GIS Tools for Non-GIS Applications

***Prepared for*:**

NEFGIS User's Group

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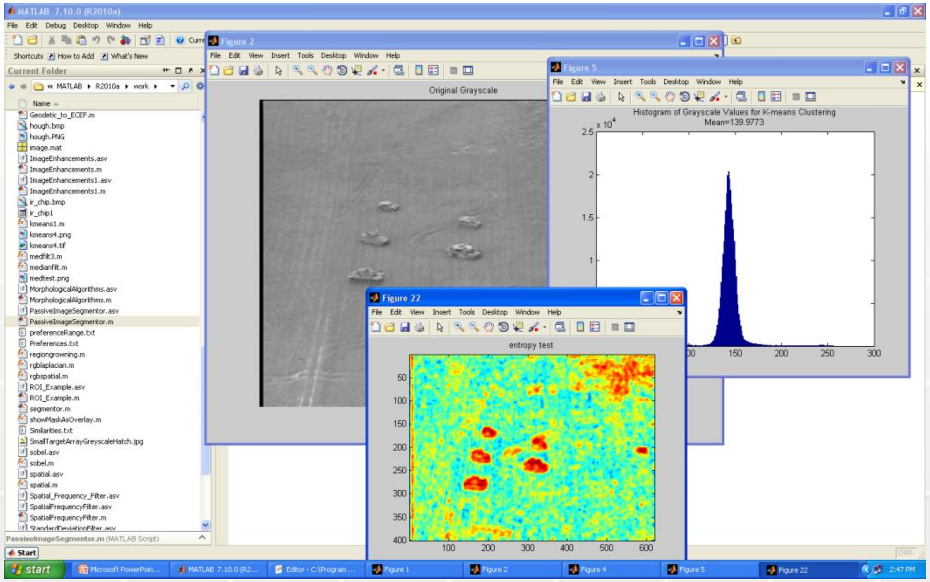
Overview

- **Illustrate use of commonly-used GIS tools for non-GIS applications**
- **Introduce tool → GIS Application → Non-GIS Application**
- **Tools considered**
  - – Supervised Classification
  - – Unsupervised Classification
  - – Georeferencing
  - – Spatial Filtering
  - – Lidar Point Cloud Processing



- **"No math, just business"**

Steve Alter

Tools

- **Supervised Classification**
- **Unsupervised Classification**
- **Georeferencing**
- **Spatial Filtering**
  - Low Pass (smoothing, averaging)
  - High Pass (sharpening)
  - Edge Detection
- **Lidar Point Cloud Processing**

Supervised Classification

- **Analyst assigns selected raster pixels into known feature class**
  - Selected pixels are representative samples of features to be rendered in classified raster
  - Known feature classes referred to as training data or signature file
- **Classification algorithm uses training data to classify all remaining pixels in image**
  - Classification based spectral similarity between remaining pixels and known feature classes
- **GIS Tool**
  - ArcMap Create Signature File and Maximum Likelihood Classification
  - ERDAS Image Signature Editor and Supervised Classification

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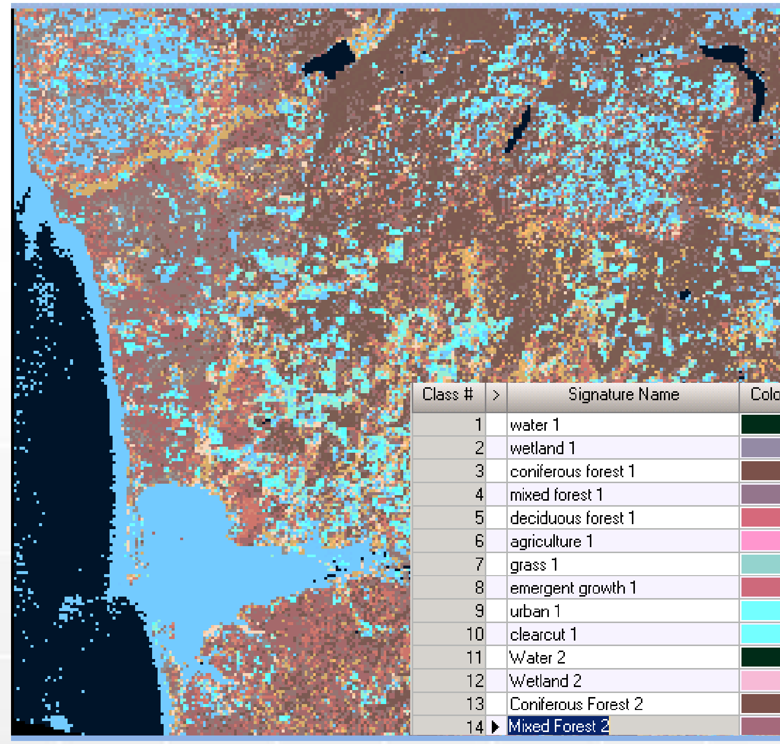
Supervised Classification (GIS)

Original Image

Classified Image



- **Identify/select small areas of interest (AOI) in image that represent distinct features found across entire image (e.g., LULC application)**
- **AOI used to create spectral signatures (i.e., signature file)**

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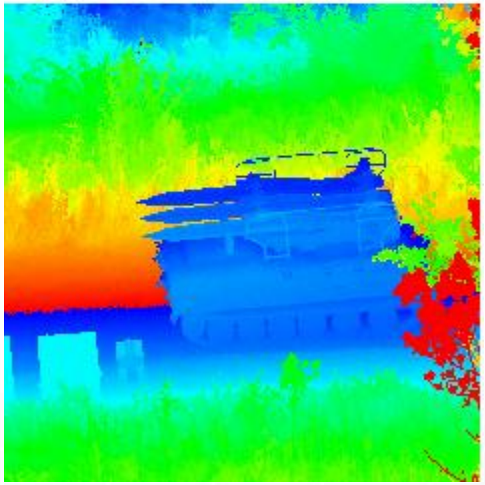
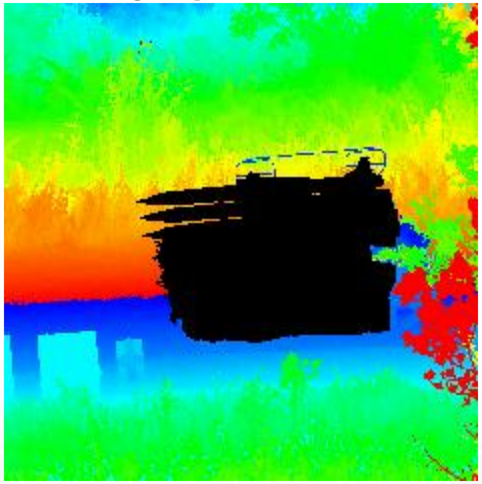
Supervised Classification (Non-GIS)

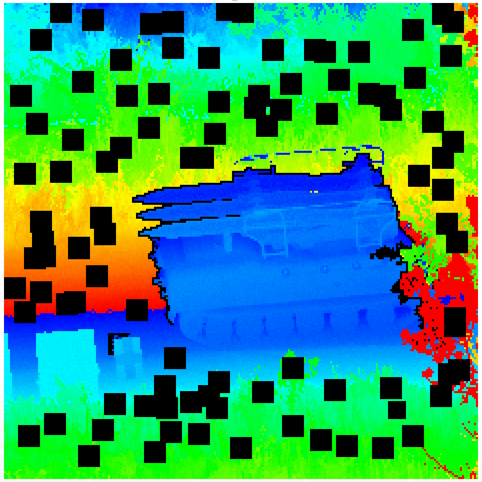
Sensor Image



All target pixels selected



Some clutter pixels selected



- Create ground truth (i.e., signature) file from selected pixels to train genetic algorithm to distinguish targets from clutter
- Each record (row) in file represents a pixel
- First field provides truth (1 = target; 0 = clutter)
- Subsequent fields provide features computed for pixel and neighboring cells

Truth	x1	x2	x3	....
0	84	20	156	....
1	193	112	69	....
0	91	28	134	....
0	80	24	135	....
1	193	102	79	....
:	:	:	:	

