate hypothesis
- Verify hypothesis
- Select hypothesis with lowest fitting error
- Generate recognition results

Verification: The hypothesis generates ***low*** fitting error

RANSAC

Random Sample Consensus (RANSAC)



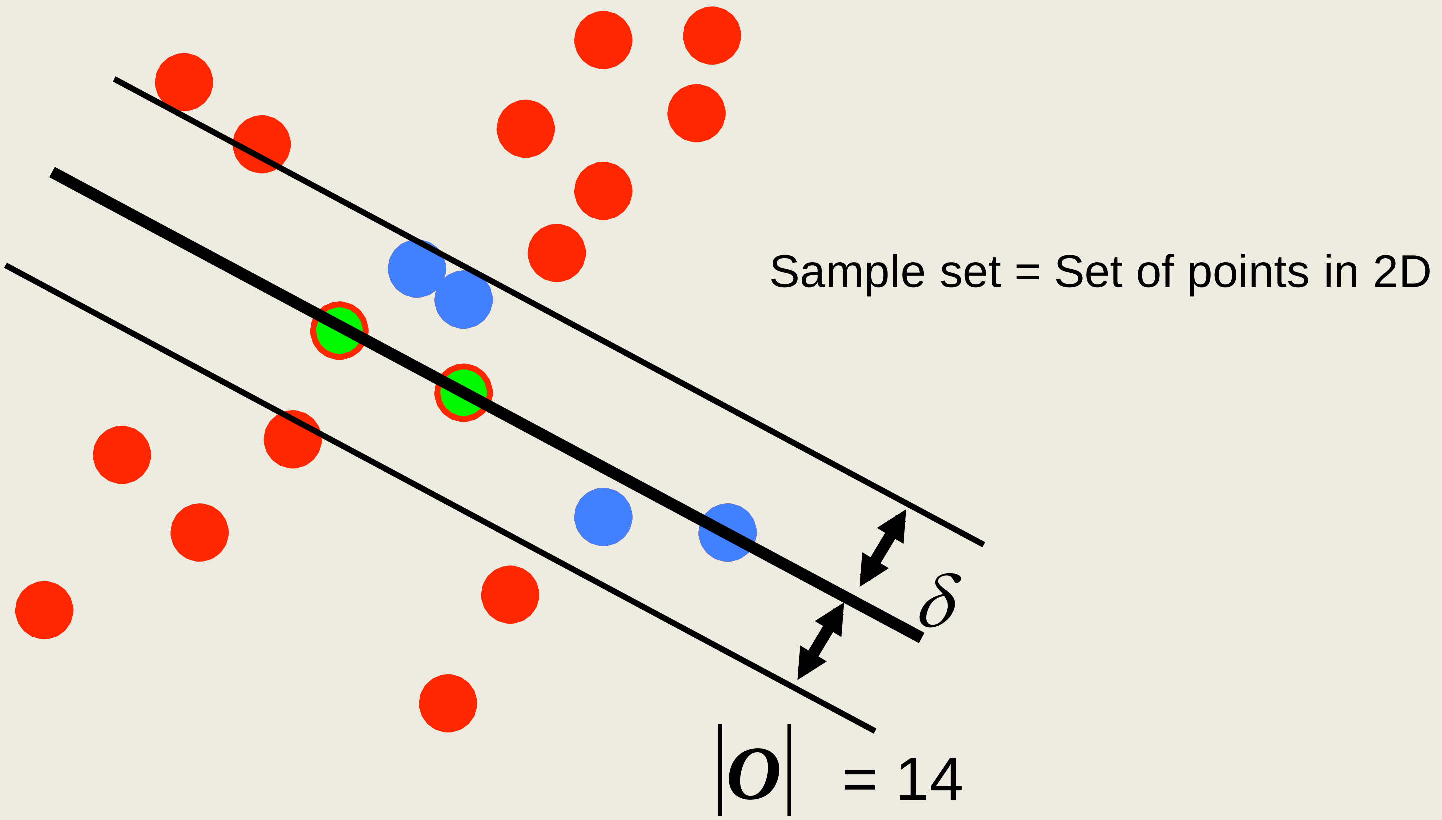
Sample set = Set of points in 2D

Algorithm:

1. Select random sample of minimum required size to fit model
2. Compute a putative model from sample set
3. Compute the set of inliers to this model from whole data set

Repeat 1-3 until model with the most inliers over all samples is found

RANSAC



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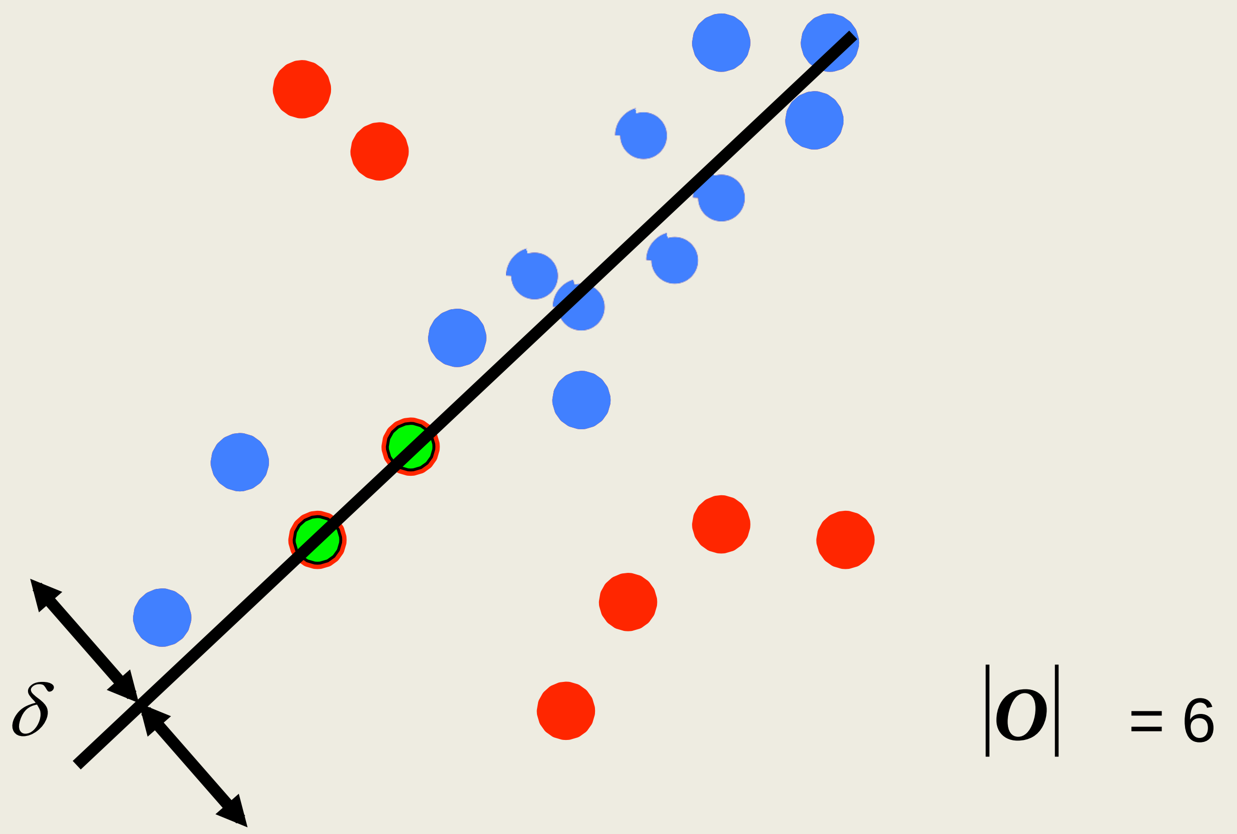
RANSAC



