

Detection/Classification of Undersea Mines



Prometheus Inc.



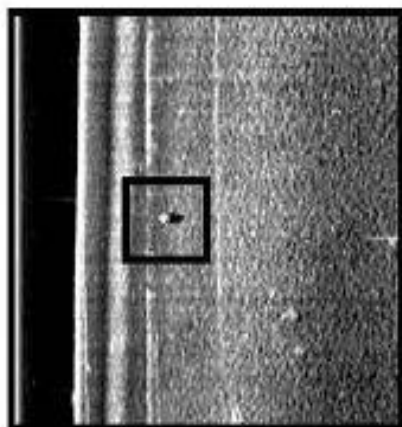
Automation Difficulties

- variable sizes and shapes of targets
- variable orientations
- variable clutter levels
- variable image data quality

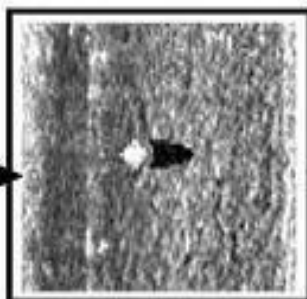
Noncommutative Group Harmonic Analysis



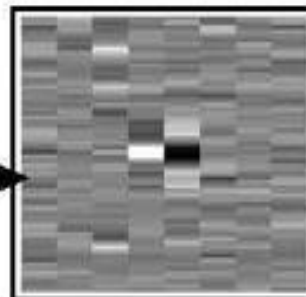
- Noncommutative group structure on image data indexing set including non-standard translations
- Affine motion within the image data space
- Multi-dimensional (non-separable) feature encoding
- Localization in image/spectral domain



Original Image

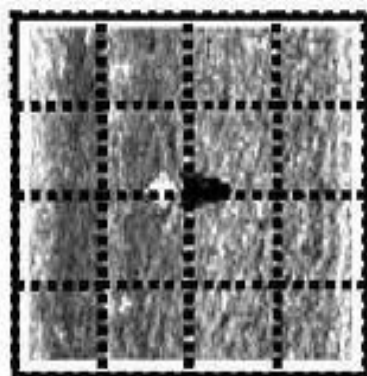


Extract 128 x 128
Frame with Overlap



Apply
Group Filter

Cluster Threshold
Outputs and
Localize ROI



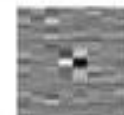
Separate 128 x 128
Frame into 16 Sub-Frames

2-D DFT
of Each
32 x 32
Sub-Frame

Using Binary Mask
Select Spectrum Coeffs
From Each Subframe
Pertaining to:

- Horizontal Lines
- Lines of Slope = 1
- Lines of Slope = -1

2-D IDFT Each
32 x 32
Sub-Frame
for Each
Line Orientation



Threshold
Horizontal
Projections



Threshold
Slope=1
Projections



Threshold
Slope=-1
Projections

Group Filter Operation

Processing Speed

Projection Computation $< N \log N$

- MATLAB, Windows Laptop, per image

Projection computation ~ 0.9 seconds

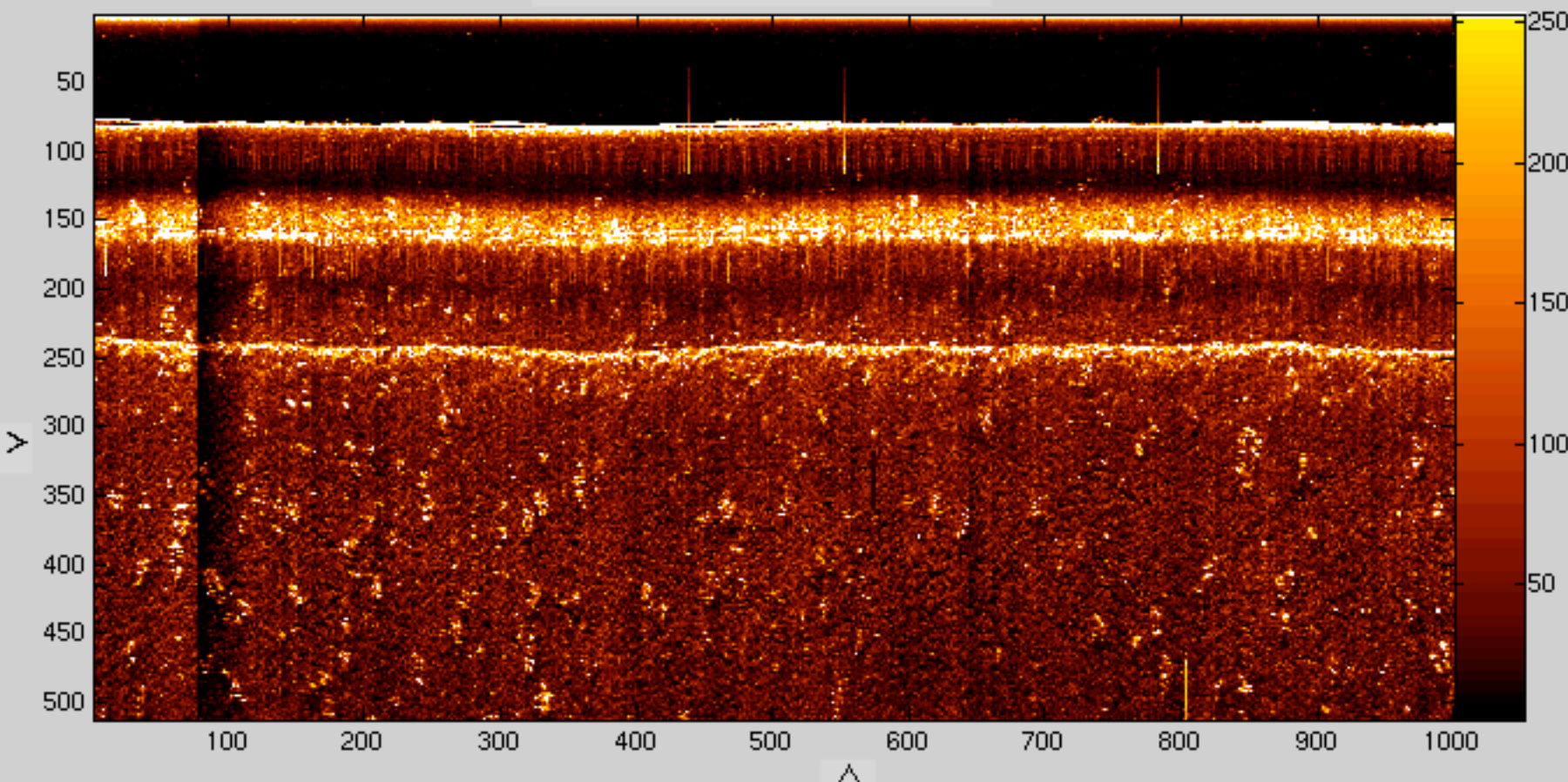
(robust and fast detection)

Classification on reduced (by $\sim 90\%$) data set

~ 2.5 seconds

(image-domain classification, room for improvement)

01FEB018A_RIGHT.PGM



Navigation and Control Buttons:

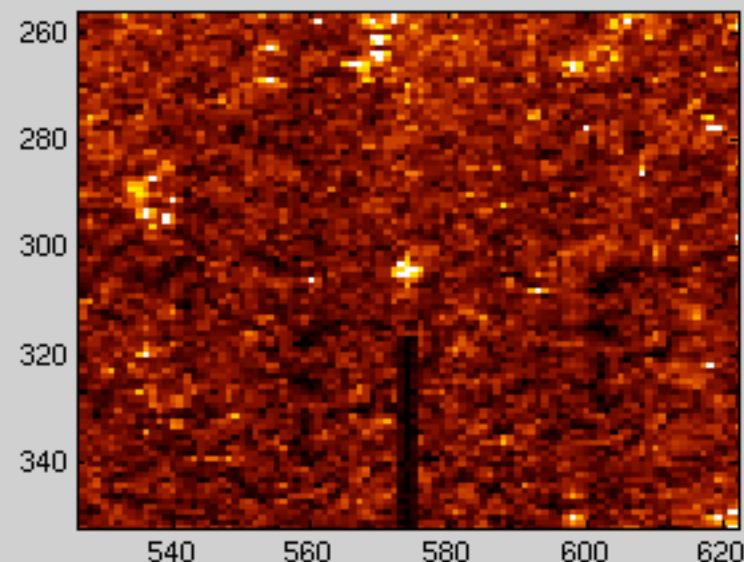
- LAST, NEXT, NAVSEA, Settings, Info
- 2, LOAD, EXIT, PROCESS, SCORE

PROCESSING DETAILS:

1 target detected in 4.07 s.
 Generating group projections took 3.35 s.
 brightspot.m took 0.11 s and found 1 target.
 boxtargets.m took 0.07 s and found 0 targets.
 thintargets.m took 0.49 s and found 1 target.

Ground truth lists 1 target.

Found 1 ground truth target and 0 false alarms



TARGET 1 DETAILS

Location: (574,304)
 Present in segment: (533,283)
 Filter(s) used: brightspot.m thintargets.m

Ground truth verification: target confirmed, listed at (573,304)