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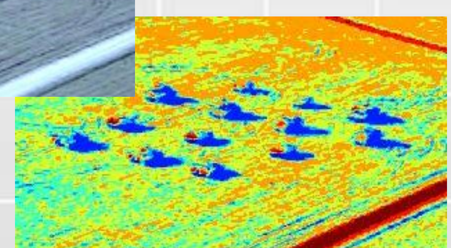
Tools

- **Supervised Classification**
- **Unsupervised Classification**
- **Georeferencing**
- **Spatial Filtering**
  - Low Pass (smoothing, averaging)
  - High Pass (sharpening)
  - Edge Detection
- **Lidar Point Cloud Processing**

Unsupervised Classification

- **Sorts raster pixels into individual classes (or, clusters)**
- **Algorithm determines which pixels are grouped together in classes; no need for *a priori* ground truthing**
- **But, analyst must decide what features those classes represent**
- **GIS Tool**
  - ArcMap Spatial Analyst ISO Cluster and Maximum Likelihood Classification
  - ERDAS Image Unsupervised Classification

Original image



Classified image

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Unsupervised Classification (GIS)

- Perform unsupervised classification to segment water feature from land features
- Study Area: Newnans Lake, Alachua County, FL

Landsat 5 Thematic Mapper Image LT50170392011072GNC01

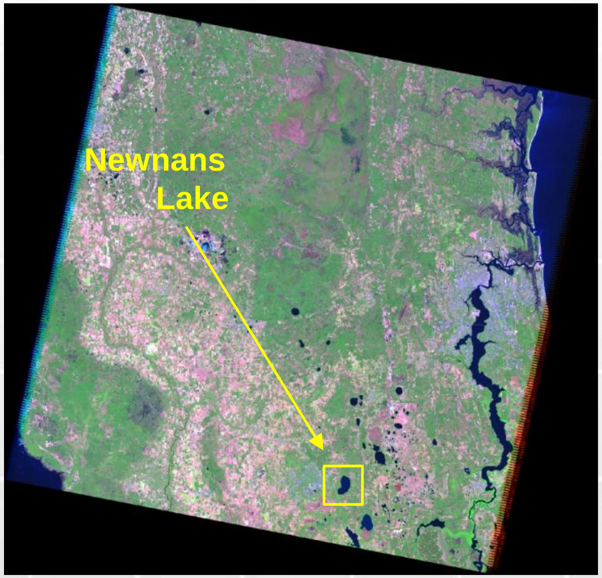
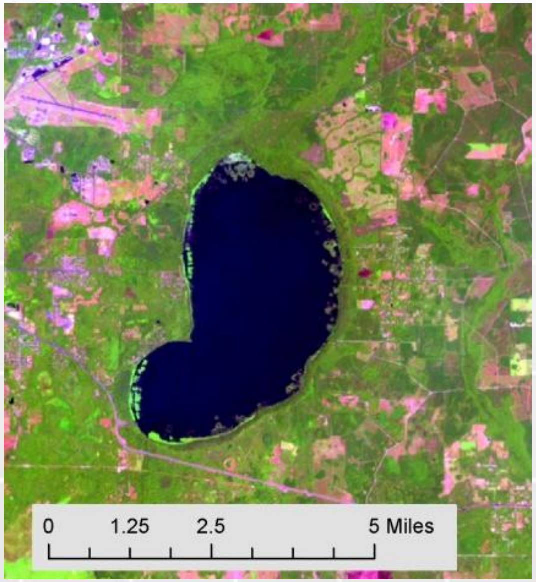
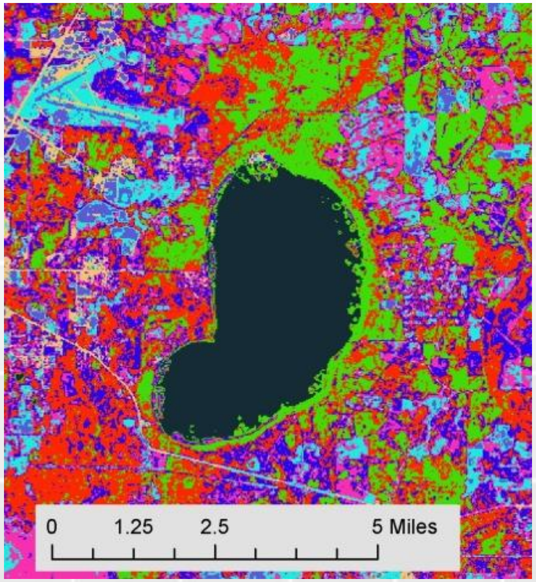


Image Chip



Classified Chip (8 Classes)



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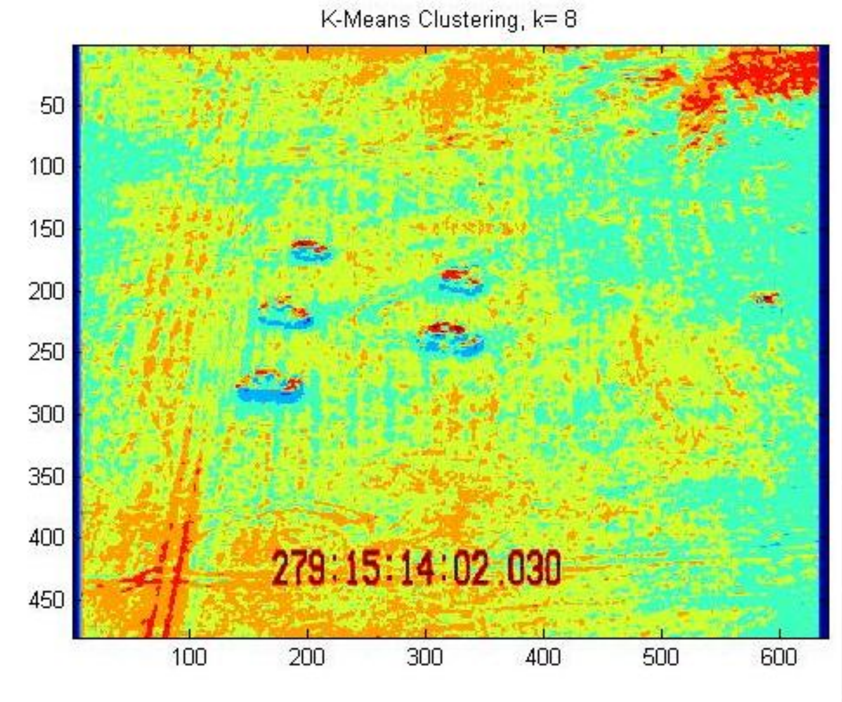
Unsupervised Classification (Non-GIS)

- **Perform *k-means clustering* to segment image pixels into ‘k’ clusters to distinguish tanks from background clutter**

- **Pixels assigned to cluster with nearest mean value**



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Tools

- **Supervised Classification**
- **Unsupervised Classification**
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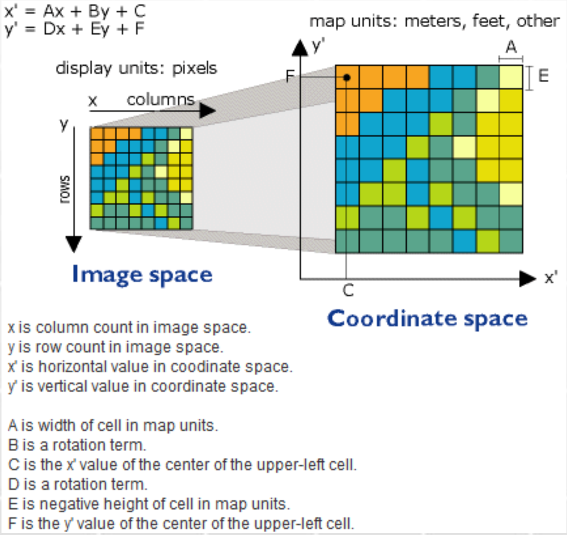
Georeferencing

- **Aligns raster/vector datasets to common coordinate system**
- **Control points used to link known positions in respective datasets**
- **One dataset is translated, rotated, and scaled relative to second dataset to achieved georeferenced image**
- **First-order polynomial (i.e., affine transformation) commonly used**
- **GIS Tool**
  - **ArcGIS Georeferencing Toolbar**
    - **Add Control Points**
    - **View Link Table**