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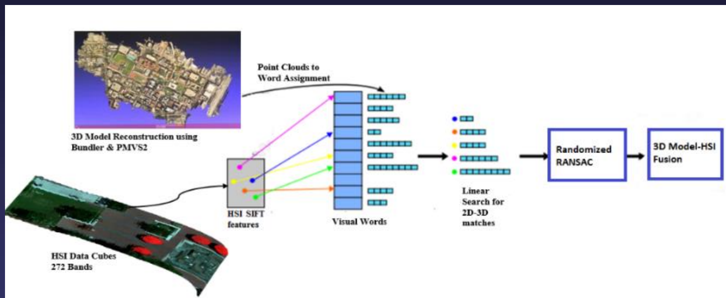
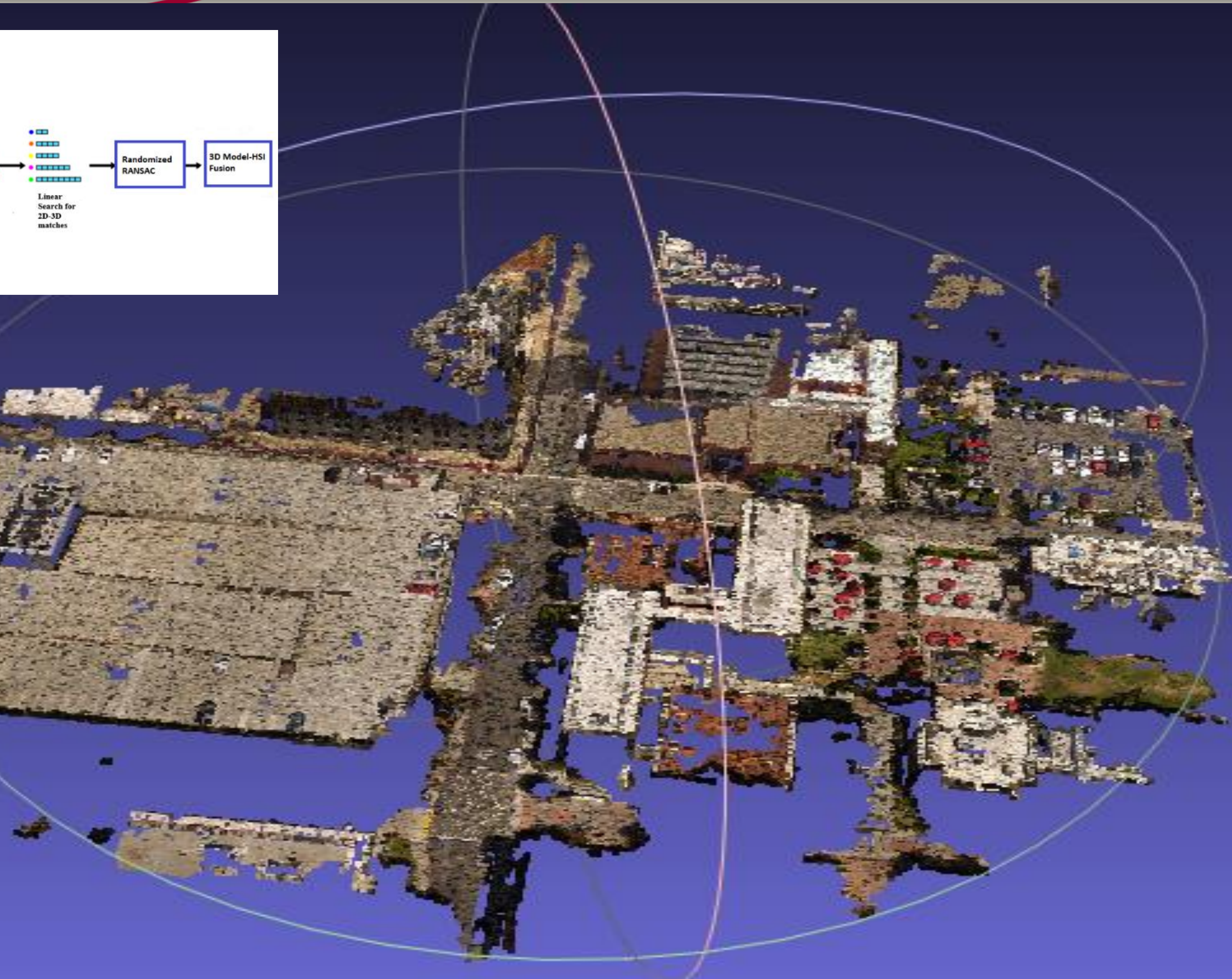
Fusion of 3D Structure & Spectra