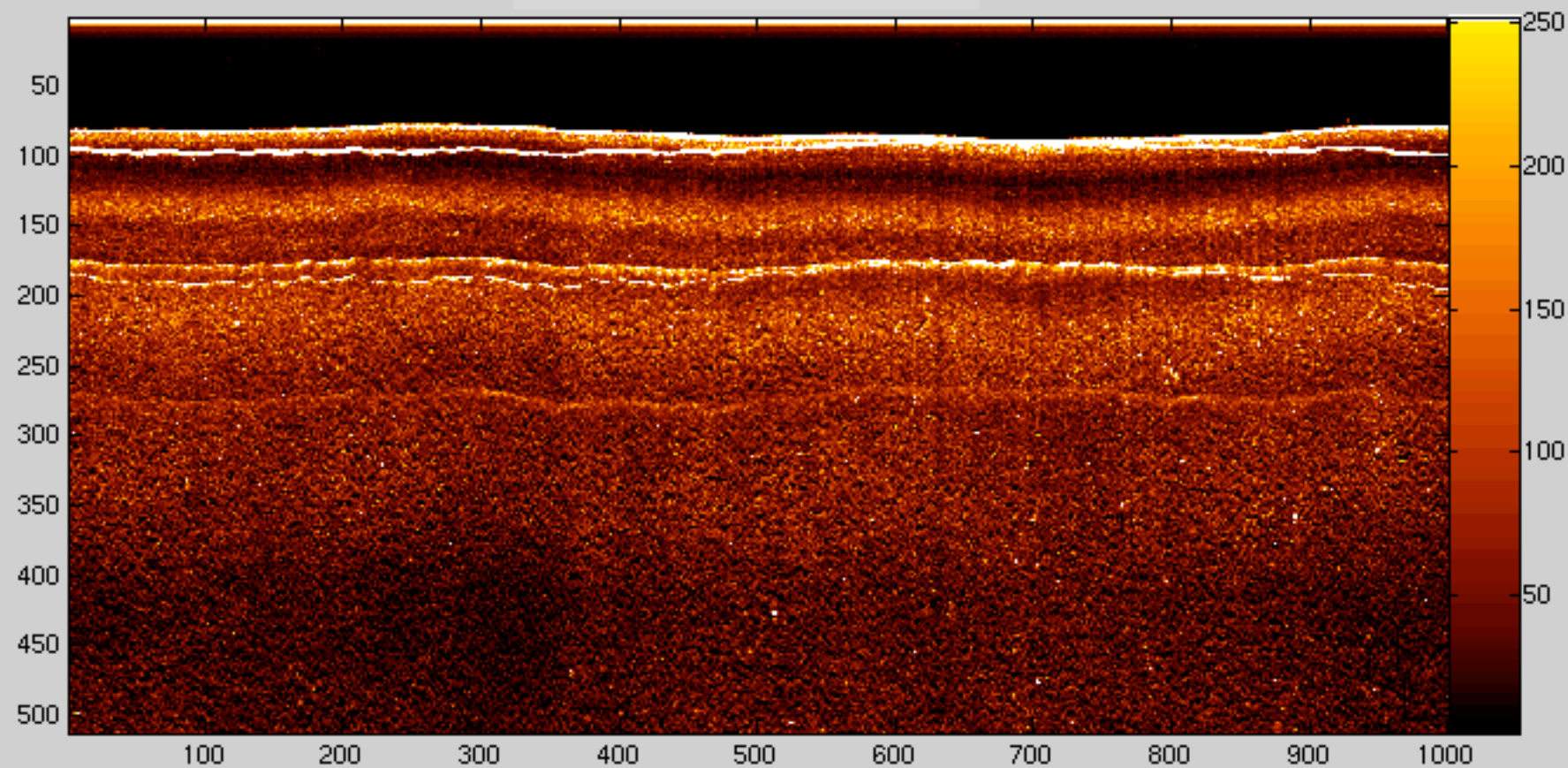
Target 1

Projections

Figure 1: Underwater Mine Detection

File Edit View Insert Tools Desktop Window Help

01 FEB019_LEFT.PGM



Navigation and Control Buttons:

- LAST
- NEXT
- NAVSEA
- Settings
- Info
- 3
- LOAD
- PROCESS
- EXIT
- SCORE

PROCESSING DETAILS:

0 targets detected in 3.72 s.

Generating group projections took 3.15 s.

brightspot.m took 0.09 s and found 0 targets.

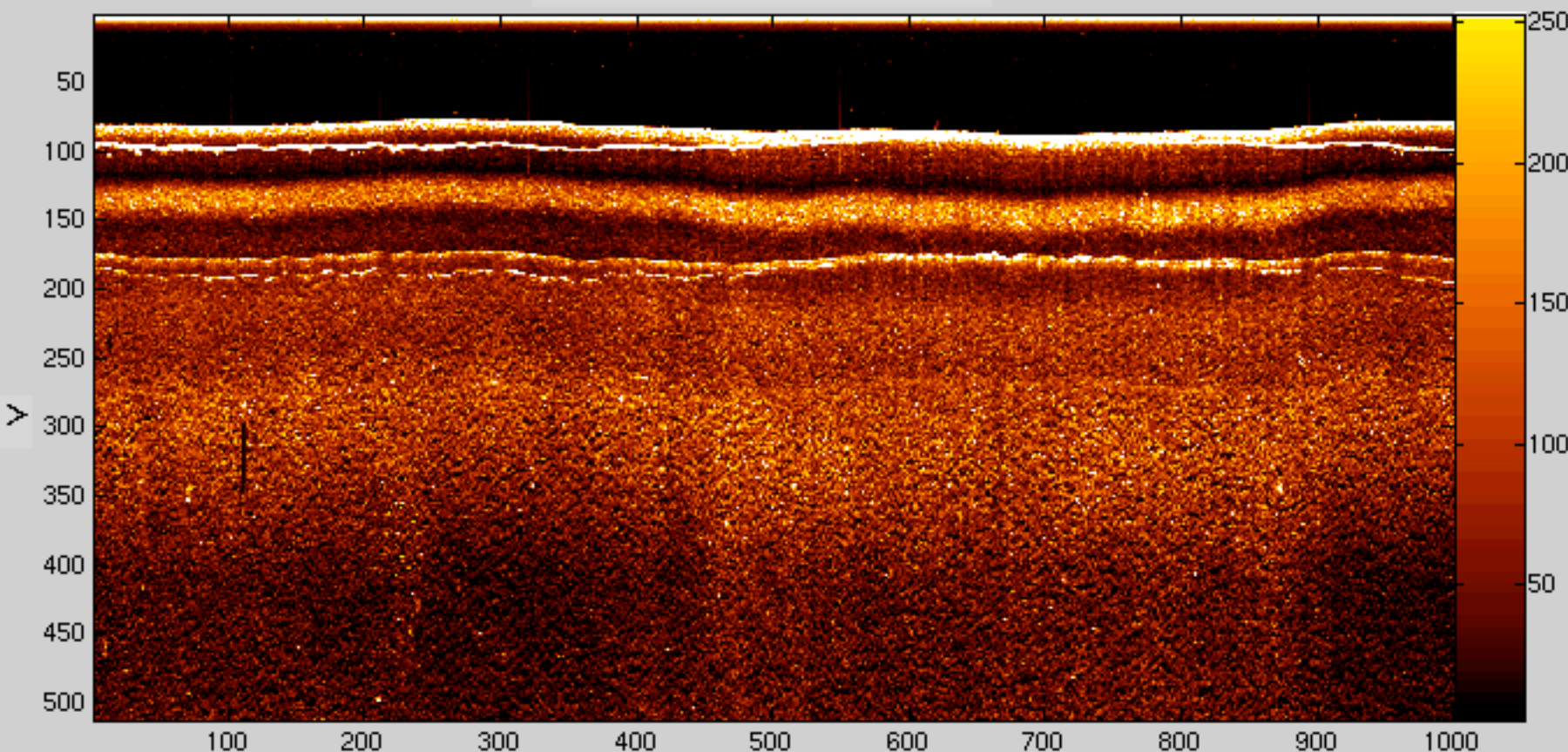
boxtargets.m took 0.09 s and found 0 targets.

