UNIVERSITY of DAYTON

VISION LAB

Computer Vision and Wide Area Surveillance Laboratory

Pipeline Right-of-Way Automated Monitoring Program

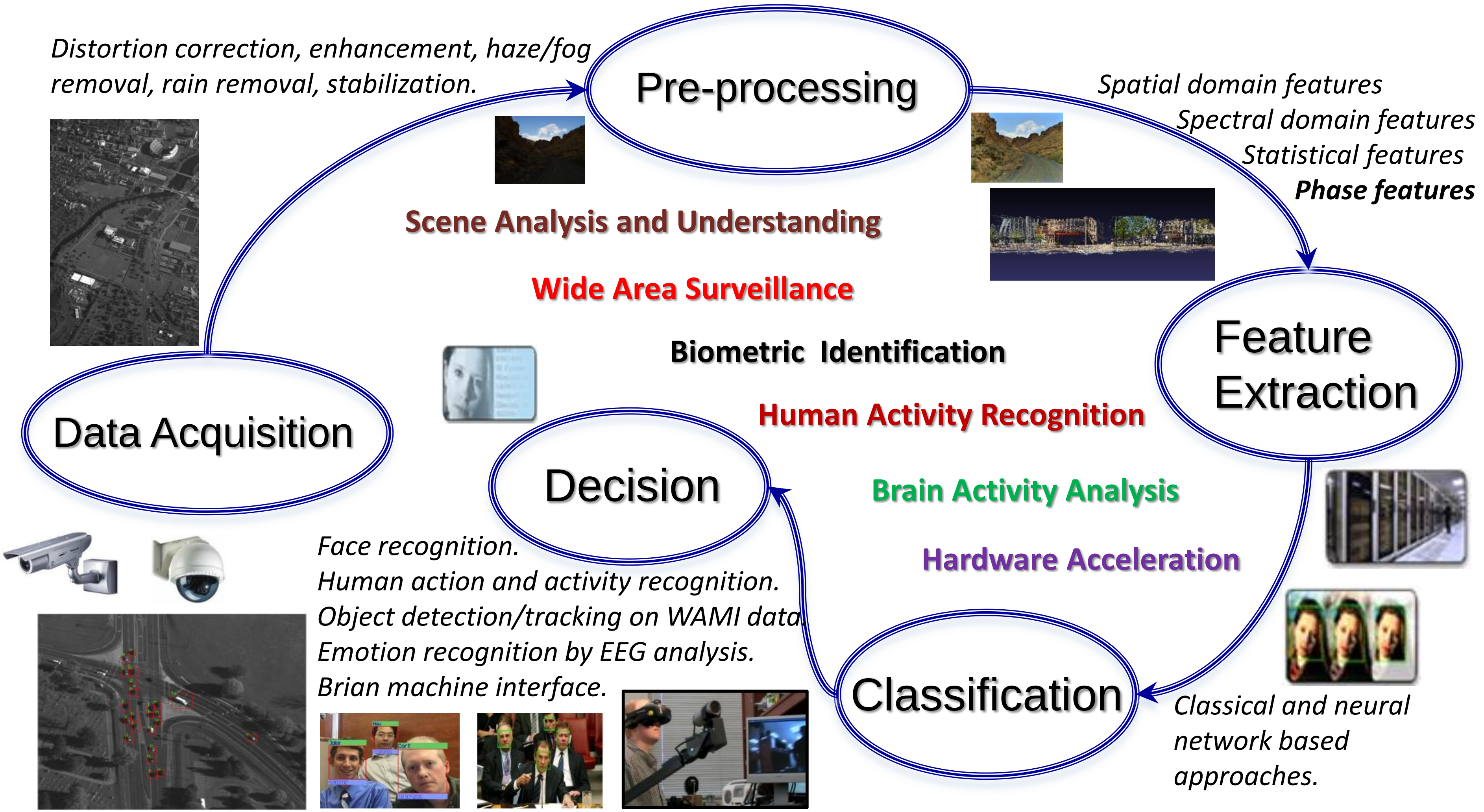
Advanced Image Analysis for Automated Pipeline Threat Detection

PRCI *Collaborative Research Sponsored by PRCI*

Dr. Vijayan K. Asari
University *of* Dayton

University of Dayton Vision Lab: Main Research Theme and Focus Areas

Sensing, Processing and Automatic Decision Making in Real Time



Sensing and Processing Facilities
- Cameras & Sensors


Arecont IP Camera


AXIS Cameras

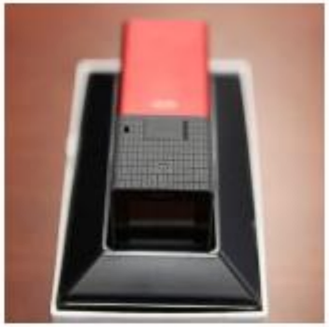

Canon Cameras


Hyperspectral Camera


Iris Camera


Kinect


Long-range Cameras


Lytro


Thermal Cameras


HD Video Recorder

Nano SAR

FARO LiDAR Sensor

3dMD Face System

Hyperspectral Imaging system

Sensing and Processing Facilities
- EEG & Robotics

Robotics

RAIDER

7 DOF Robotic Arm (Robai)

Hexacopter

Segway

EEG

14 Electrode EEG Sensor (Emotiv)

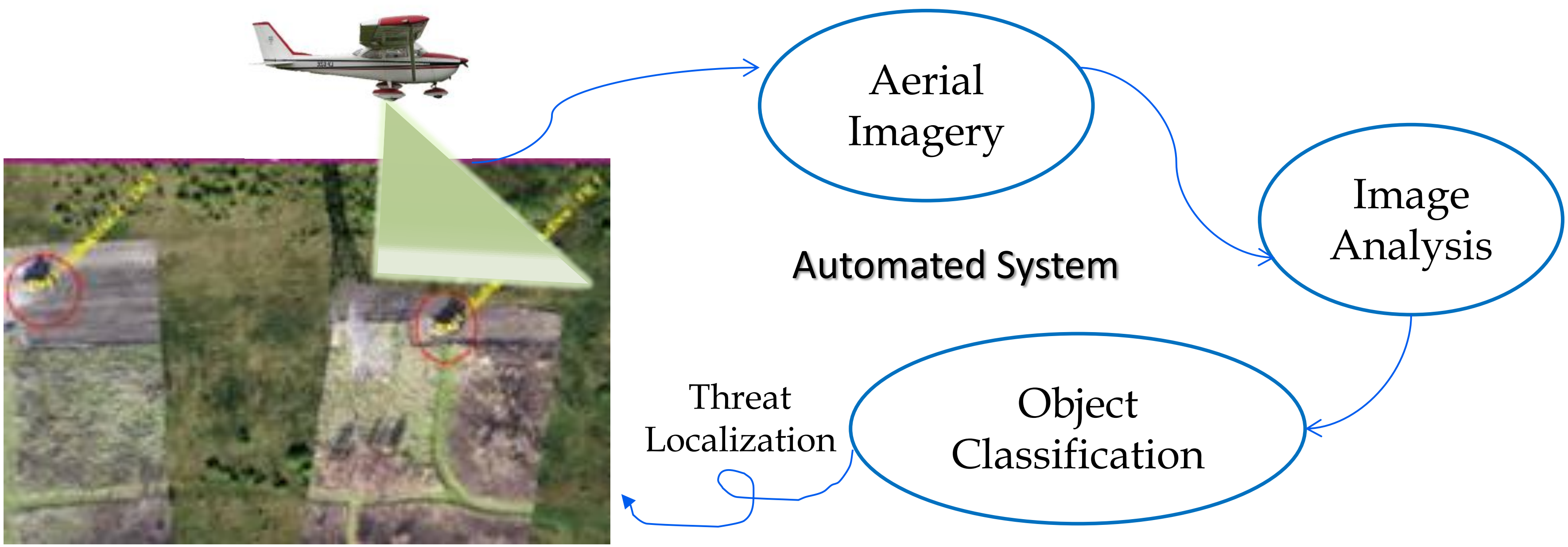
265 Channel Dense Array EEG (EGI)

3dMD Face System

Machinery Threat Detection Objective

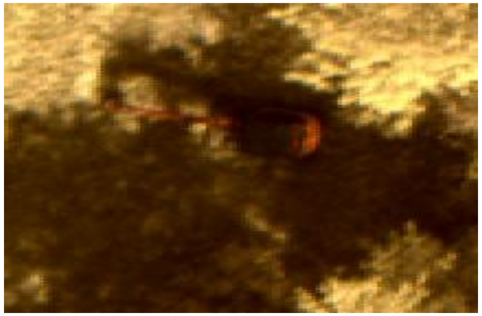
To Automate The Airborne Monitoring and Surveillance of Gas and Oil Pipeline on Right-of-Way

- To prevent human-caused damages to surface pipelines
- To detect and identify machinery threat on pipeline ROW
- To localize threat and classify the severity of threat to the pipeline.
- To develop a real-time threat detection system which works on the flight

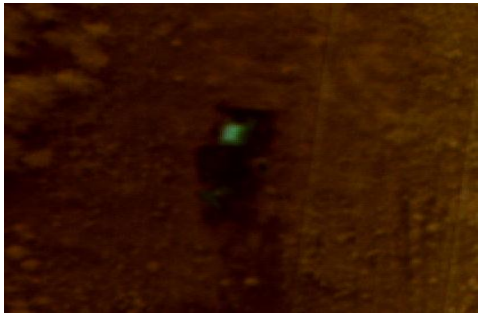


Challenges

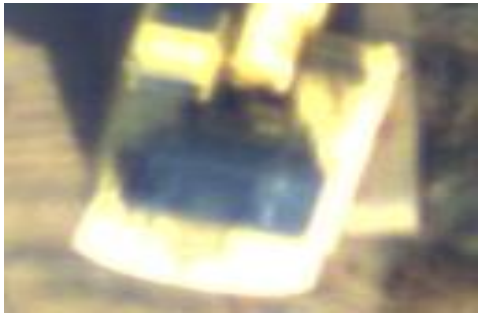
- Varying illumination (cast shadows, sensor artifacts)
- Varying viewpoint and orientation
- Partial occlusions (objects are occluded by overhanging trees)
- Different scale due to various altitudes of the flights
- Varying resolution due to image capturing systems