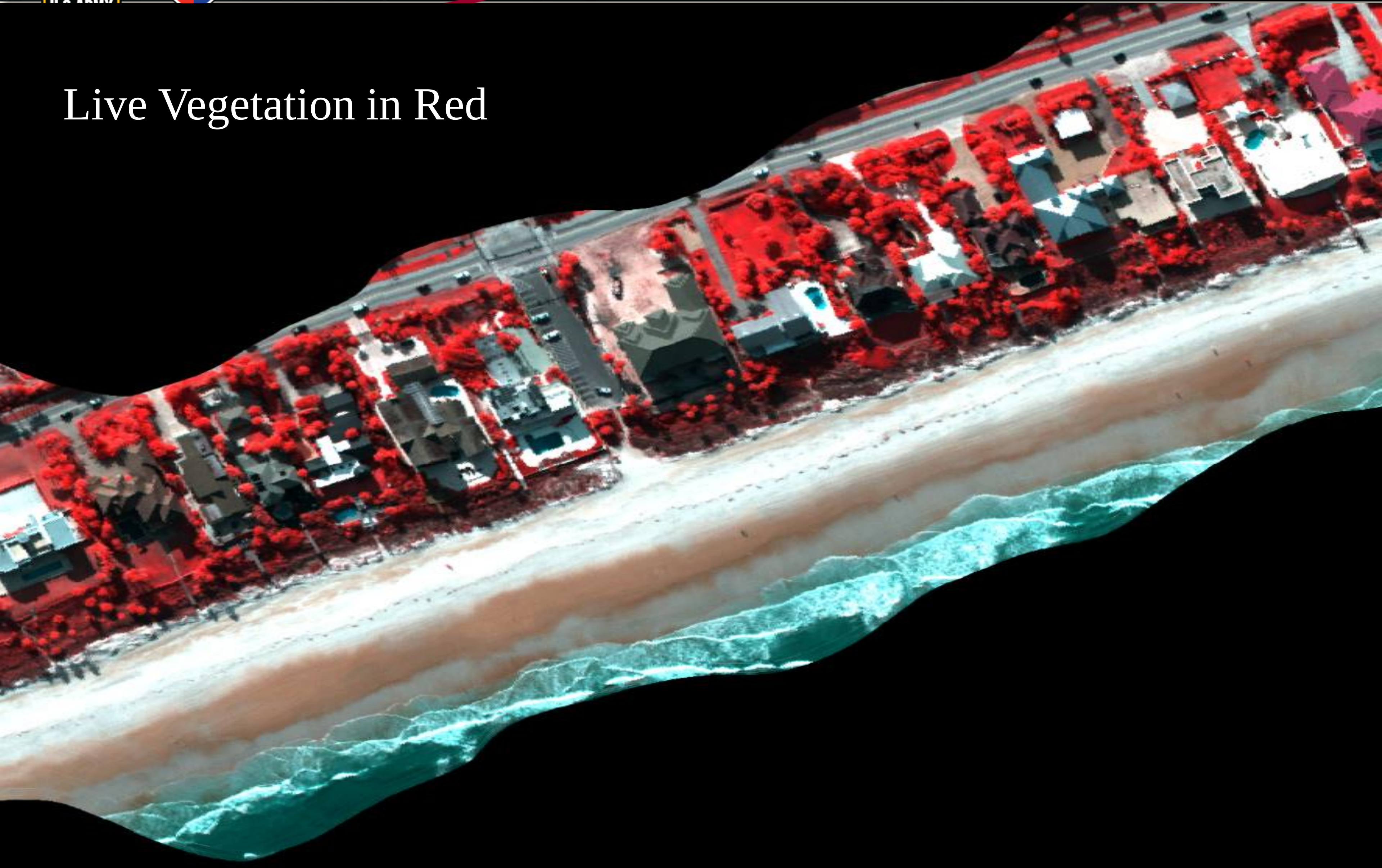




Geo-registration *not* required

Geo-Based Fusion of 3D DEM & Spectra

Live Vegetation in Red