Courtesy of ESRI

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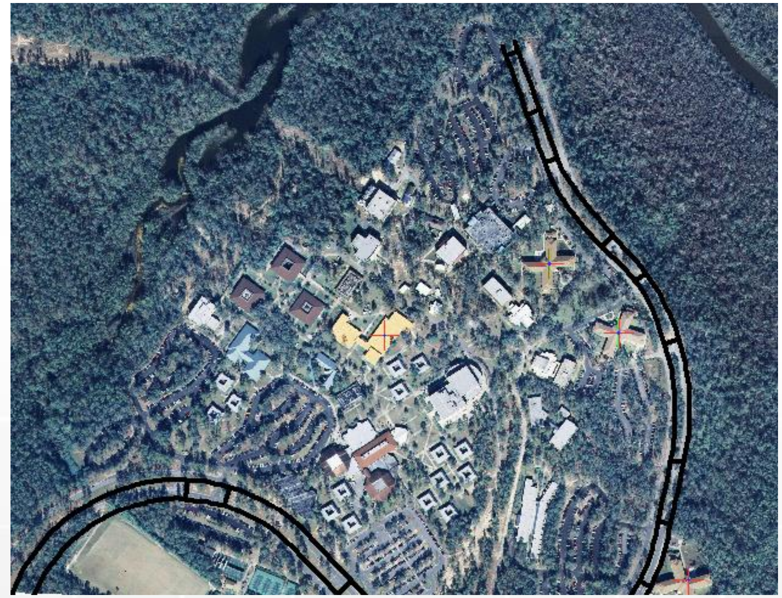
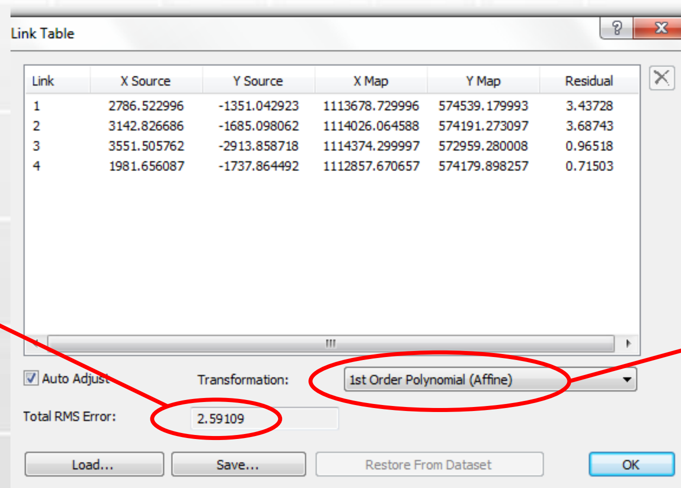
Georeferencing (GIS)

Vector data (roads and building) not georeferenced to aerial image raster

Georeferenced Image





Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	2786.522996	-1351.042923	1113678.729996	574539.179993	3.43728
2	3142.826686	-1685.098062	1114026.064588	574191.273097	3.68743
3	3551.505762	-2913.858718	1114374.299997	572959.280008	0.96518
4	1981.656087	-1737.864492	1112857.670657	574179.898257	0.71503

Link Table

rms = 2.59

1st-order polynomial (affine transformation)

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Georeferencing (Non-GIS)

Color
(Converted to grayscale)

IR

Color/IR Overlaid

- **Georeferencing often referred to as *image registration***
- **Although synchronized in time, vehicles in color image are offset (specifically, left and below) from corresponding vehicles in IR image**
- **Must "register" images to a single coordinate frame**
  - Facilitates and optimizes data fusion from the two sensors

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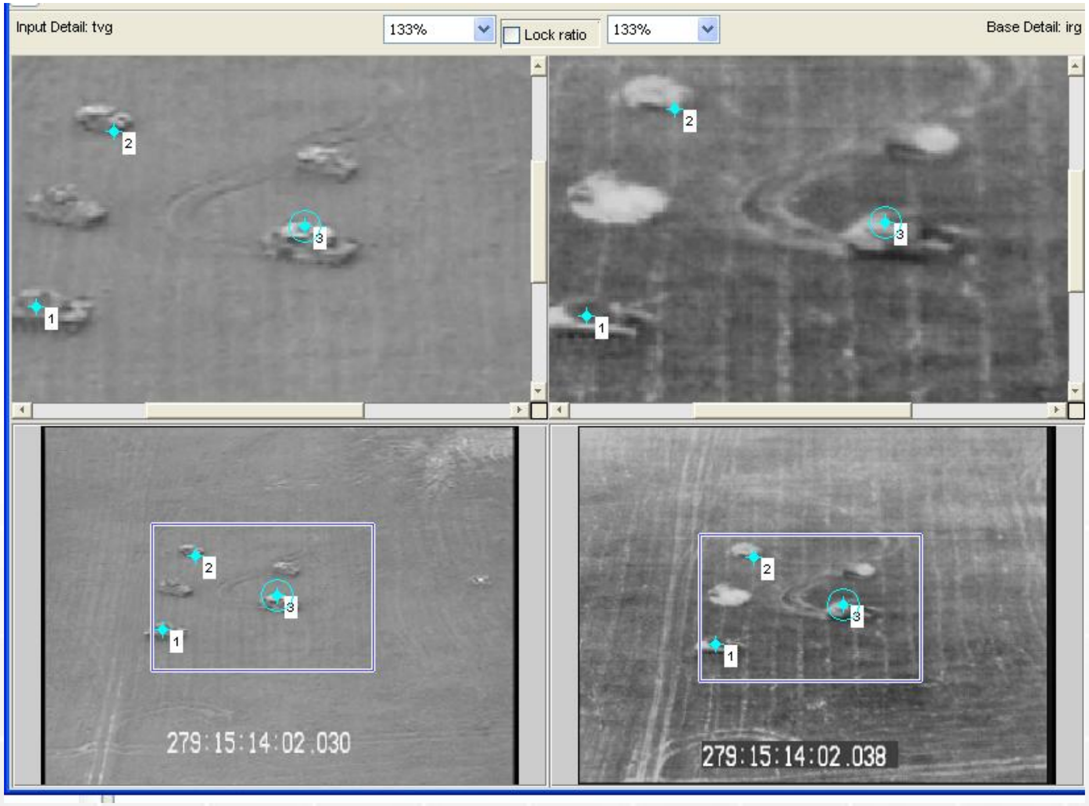
Image Registration (via MATLAB)



- **Form following matrix equation, and solve for A (Affine Transformation matrix)**

IR control points **Color control points**

$$\begin{bmatrix} 293 & 175 & 240 \\ 185 & 235 & 355 \\ 1 & 1 & 1 \end{bmatrix} = A \begin{bmatrix} 274 & 174 & 228 \\ 163 & 207 & 316 \\ 1 & 1 & 1 \end{bmatrix}$$

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Image Registration (Cont.)

$$A = \begin{bmatrix} 293 & 175 & 240 \\ 185 & 235 & 355 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 274 & 174 & 228 \\ 163 & 207 & 316 \\ 1 & 1 & 1 \end{bmatrix}^{-1} = \begin{bmatrix} 1.18 & 0.009 & -33.05 \\ -0.128 & 1.107 & 8.02 \\ 0 & 0 & 1 \end{bmatrix}$$

Overlaid Registered Images

- **Register color image to IR image by multiplying each color pixel $(row, col, 1)^T$ by transformation matrix, A**

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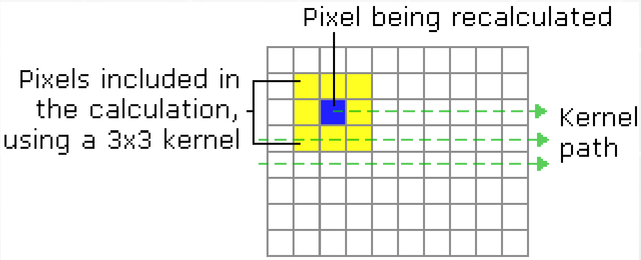
Spatial Filtering