Cast Shadows



Low illumination



Over Exposure

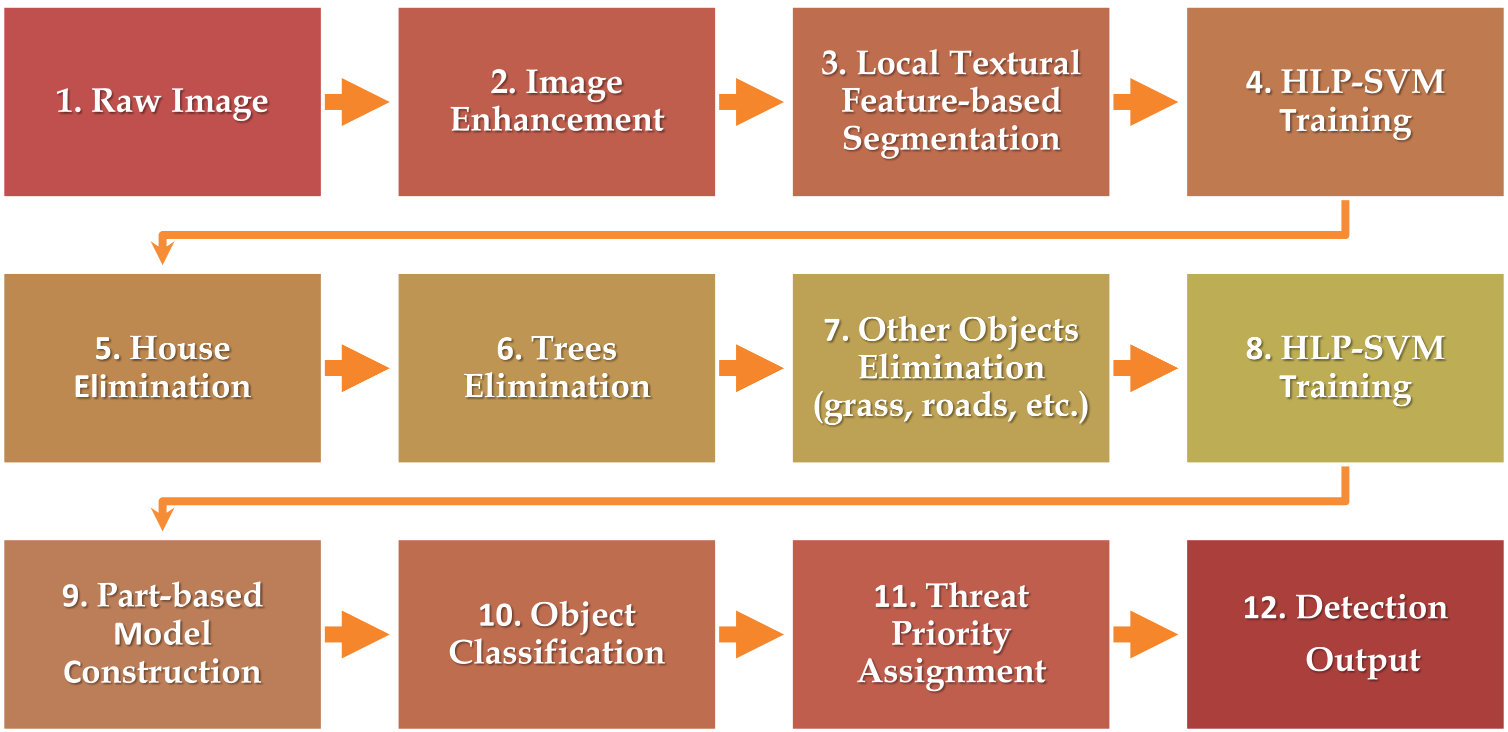
Partial Occlusion

Small Scale

Low Resolution

Threat Detection Technique Framework

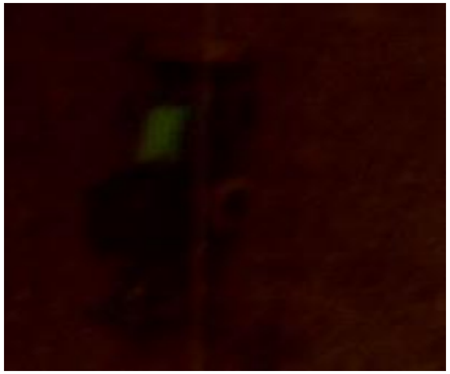
- The threat detection procedure is broken into several distinct phases:



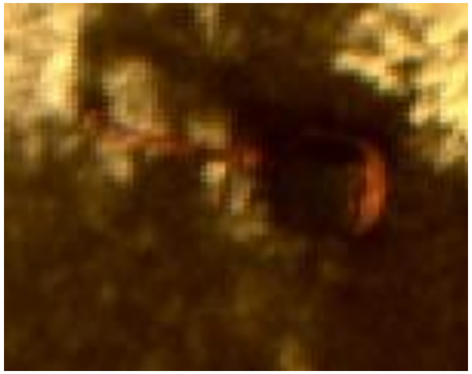
HLP: Histogram of Local Phase   SVM: Support Vector Machine

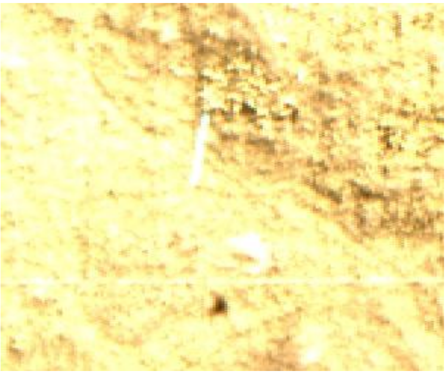
Image Enhancement and Super-resolution:
RAM Data Analysis for Visibility Improvement

- Right-of-way Automated Monitoring Data (Sample regions):


Low illumination


Dark region

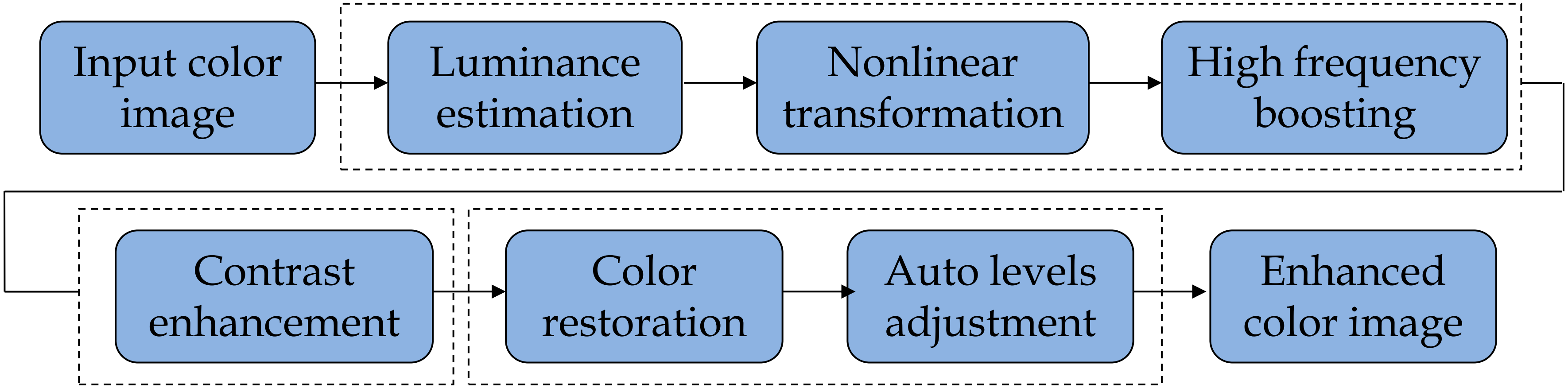

Shadow region


Overexposed

Objectives

- Visibility improvement in low/non-uniform lighting conditions for wide area surveillance applications.
- Feature enhancement to improve the performance of automatic object detection/ tracking/ recognition algorithms on wide area surveillance data.
- Quality improvement for low quality images for accurate object classification.