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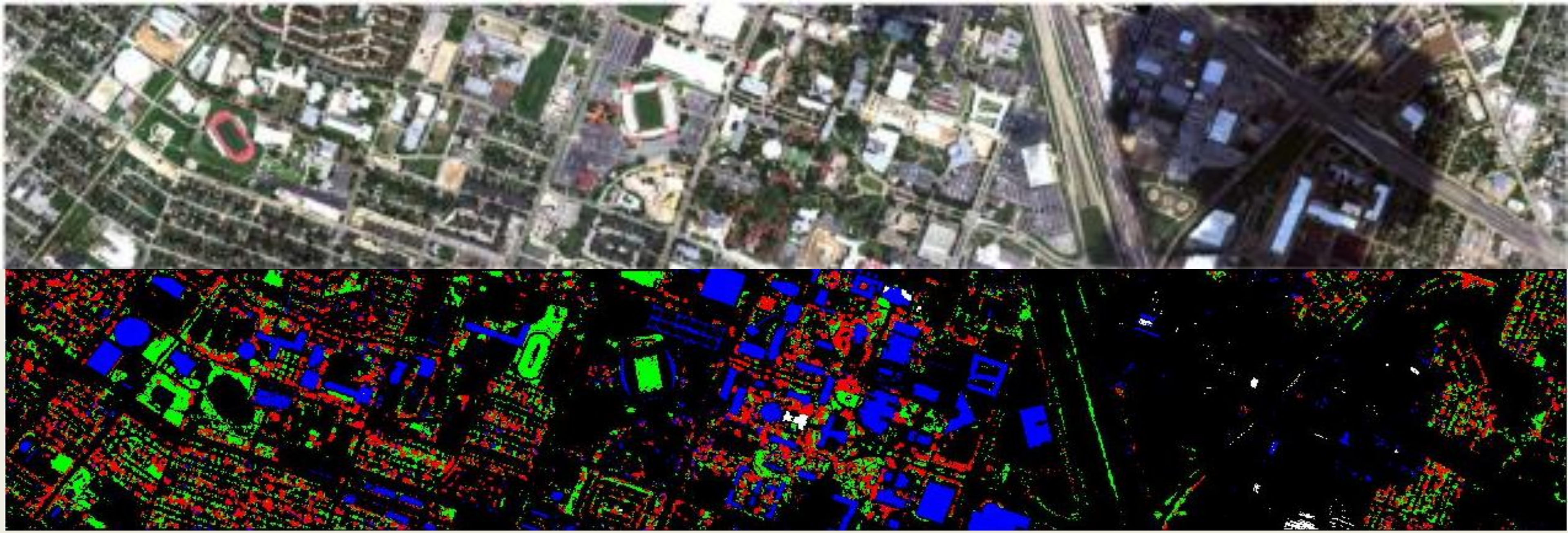
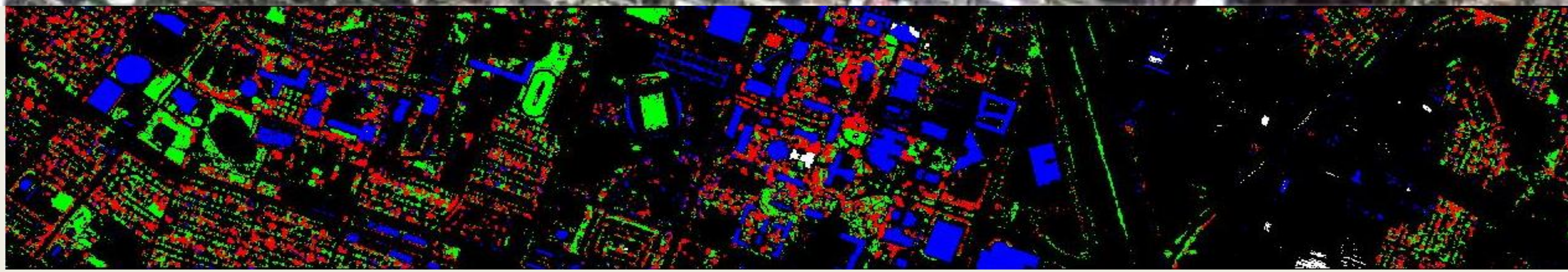
Rule-Based Image Segmentation