- **Spatial filter (aka, kernal or mask) is group of cells around target cell**
- **Filter sequentially shifted across each cell in raster data set to recalculate value of target cell that lies at its center**
- **GIS Tool**
  - **Spatial Analyst Filter-Low for image smoothing**
  - **Spatial Analyst Filter-High for image sharpening**
  - **Spatial Analyst Contour for edge detection**



Courtesy of ESRI

20	21	19	20	24	25	26
22	24	25	23	25	28	29
23	25	26	28	32	31	33
24	29	**28**	30	32	32	34
23	32	31	32	29	30	32
22	30	26	33	30	31	30
22	29	28	29	31	32	31

Raster data (28 is target cell)

1	1	1
1	1	1
1	1	1

Low Pass Filter

	29	

Filtered value

(25 x 1) / 9 + (26 x 1) / 9 + (28 x 1) / 9 +
(29 x 1) / 9 + (28 x 1) / 9 + (30 x 1) / 9 +
(32 x 1) / 9 + (31 x 1) / 9 + (32 x 1) / 9 **= 29**

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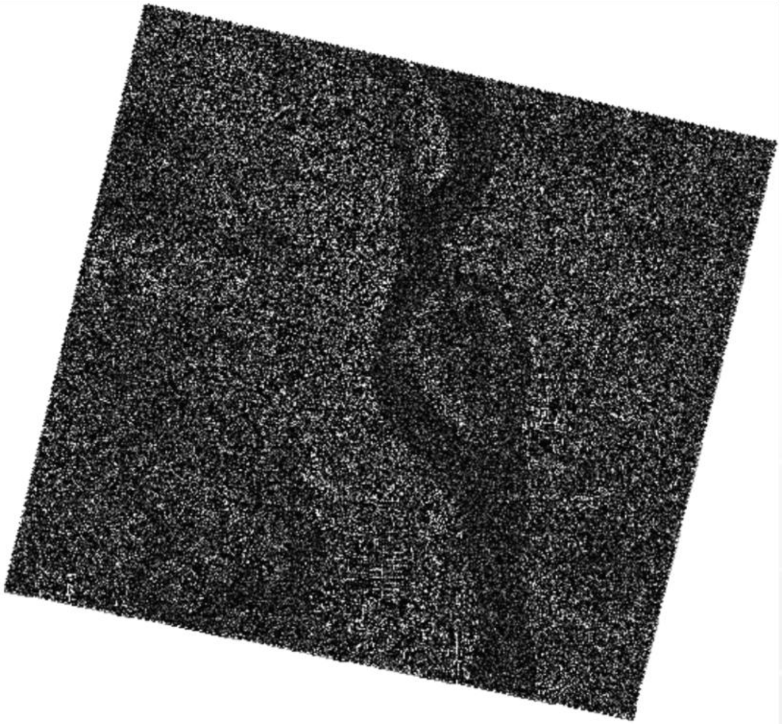
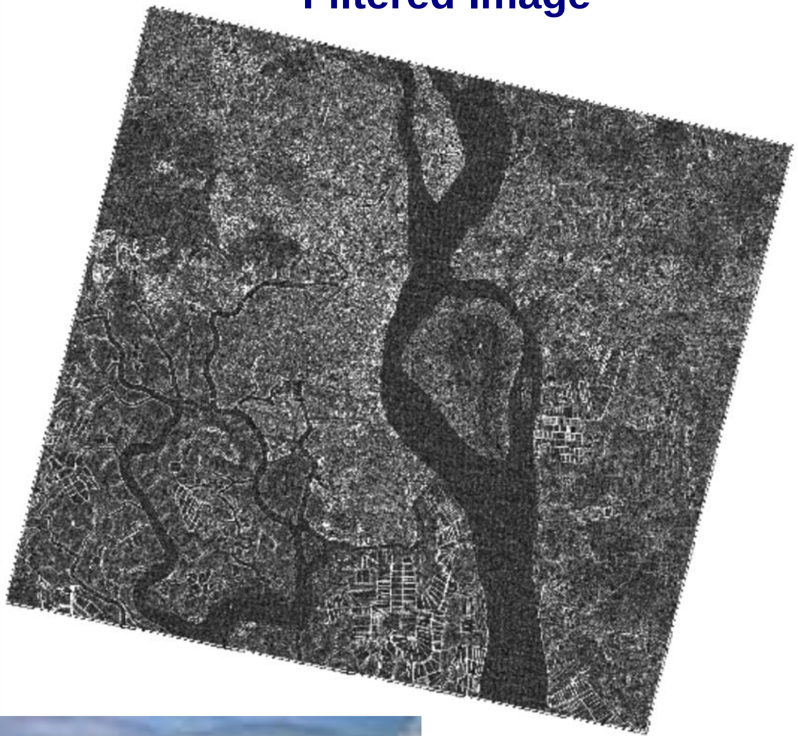
Low Pass Filter (GIS)

Original Image (ETM, Band 8)



Filtered Image



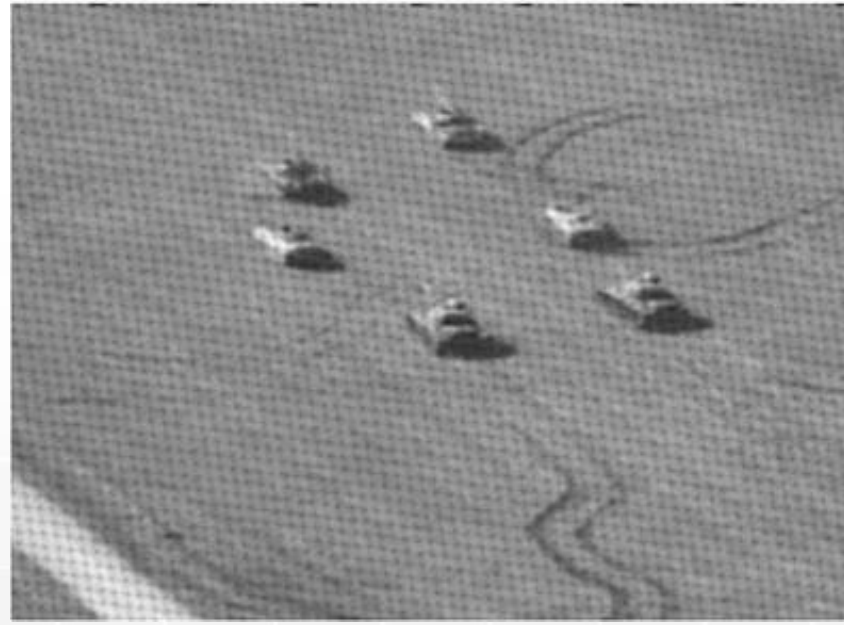
- **Filter smooths (averages) data**
- **Pixels blend better with neighboring pixels**

Guayus River
Quayaquil, Ecuador

Low Pass Filter (Non-GIS)

Original Image

Filtered Image



- **Filter smooths noisy image data**

However ...

- **Vehicle edges blurred and less distinct**

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High Pass Filter (Non-GIS)

Original Image

Filtered Image

- **High-pass filter sharpens vehicle edges making them more distinct**

However ...