Image Enhancement and Super-resolution Framework

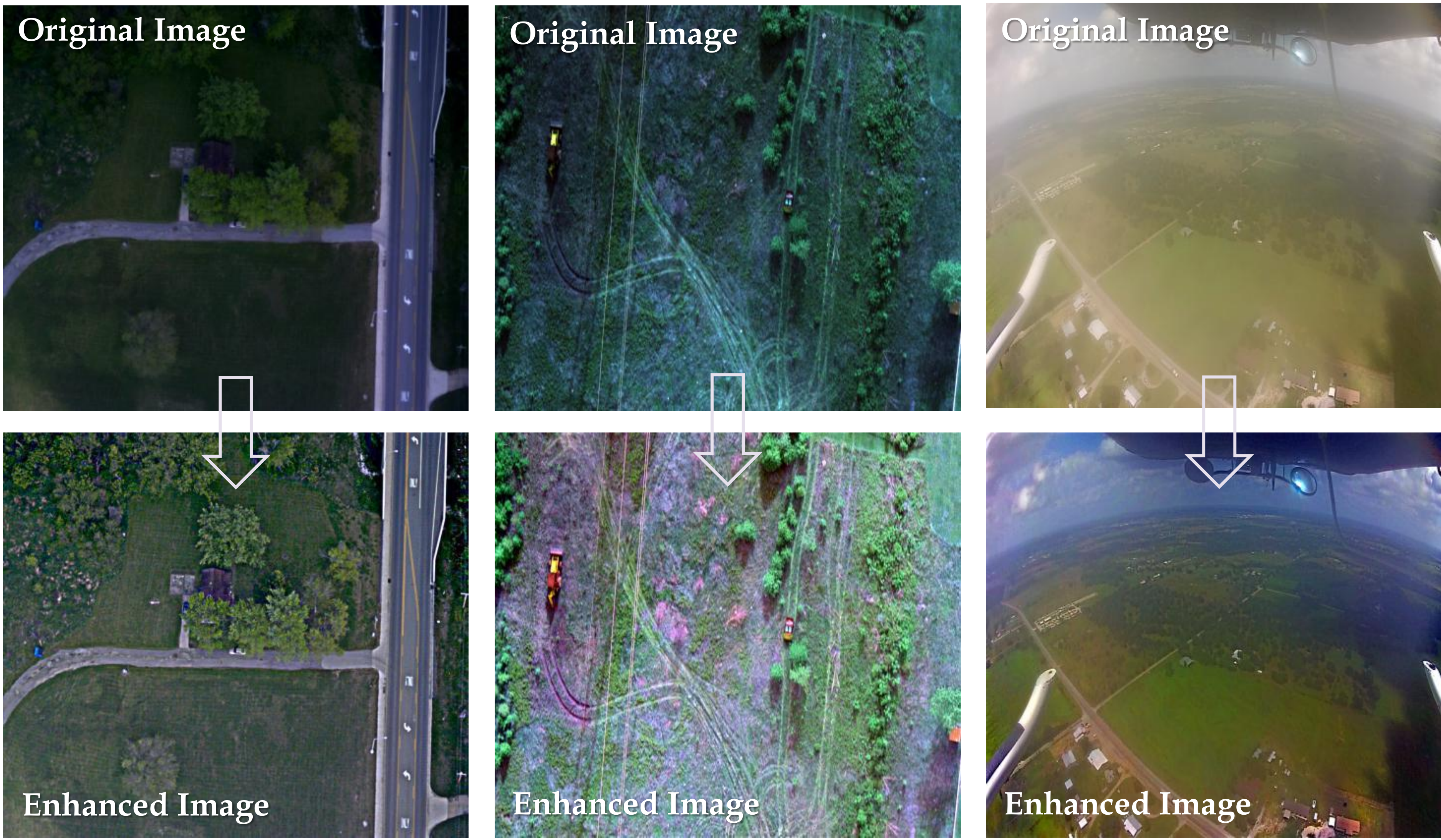



Raw Image


Enhanced Image

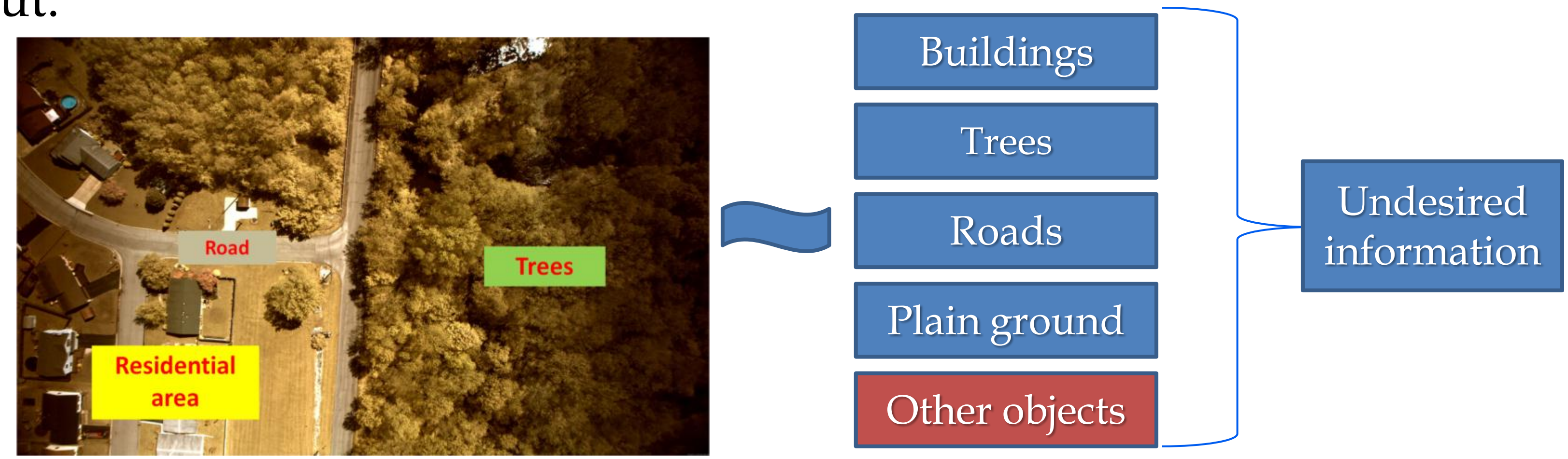
Scene Visibility Improvement: Enhancement of Low Lighting and Over Exposed Images

Visibility Improvement on RAM Dataset



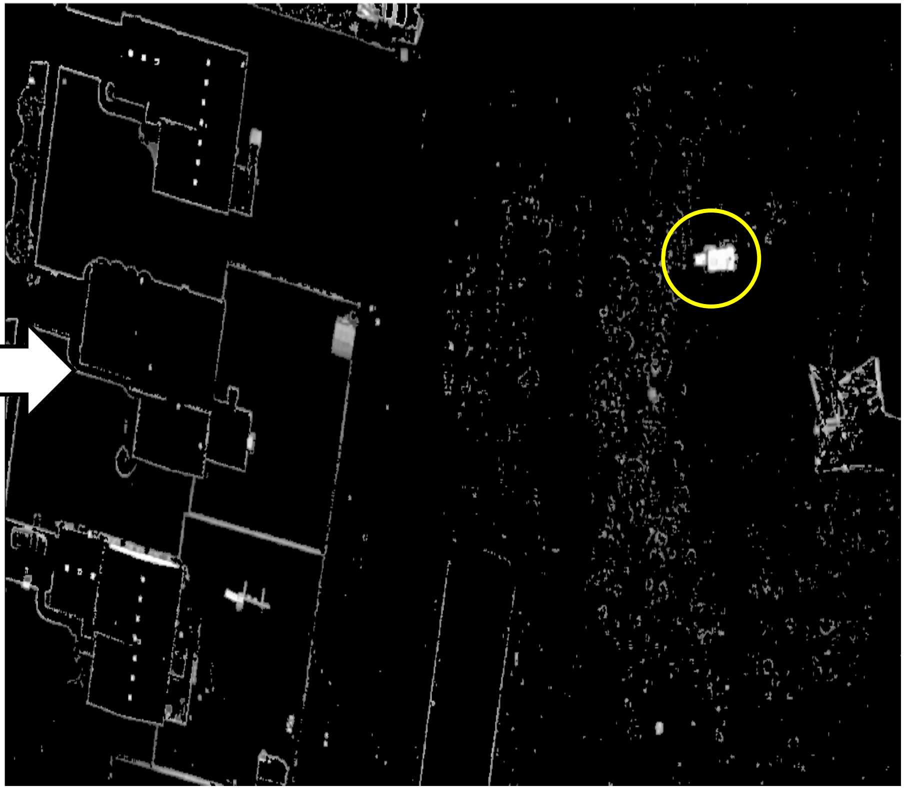
Background Elimination

- Objectives
  - Elimination of background in aerial imagery for faster threat identification.
  - Extract information from scenes that can aid in threat detection.
  - Gather intelligence from a scene automatically to aid in informed decision making for users.
- Key Observation
  - Aerial imagery mainly consists of buildings, plain ground, trees and roads that do not contain objects of interest and can be segmented out.



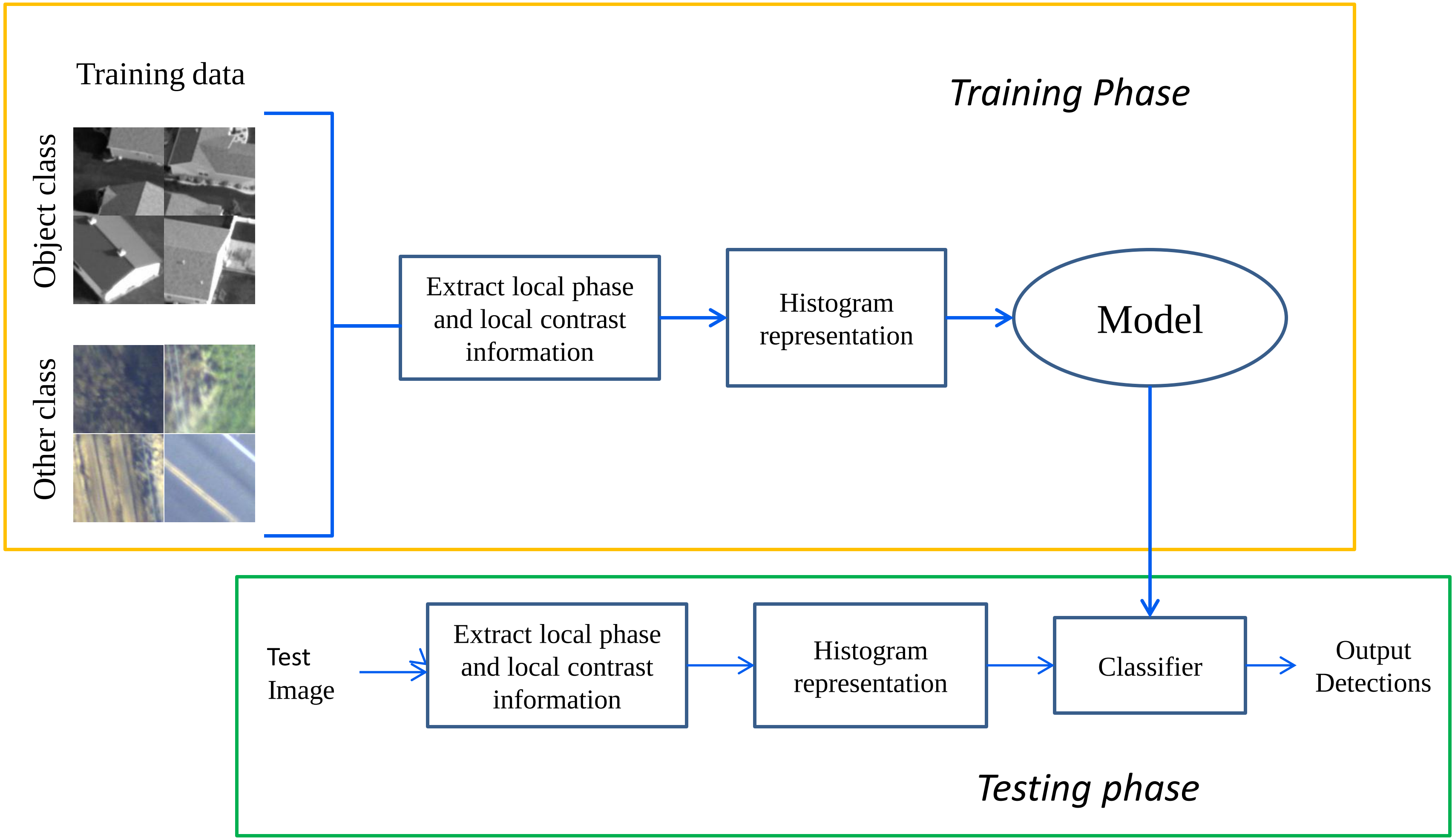
Local Textural Feature based Segmentation (LTFS)

- The LTFS algorithm utilizes the property of the neighborhood around every pixel in input images to extract high frequency components for aiding further image analysis.



Adaptive Perception based Segmentation (APS)

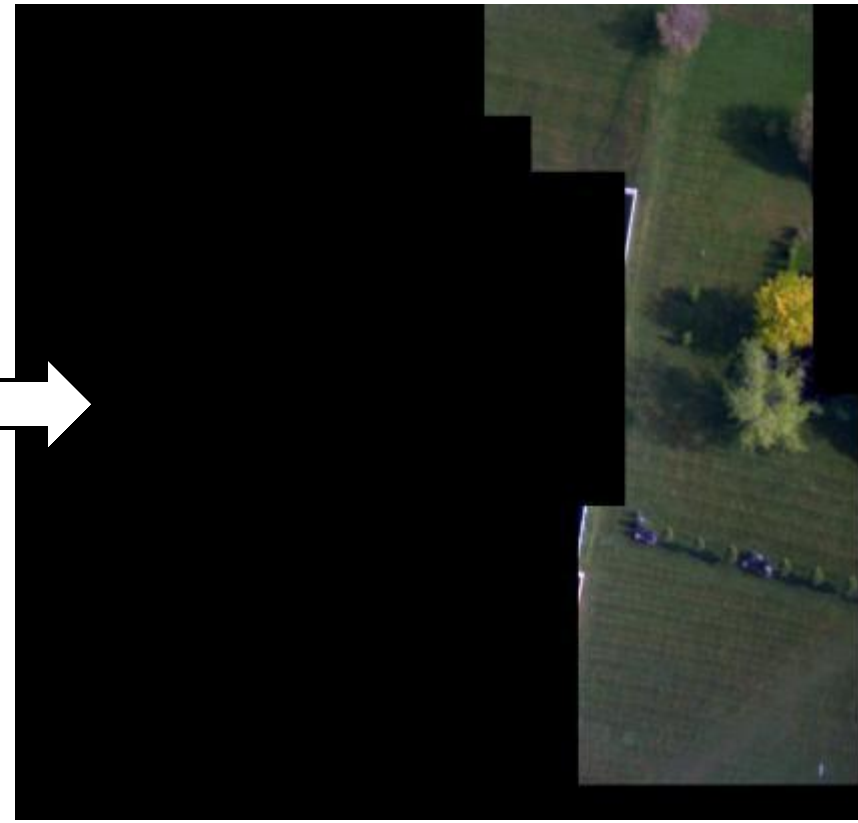
- The APS algorithm was designed to sequentially eliminate undesired information in aerial imagery (buildings, trees, etc.).