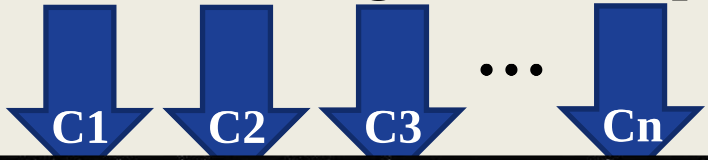
Predefined Classes

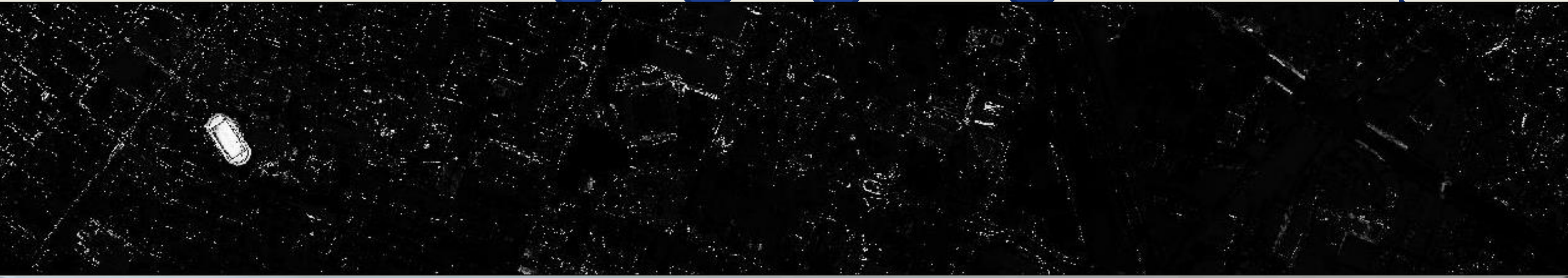
Class	Spectral Property	Height Property
Trees	High Vegetation Index	High
Grass	High Vegetation Index	Low
Water	High Water Index	Low
Buildings	Low Vegetation Index	High
Unknown	Low Vegetation Index	Low

Adaptive Machine Learning & Target Localization



Autonomous Background Sampling





Concluding Remarks

Dataset

Collected drone based USC hyperspectral dataset & USC-ICT 3D DEM for research and algorithm development

Algorithmic Approach

- Fusion of 3D structure & hyperspectral data
- Spectral & height rule based image segmentation
- Unsupervised selection of background material spectra using segmented map
- Adaptive machine learning

Impact

Adaptive, Aerial Image Understanding

  - Material classification maps for Common Operating Picture (COP)
  - Target material localization

Follow Up

- Adapt approach to SWIR Hyperspectral data and 3D Point Clouds (e.g., LiDAR, Photogrammetry)
- Enhance situational awareness via 3D augmented reality visualization (e.g., Microsoft Hololens)