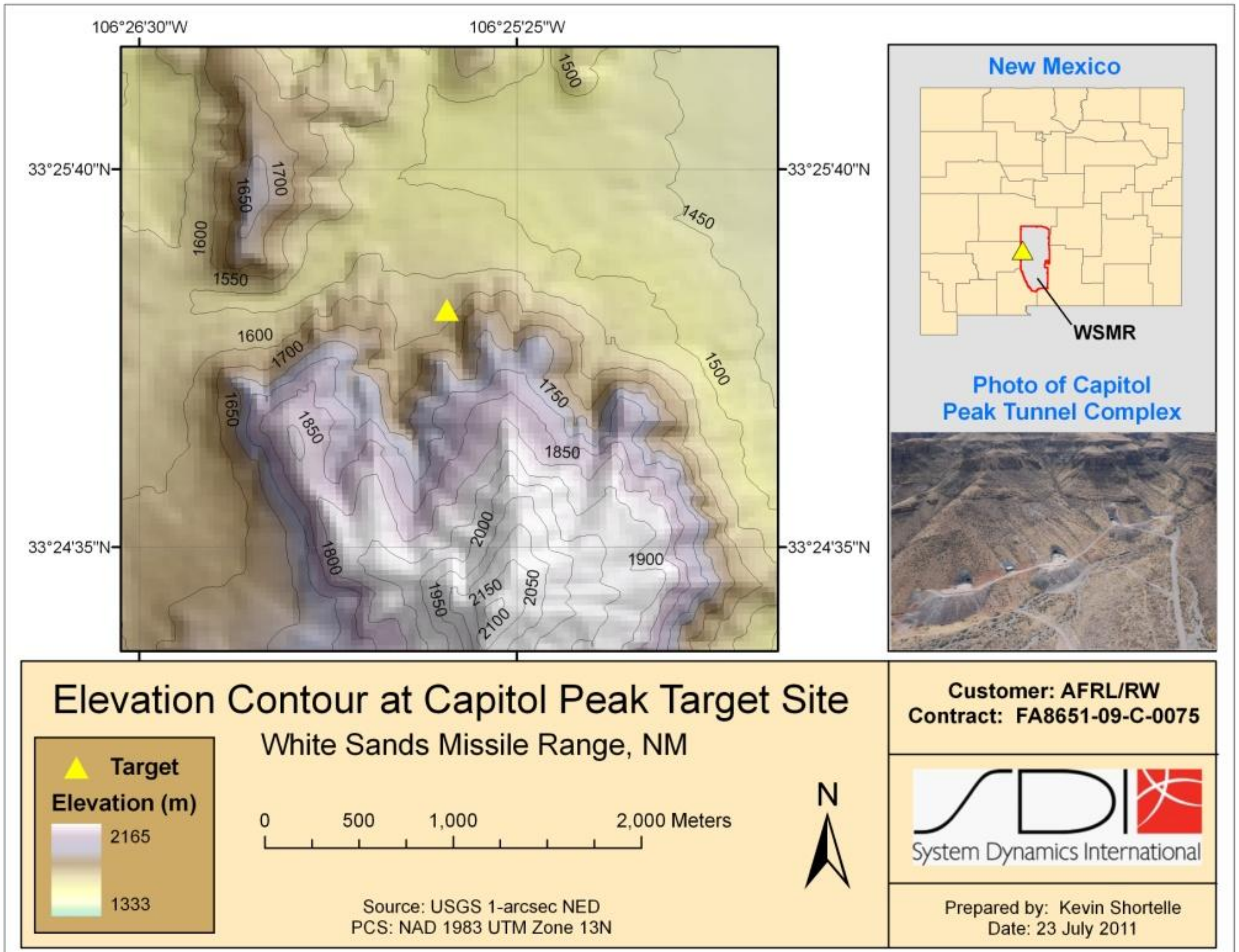
- **Undesirable image noise also accentuated**

0	-1	0
-1	5	-1
0	-1	0

High Pass Filter

Edge Detection – Contour Tool (GIS)

- Identify gradients such as discontinuities and abrupt changes in DEM rasters to compute contour lines



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Edge Detection (Non-GIS)

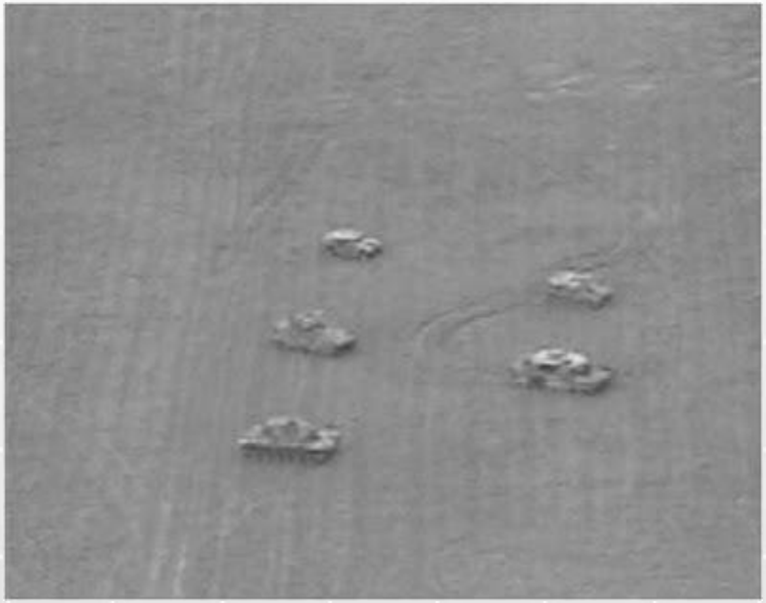
- **Filter used to identify distinct edges in raster image**
- **Result is reclassified two-code image -- value of 1 indicates a distinct edge, 0 otherwise**
- **"Sobel" filter uses a pair of 3 x 3 filters, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows)**

Gx =

-1	0	1
-2	0	2
-1	0	1

Gy =

1	2	1
0	0	0
-1	-2	-1



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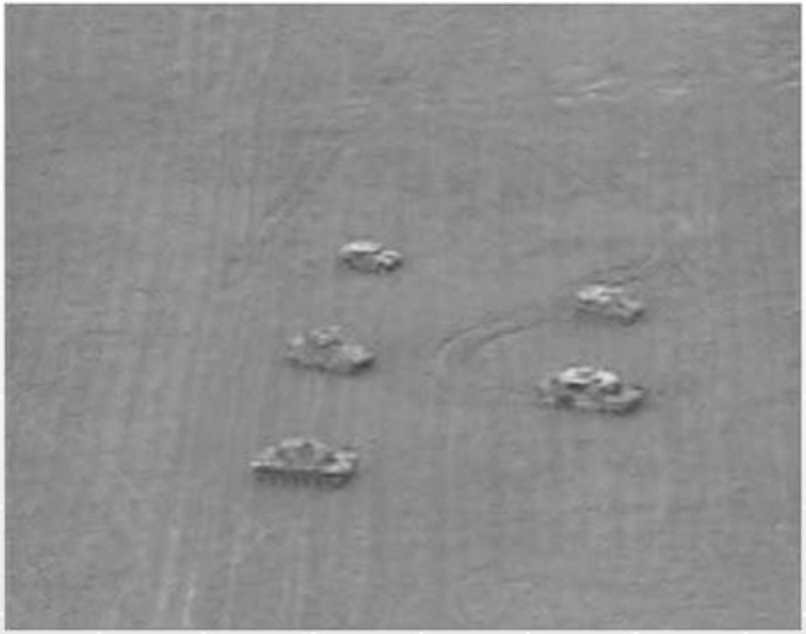
Contour Tool Edge Detection (Non-GIS)

- As an experiment, use Spatial Analyst **Contour Tool** to segment military vehicles based on abrupt changes in grayscale values