Sample Output Using APS

Raw Aerial Image

Building Elimination Output



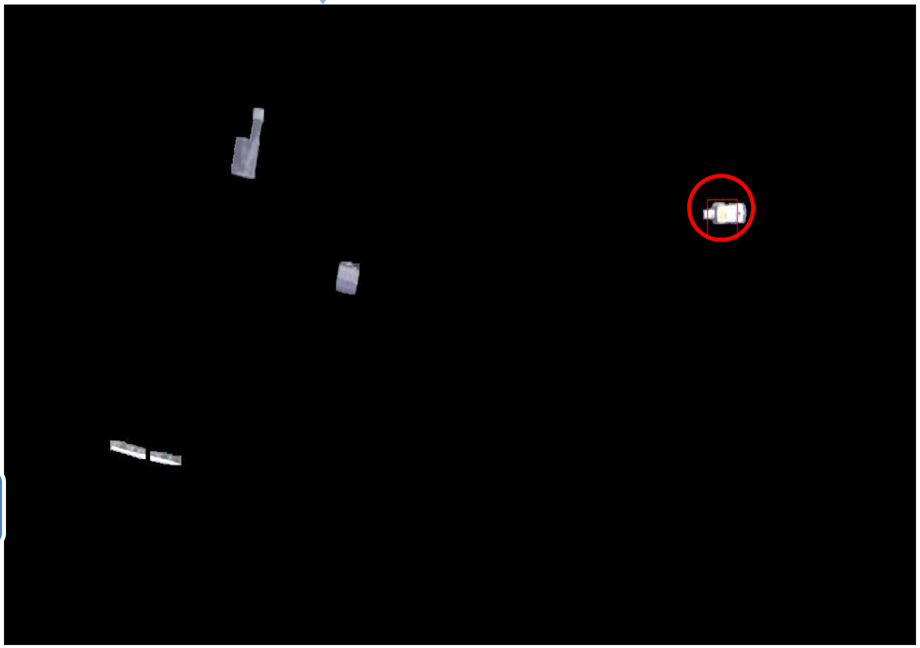
Sample Results using Background Elimination Technique (LTFS + APS)

Raw Image

Final Output

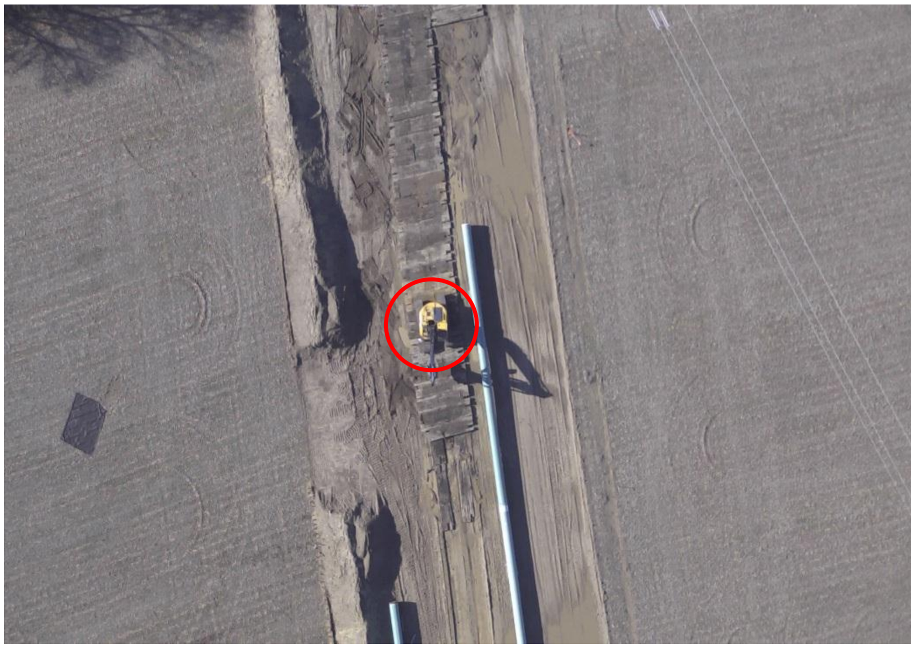
Sample Results using Background Elimination Technique (LTFS + APS)

Raw Image

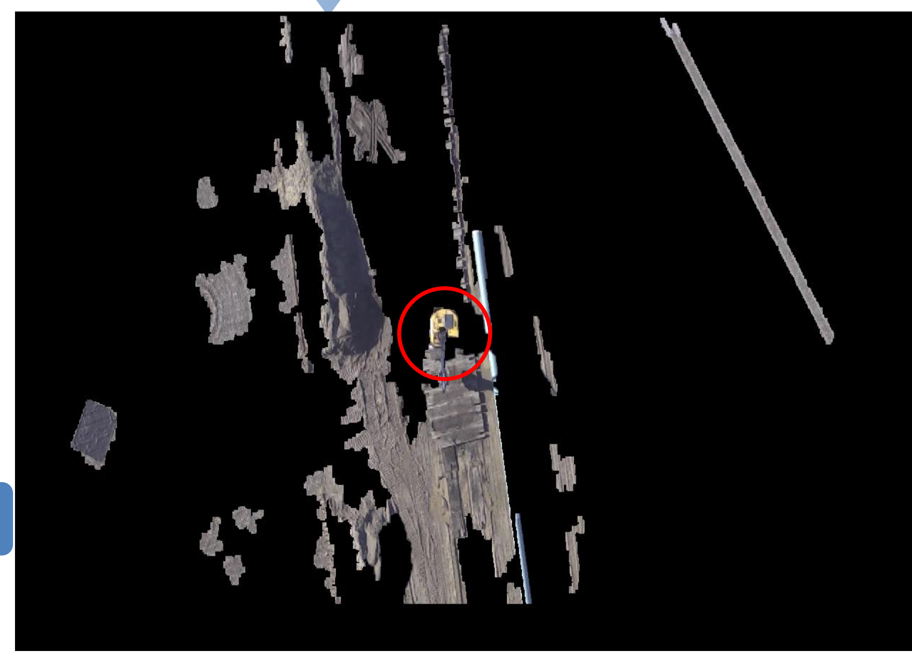


Final Output

Sample Results using Background Elimination Technique (LTFS + APS)



Raw Image



Final Output

Part-based Model for Robust Classification

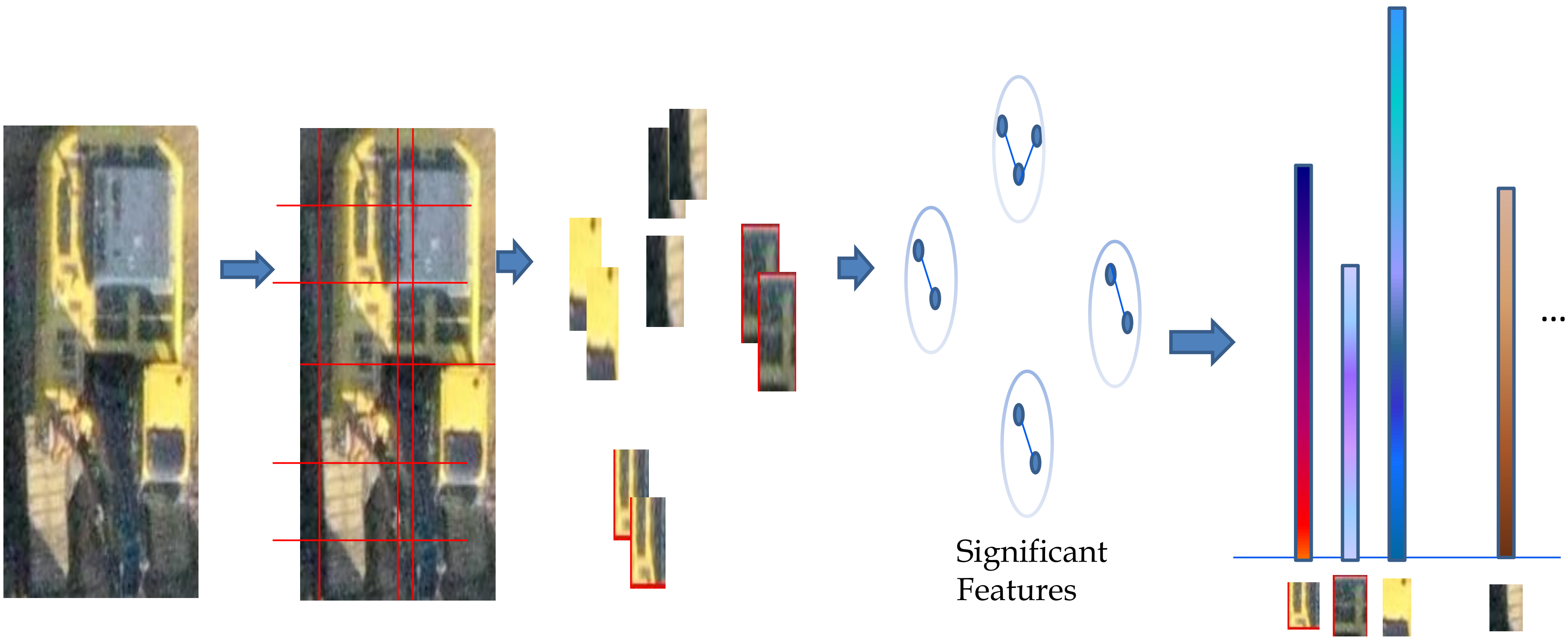
- The purpose of developing a part-based model is to cope with partial occlusion and large appearance variations.