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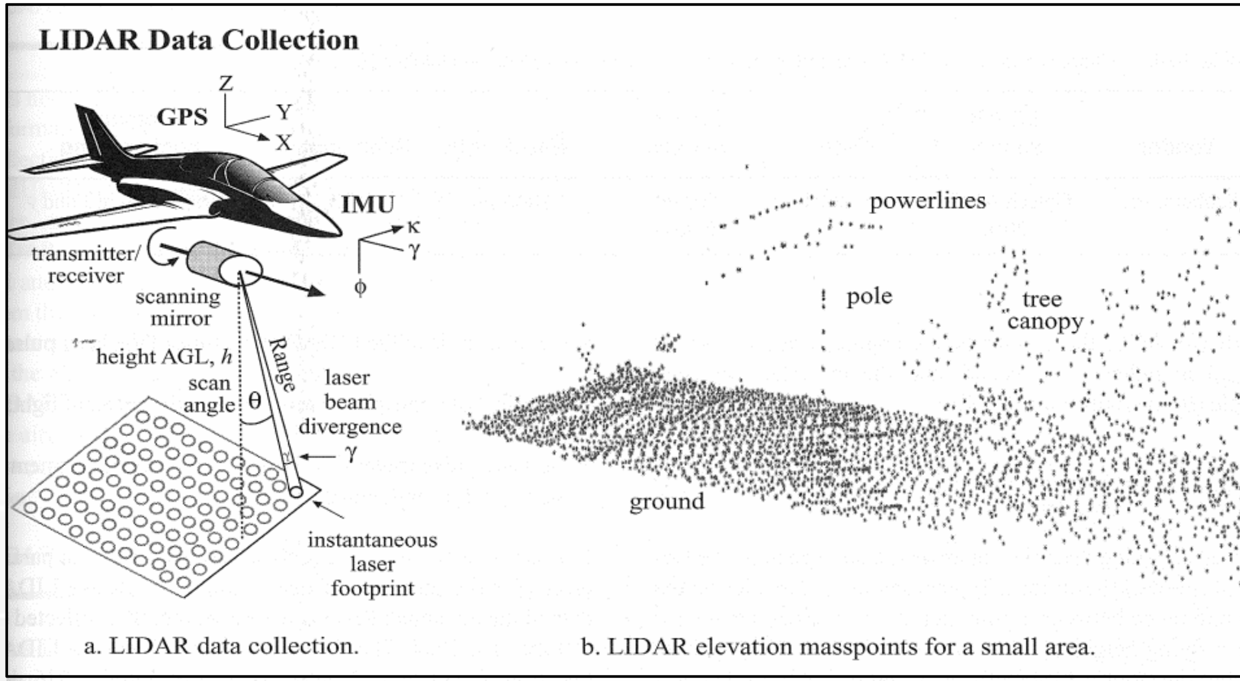
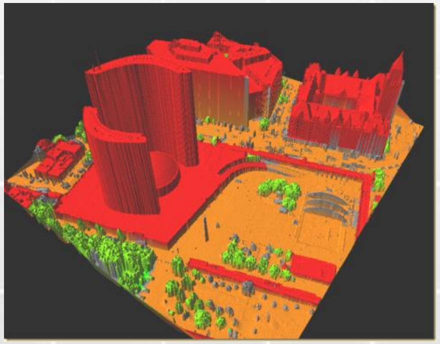
Lidar Mass Point Processing

- **3D lidar data allows mapping of earth's surface and non-surface objects to render DTM and DSM**
- **Raw x, y, z data converted to LAS format to facilitate data exchange between users**
- **GIS Tools**
  - ArcMap 3D Analyst LAS to Multipoint tool
  - Quick Terrain Modeler for point cloud visualization



a. LIDAR data collection. b. LIDAR elevation masspoints for a small area.

Text: Remote Sensing of the Environment



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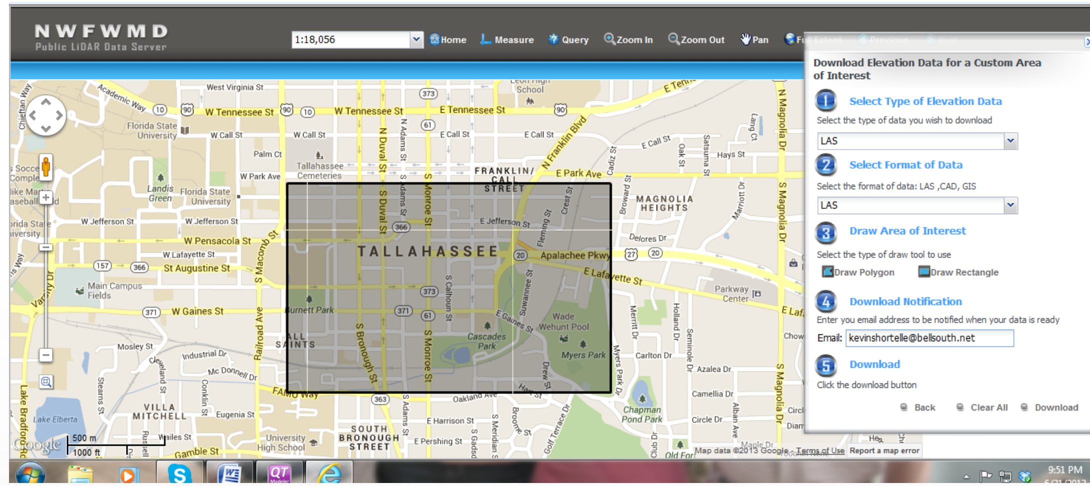
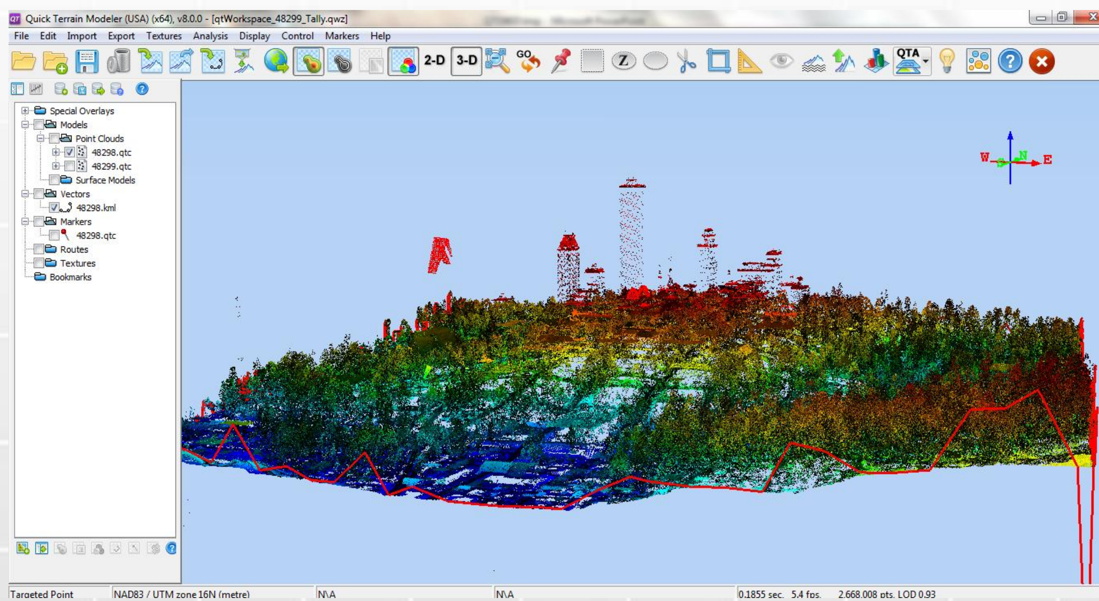
Lidar Mass Point Processing (GIS)

- **Access NWFWMD portal to retrieve Lidar data for selected area around Tallahassee, FL** (www.nwfwmdlidar.com)



- **Utilize Quick Terrain (QT) Modeler to visualize retrieved data**



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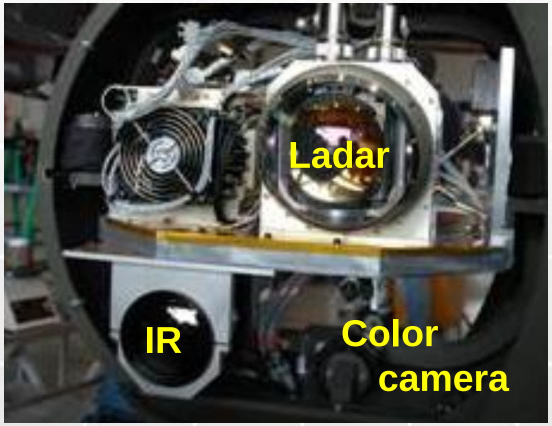
Ladar Point Cloud Processing (Non-GIS)