Raw Image → Image Enhancement → Background Elimination → **Part-based Model for Object Recognition**

Part-based Model for Robust Classification

- The main concept

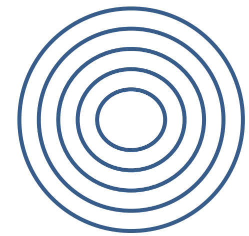
Object → Partitioning → Parts → Feature Extraction and Clustering → Histogram Representation



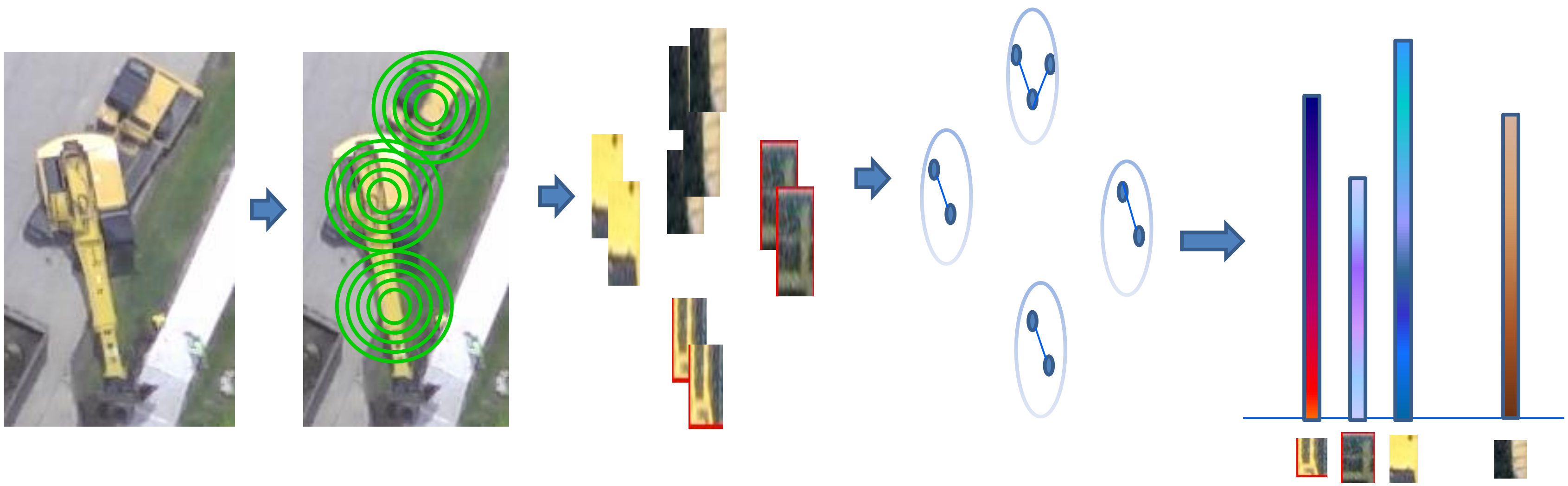
Ringlet Part-Based Model

Method: Using Ring Histogram for each part of objects

- Invariant to rotation
- Still contains spatial information
- Still contains partial occlusion ability



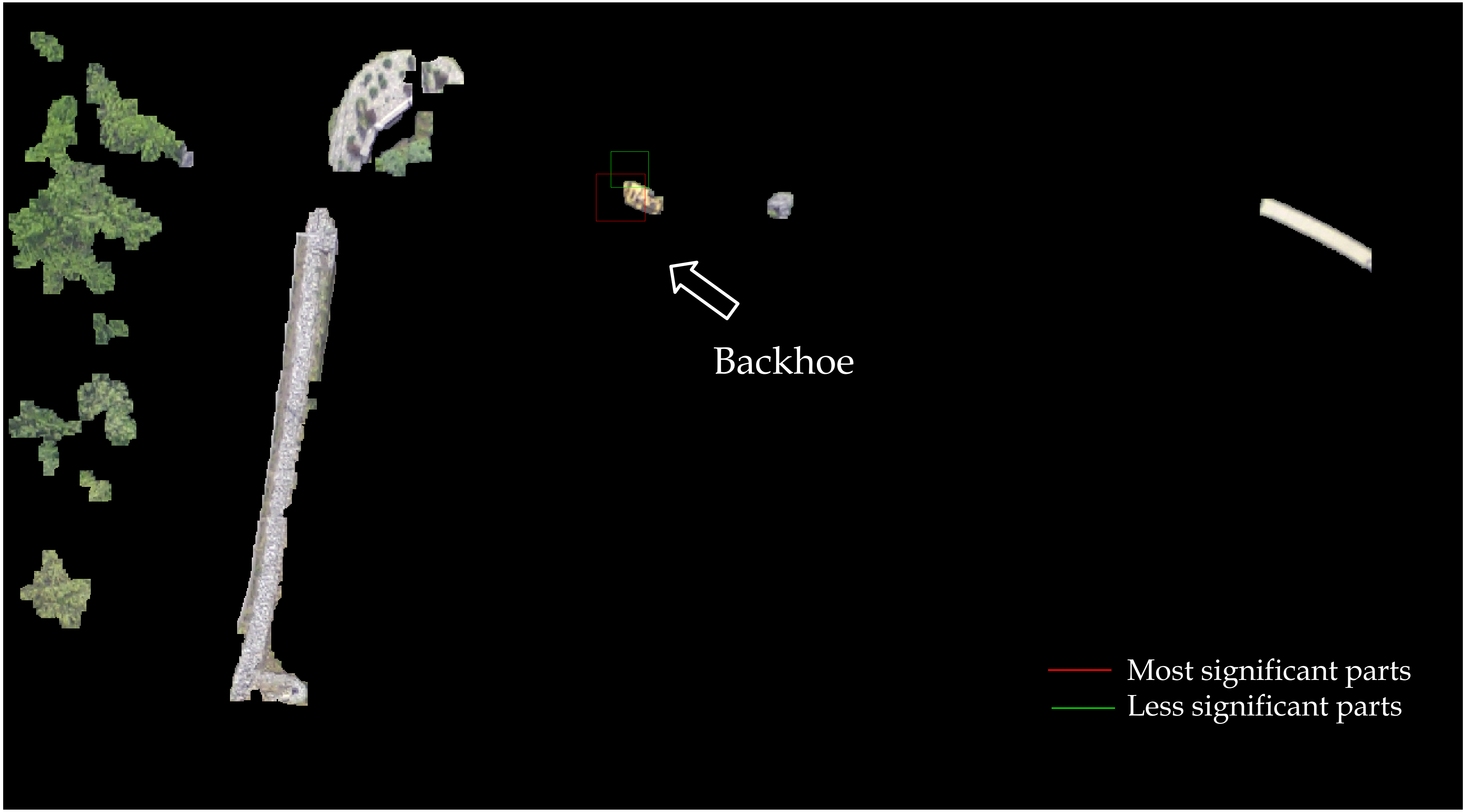
Object → Ring Based Partitioning → Parts → Feature Extraction and Clustering → Histogram Representation



Raw Image– Non Occlusion

Part-based Detection – Non Occlusion

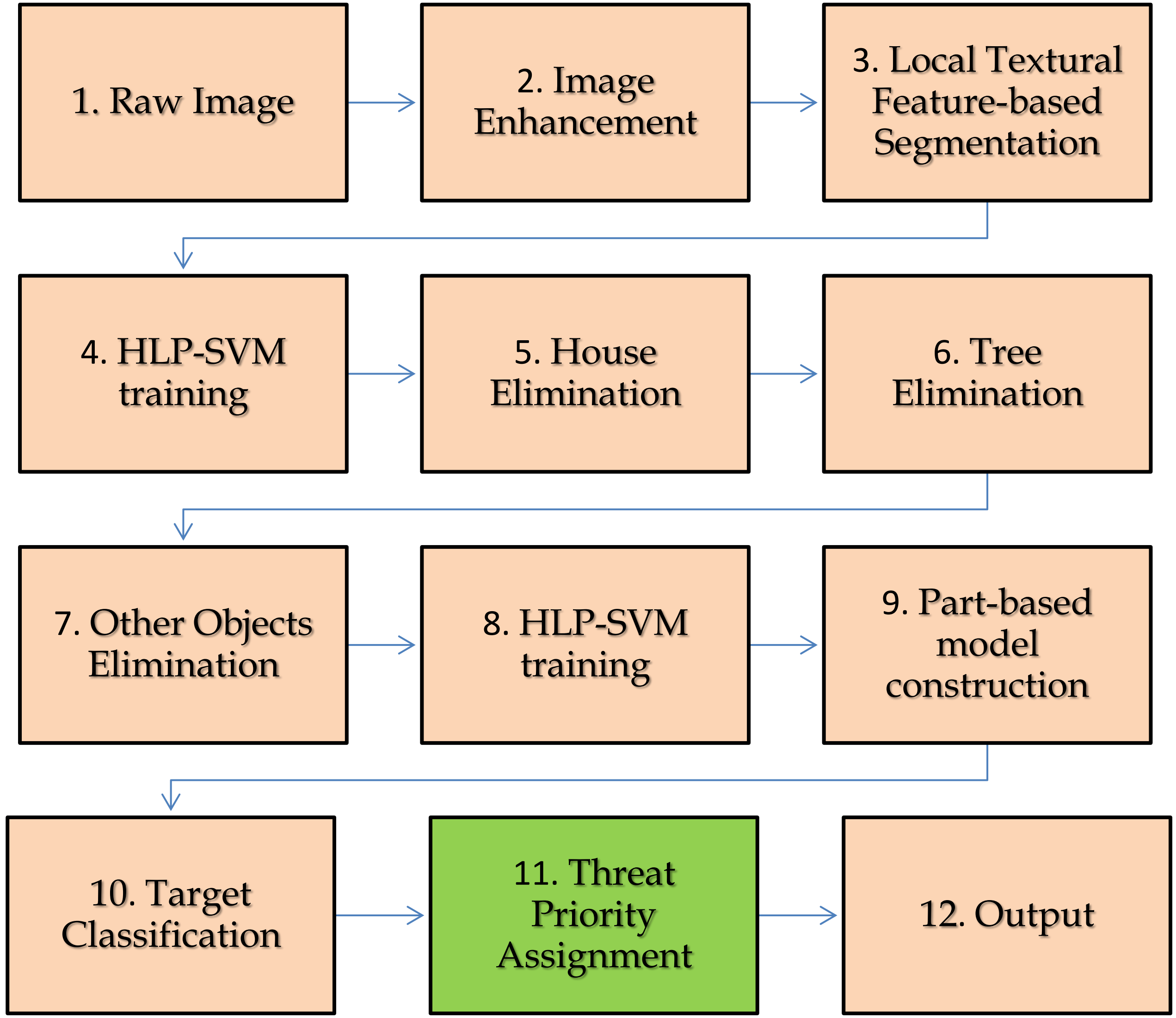
Final Detection Output



Raw Image– Partial Occlusion

Threat Priority Assignment

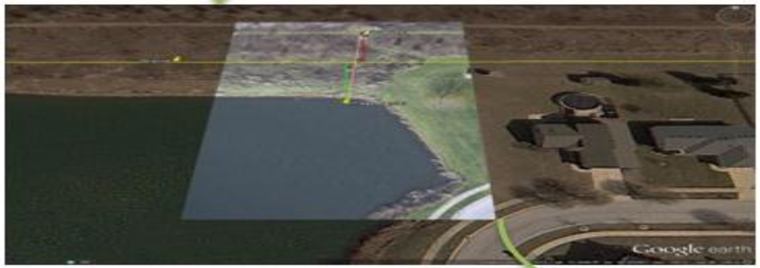
- **Due to false positives or unlikely threats present in detection outputs, probabilistic estimation of priority of threats is required.**



Threat Priority Analysis

Threat Priority Assignment:
Distance of Threat Object to Pipeline ROW

Pipeline Route



Captured Image Footprint in Google map

D1: distance from target to pipeline.

D2: distance from target to image center.

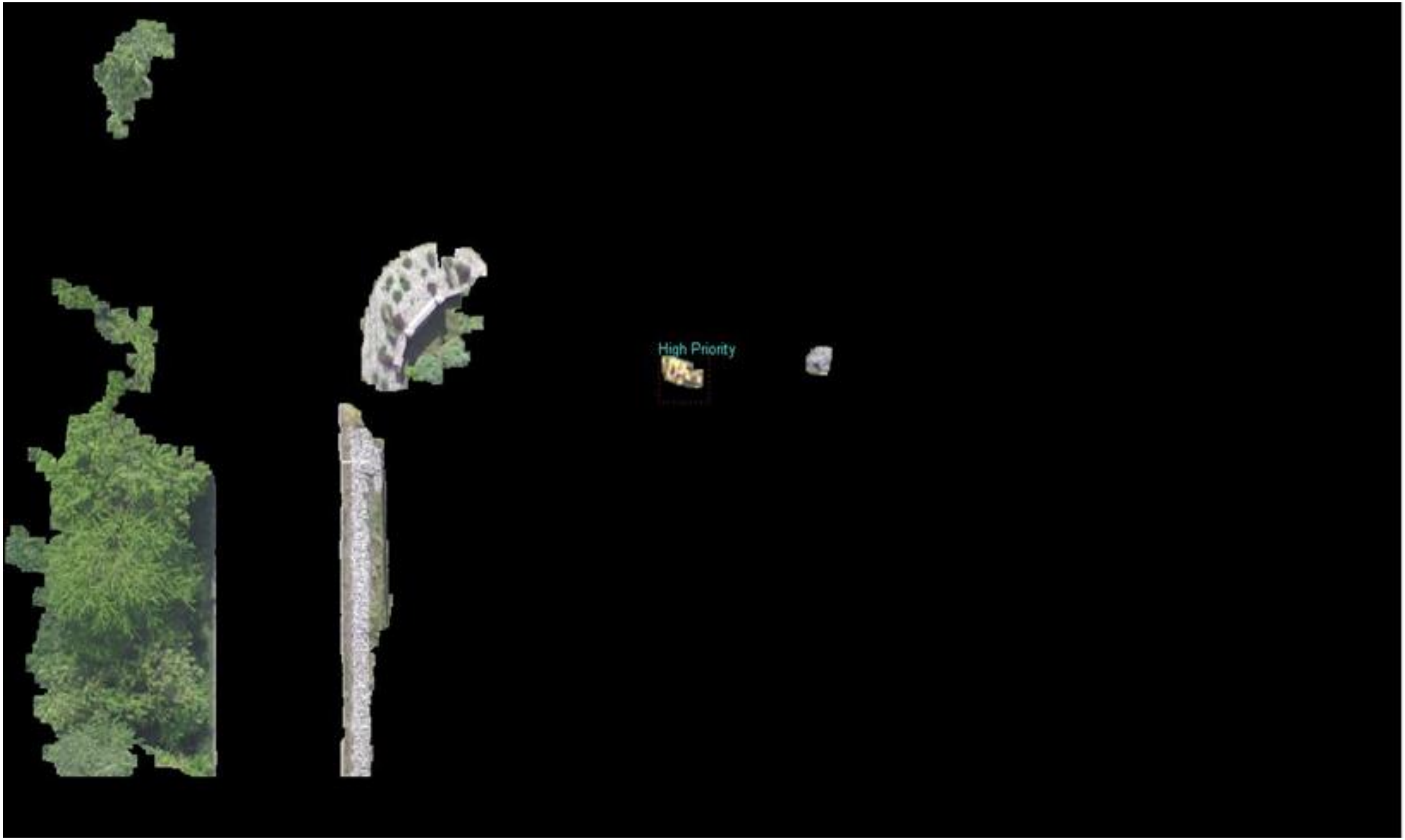
D3: distance from image center to pipeline.

Backhoe - Raw Image

Background Elimination

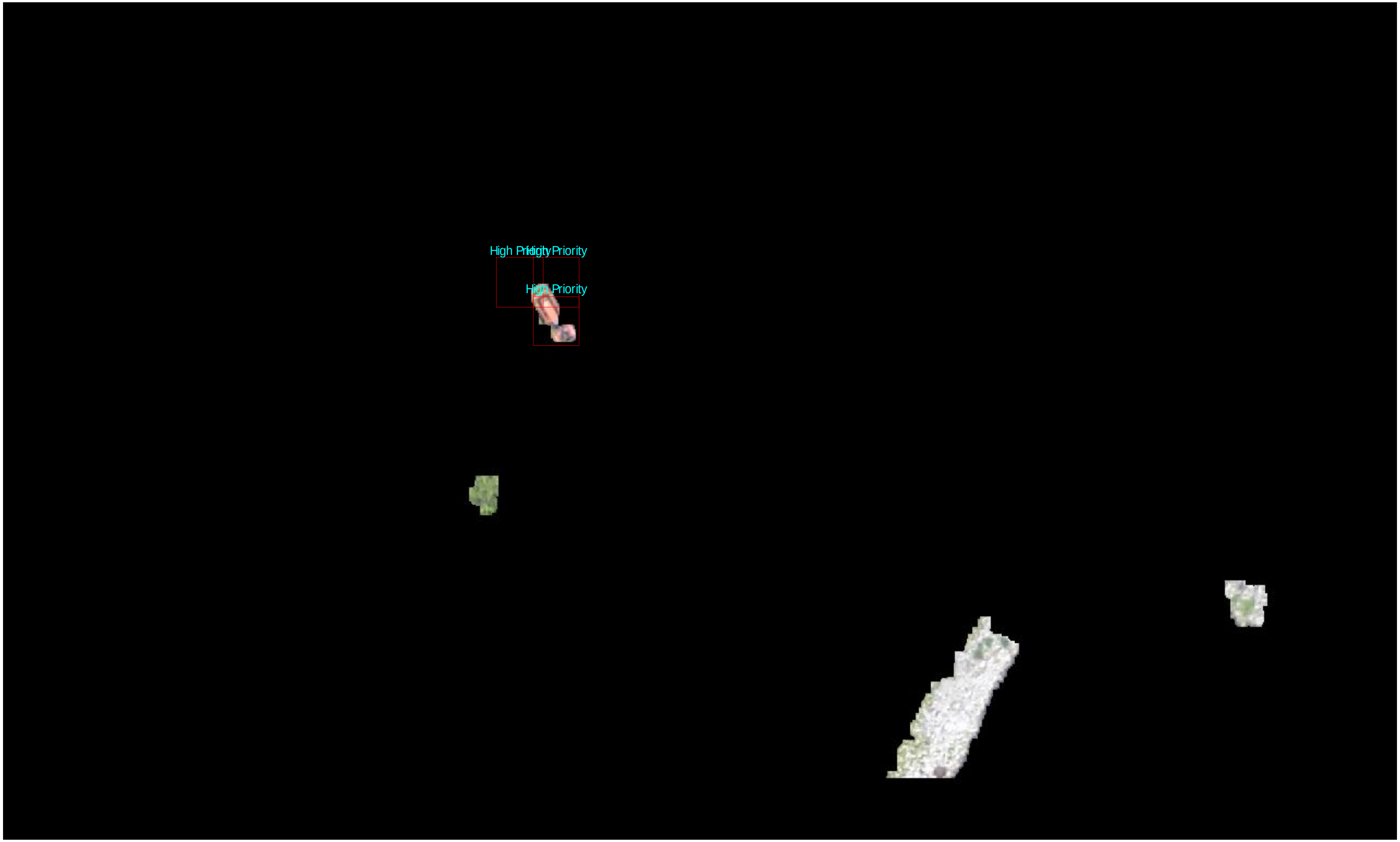
Detection Processes......