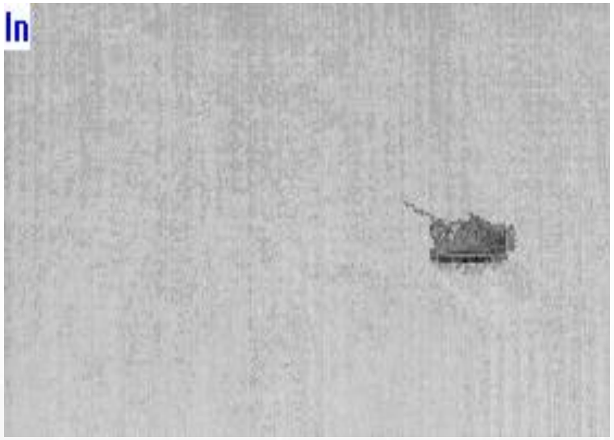
Exploit Ladar point cloud to develop automatic target recognition algorithms

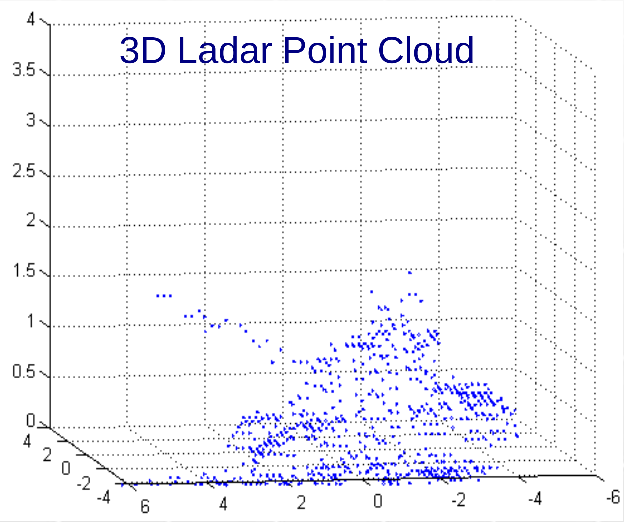
Stabilized Airborne Electro-optical Instrumentation Platform



Co-located color, IR, and ladar sensors

2D Ladar Intensity Image

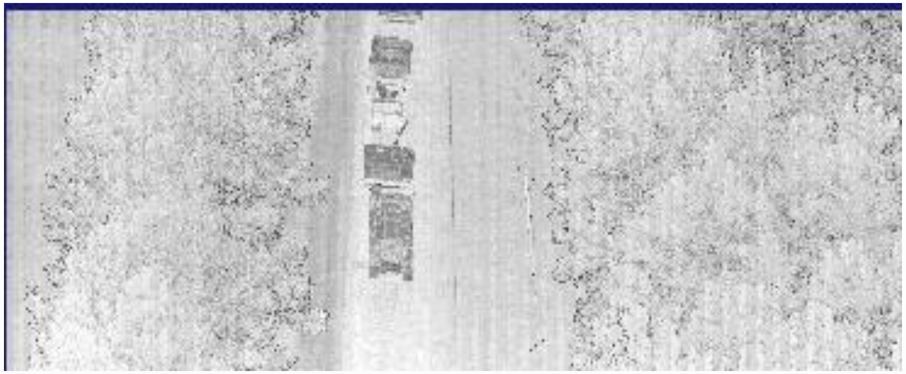


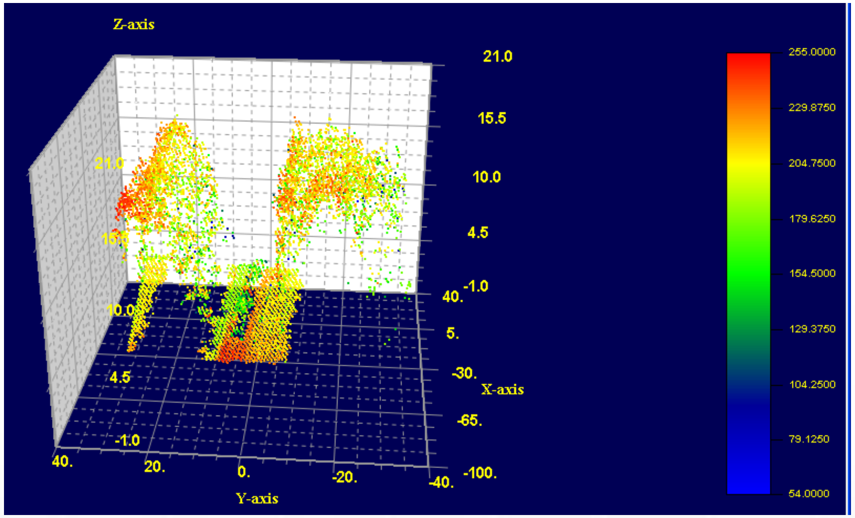


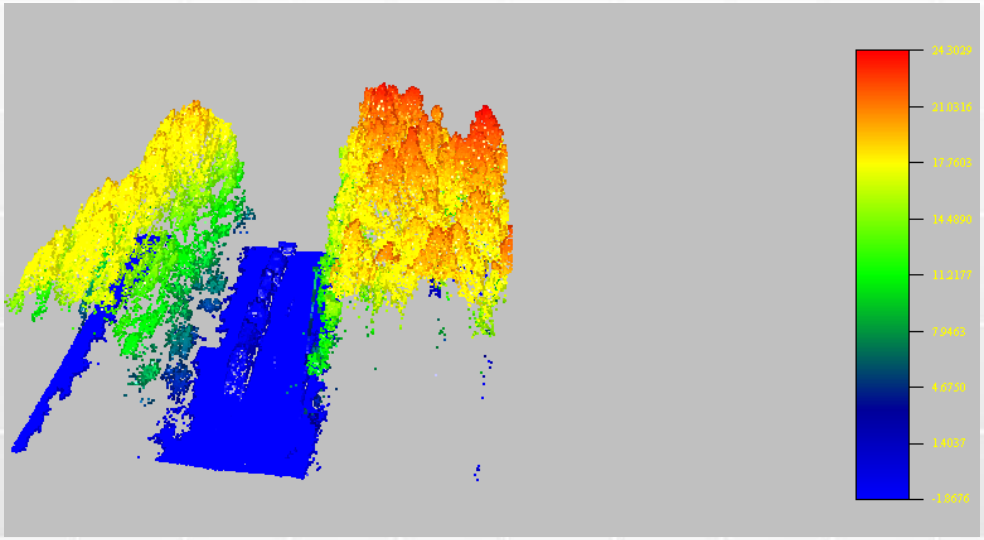
Ladar: Laser detection and ranging

Ladar Point Cloud (Cont.)

2D Ladar Intensity Image







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Questions?

Supplemental Slides

Supervised Training Example (Non-GIS)

TRAINING DATA USED FOR TARGET DETECTION

		FEATURE VALUES				
	Truth	x[1]	x[2]	x[3]	x[4]	x[5]
Target	1	11.44	0.8	5.44	0.56	3.65
	1	5.6	-0.29	3.53	-1.07	2.83
	1	22.29	0.48	21.1	-1.64	2.02
	1	23.72	0.33	26.75	6.35	8.46
	1	16.96	0.39	16.58	-2.48	1.64
	1	129.88	0.95	146.47	15.08	7.05
	1	12.27	0.46	6.4	3.06	4.97
	1	11.89	-0.15	7.46	8.4	2.34
	1	14.44	0.32	12.66	-1.32	-0.27
	1	21.12	0.29	22.49	3.06	7.69
Clutter	0	17.82	-0.2	12.58	-2.74	-2.94
	0	9.06	-0.87	3.84	-2.83	-1.88
	0	83.97	0.41	108.94	9.6	6.12
	0	138.36	0.6	108.94	6.43	1
	0	3.37	-0.8	1.2	-3.91	-0.45
	0	49.98	0.35	108.94	5.83	7.72
	0	73.44	0.7	108.94	1.54	0.71
	0	7.13	-1.2	3.18	-4.75	-1.3
	0	16.29	-1.25	7.64	-1.1	-2.95
	0	17.49	0.05	17.78	-4.67	-2.53

RESULTING PSEUDO-CODE OUTPUT

```
Name of training data file      = radar.dat
Hit miss info for best: hit/miss: (-)10/0 (+)10/0
[ 0] Registers initialized.

[ 1] Accum = Accum + X[5];

[ 2] Accum = Accum * X[1];

[ 3] Accum = Accum / X[3];

[ 4] Accum = Accum + X[5];

[ 5] Accum = Accum * X[4];

[ 6] Accum = Accum - X[3];

[ 7] Accum = Accum * X[4];

[ 8] if (Accum <= 0.0) Accum = 0.0; else Accum = 1.0;
```

$$\text{Accum} = \left[\left[\frac{x[1] * x[5]}{x[3]} + x[5]\right] * x[4] - x[3]\right] * x[4]$$

If Accum <= 0.0, Clutter; otherwise Target

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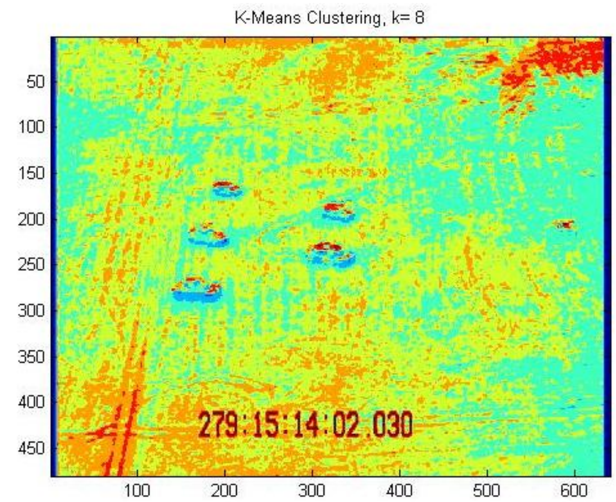
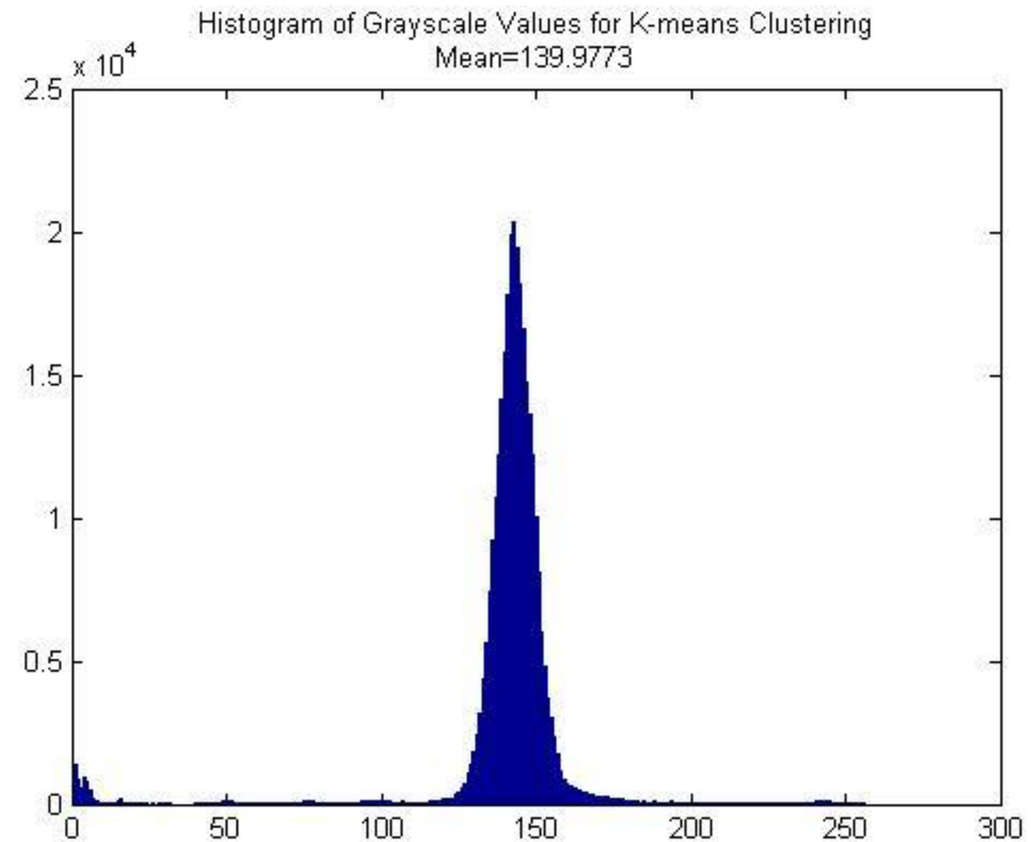
K-means clustering

- **Pixels assigned to cluster with nearest mean value**

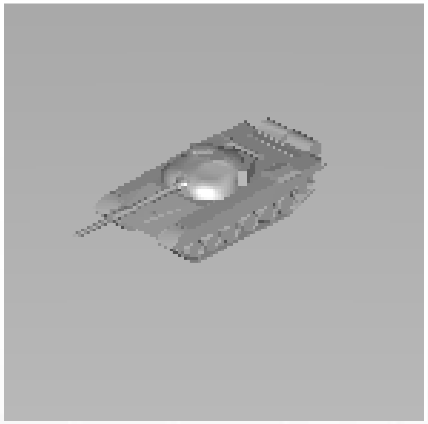
Cluster Means = [3.4037 60.4177 102.7171 134.4866 142.8289 151.2892 175.4506 233.2953]

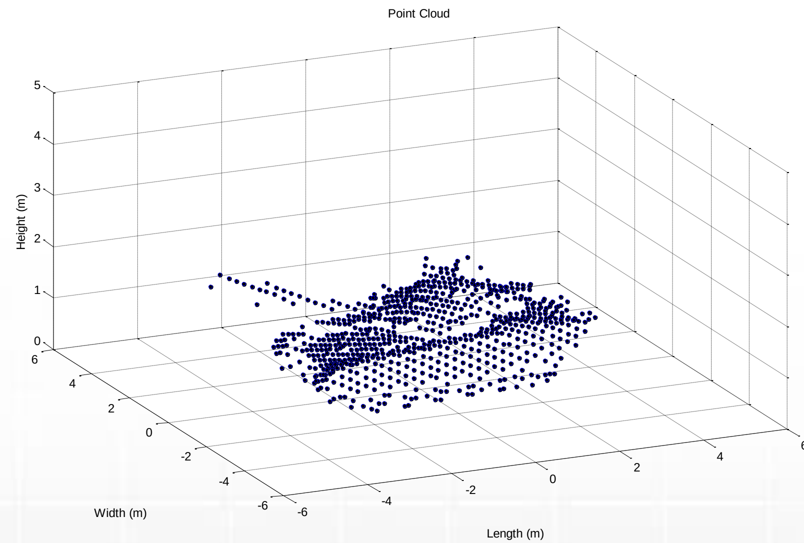


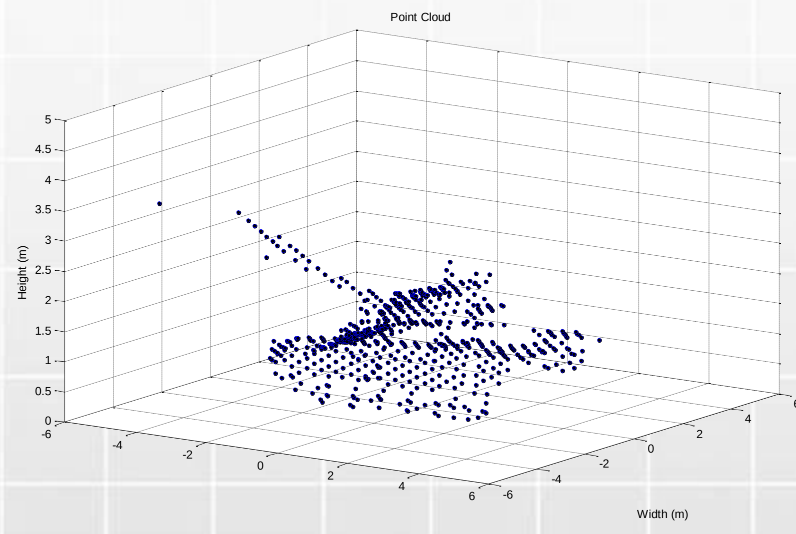


Ladar Point Cloud

Synthetically –Generated T72







- **MATLAB application provides interactive 3D rotation of rendered point cloud scene**