Final Detection and Priority Assignment



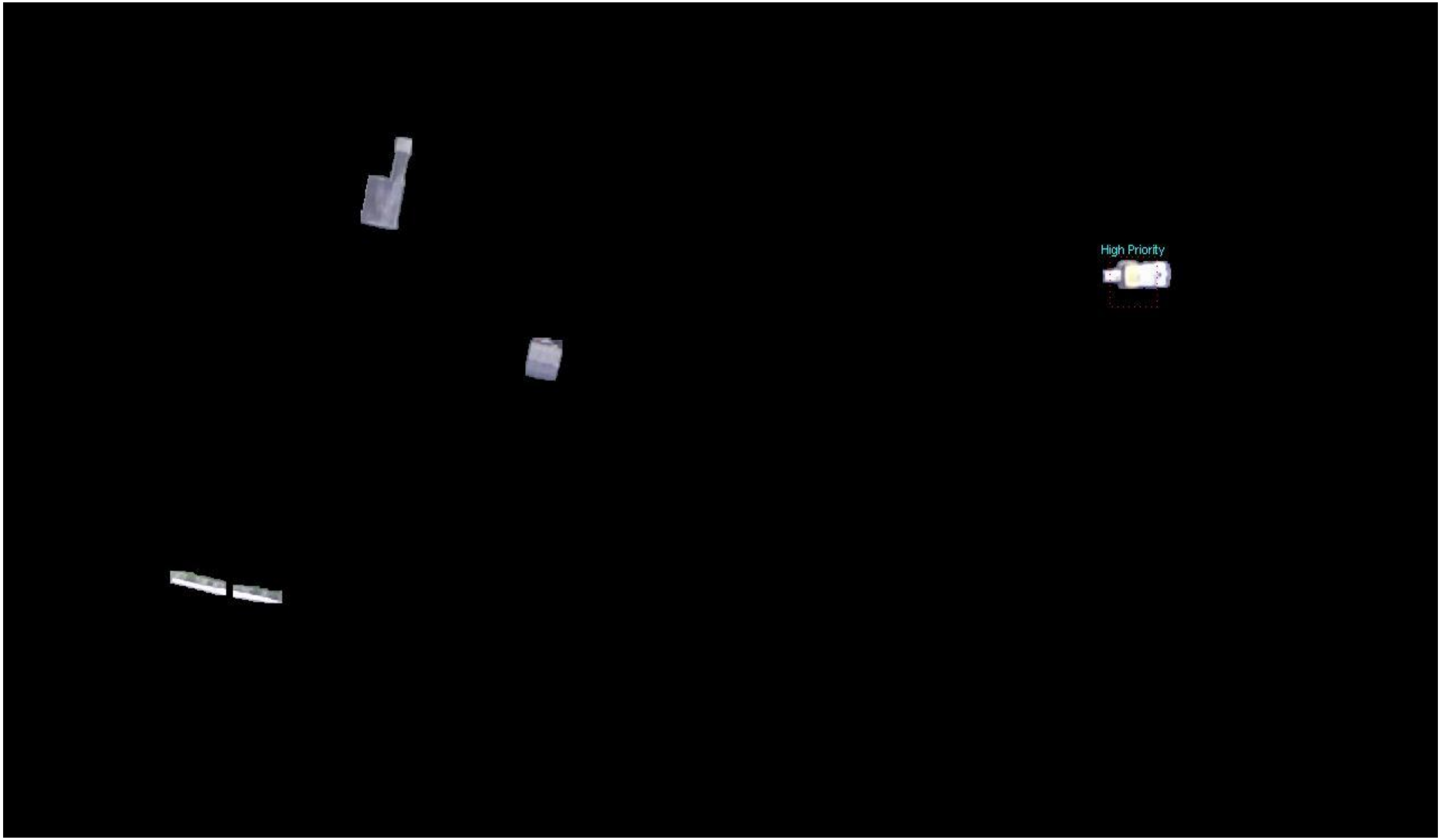
Tractor - Raw Image

Final Detection and Priority Assignment



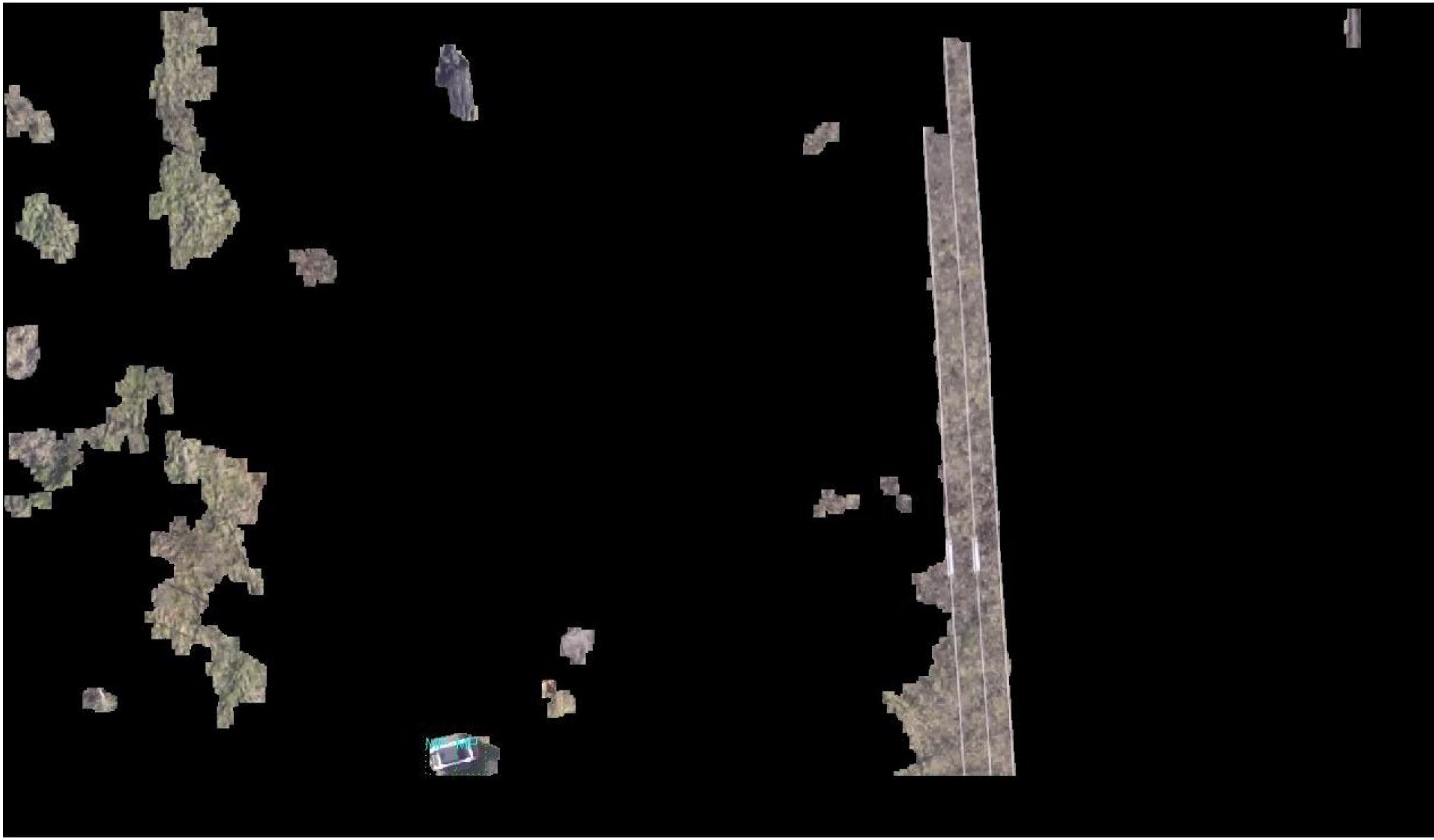
Trencher – Raw Image

Detection and Priority Assignment



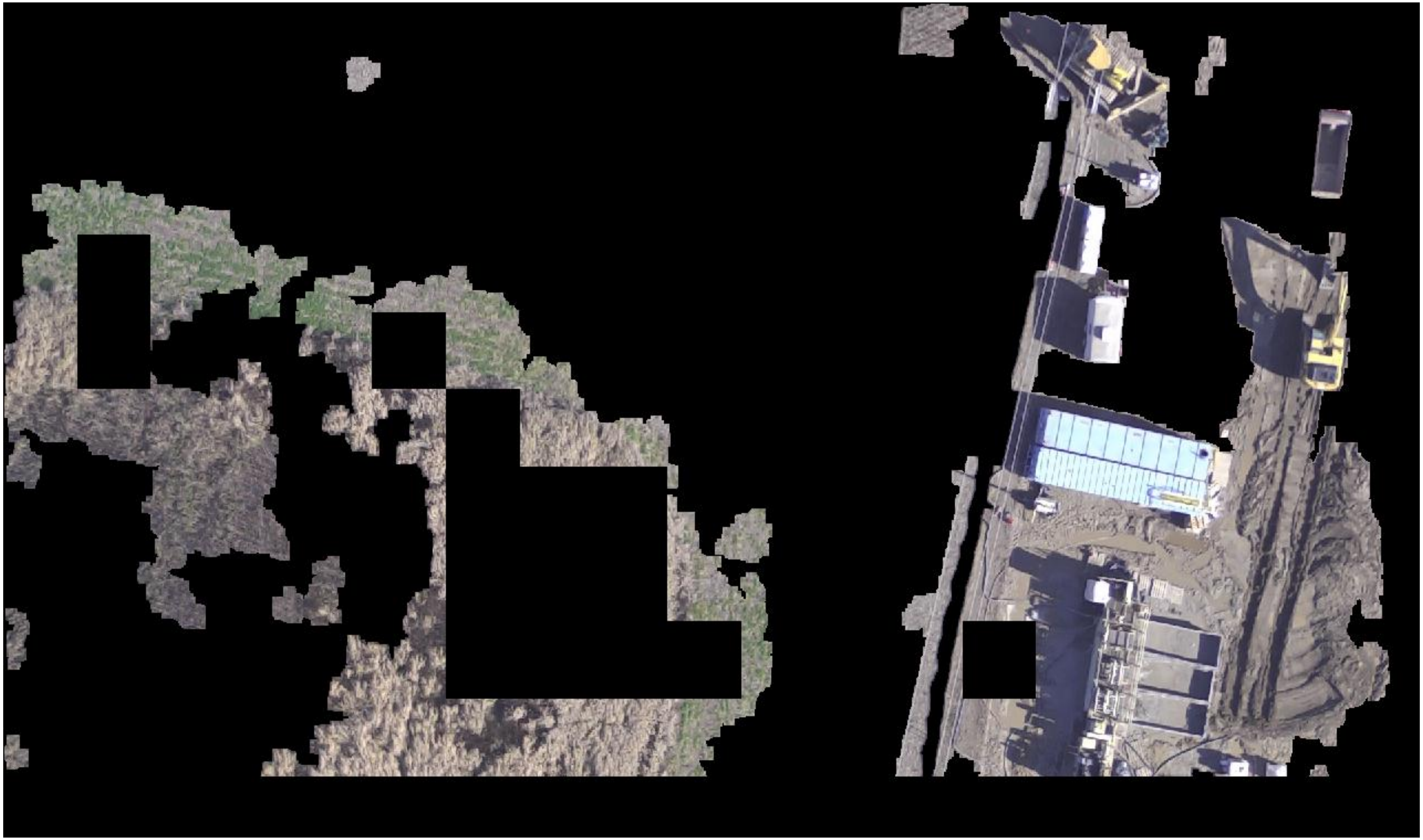
Skid Steer - Raw Image

Final Detection and Priority Assignment

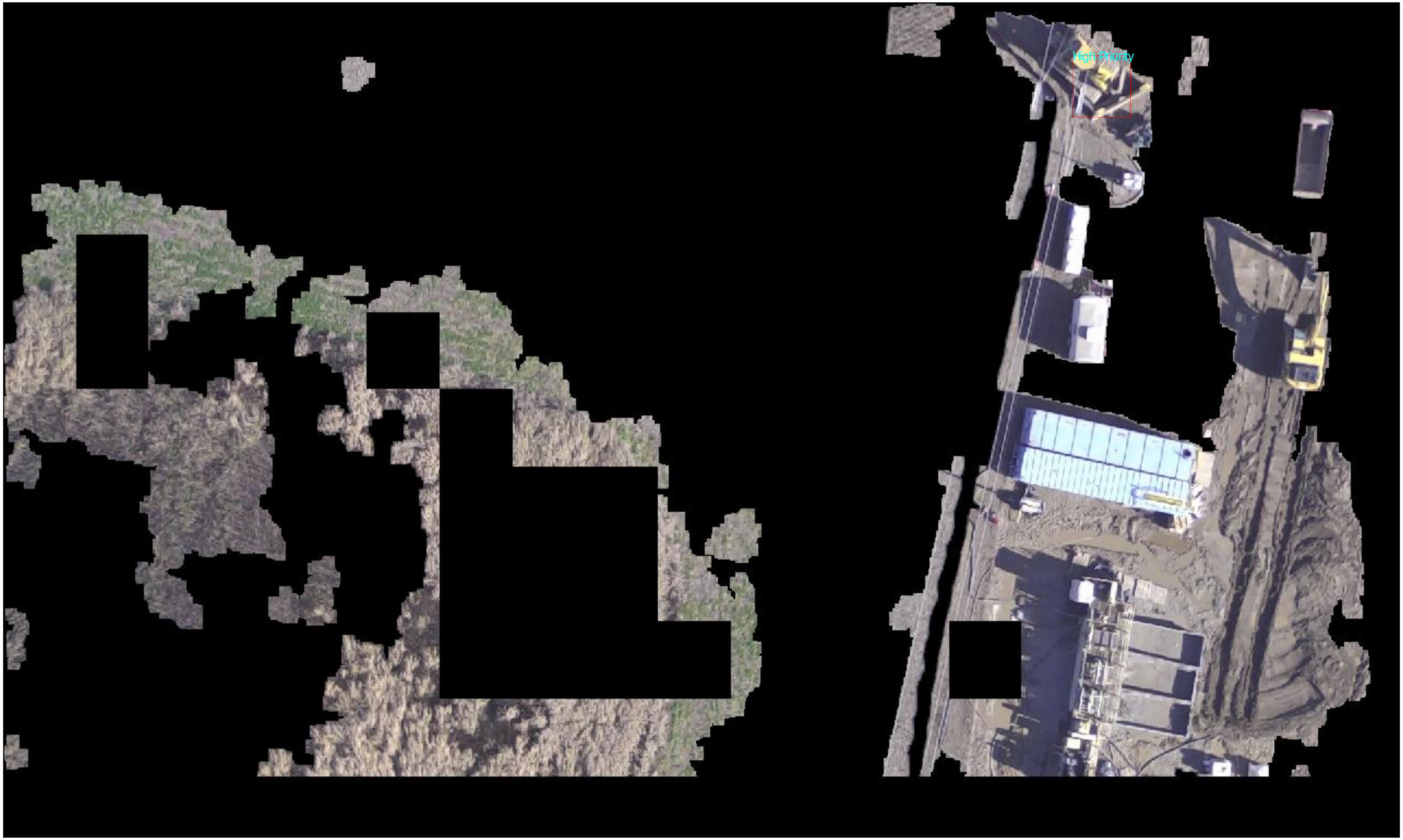


Construction Equipment Detection

Background Elimination

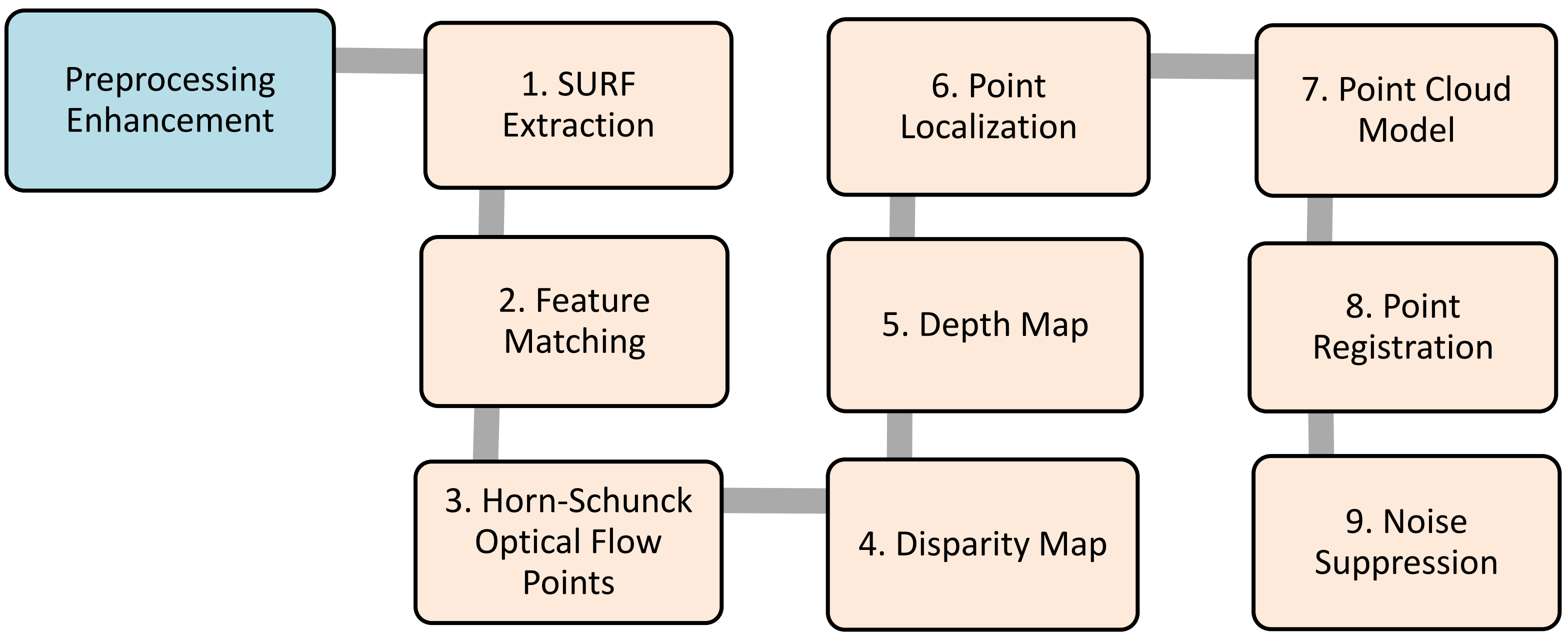


Detection and Priority Assignment



3D Scene Reconstruction Framework

- Dense Point-Could Representation (DPR): The reconstruction procedure is broken into several distinct phases:



3D Reconstruction

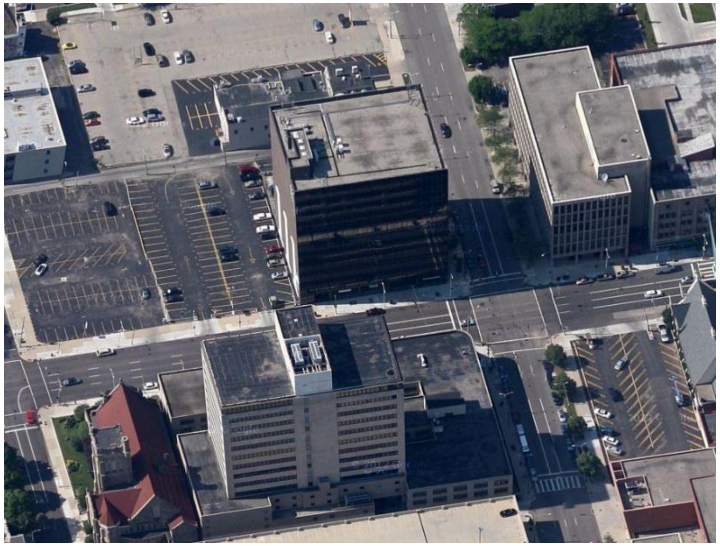
- Reconstruct a dense 3D model from imagery is reconstructed in near real-time.
- Technique utilizes un-calibrated video data
  - No usage of GPS or IMU data

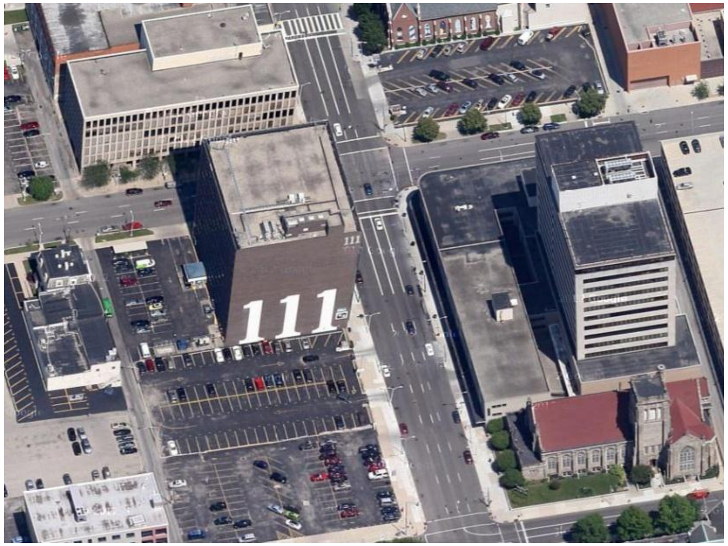
Input Imagery

3D Model

Applications of a 3D Model

- **Changed Detection Using the 3D Model**
- Contextual Information
  - Elevation, Roads, Geo-registration, Occlusions (Tree Canopy)
- Detection and Elimination of Shadows
- Track Stitching





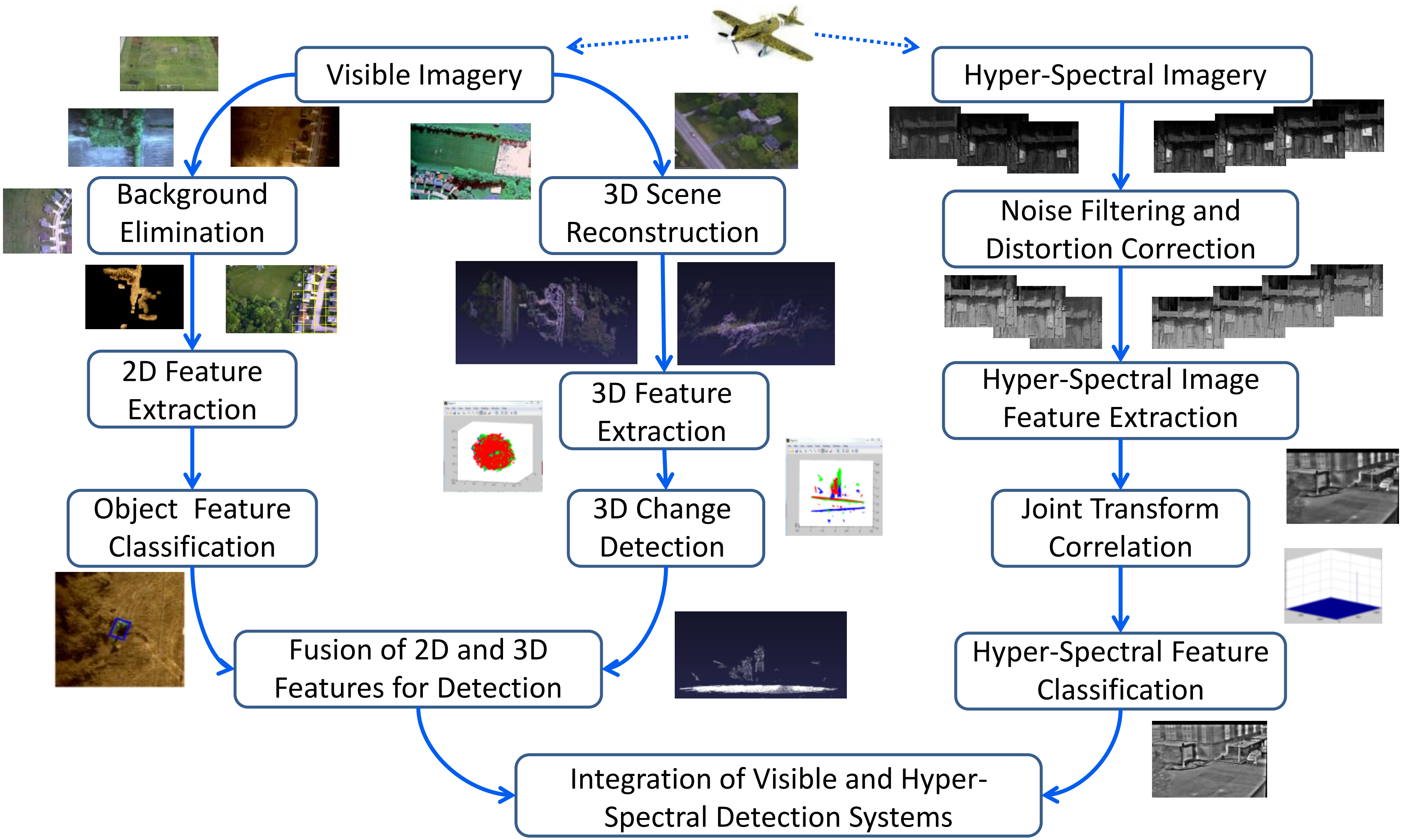
3D Change Detection

- 3D model is used to compare two scene conditions to determine changes in appearance and volume.
- Appearance changes are determined by projecting frames onto the 3D model.
- Volumetric changes are determined by comparing the difference between 3D reconstructed models at different times.

Classification of Detected Changes

Determine Natural Change vs Man-Made

Visible and Hyper-Spectral Image Analysis for Threat/Leak & Change Detection



System Integration and Prototyping

3D scene reconstruction

For accurate change detection.
Construction of a disparity map from video based on the feature point similarity in subsequent frames.
Creation of disparity to depth map.
Surface reconstruction and smoothing.

Implementation of geo-registration techniques

Implementation of a geo-registration technique that can convert the location of threat from image co-ordinates to camera co-ordinates and then to geographical co-ordinates using GPS information.

Hardware acceleration

GPU-FPGA-CPU cluster for hardware acceleration.
Algorithm partitioning and hardware architecture design.
Hardware-software co-design for area-power-time optimization.

Portable software for system integration

Software implementation of the algorithm to interface with other data acquisition, storage and communication systems.