thintargets.m took 0.34 s and found 0 targets.

Ground truth lists 0 targets.

Found 0 ground truth targets and 0 false alarms

01FEB019_RIGHT.PGM



Navigation controls:

- LAST NEXT
- NAVSEA ☒
- Settings Info

Buttons:

- 4 LOAD
- PROCESS
- EXIT
- SCORE

PROCESSING DETAILS:

1 target detected in 3.8 s.

Generating group projections took 3.38 s.

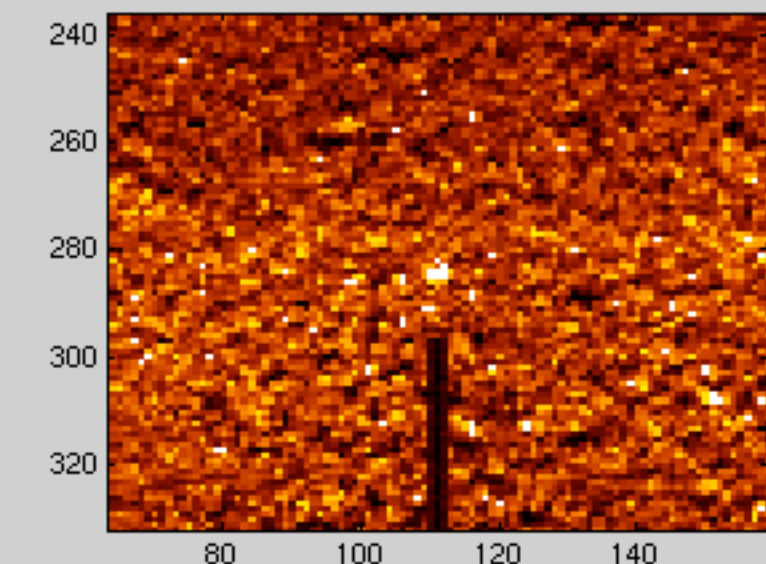
brightspot.m took 0.09 s and found 1 target.

boxtargets.m took 0.14 s and found 0 targets.

thintargets.m took 0.15 s and found 1 target.

Ground truth lists 1 target.

Found 1 ground truth target and 0 false alarms



TARGET 1 DETAILS

Location: (111,284)

Present in segment: (77,236)

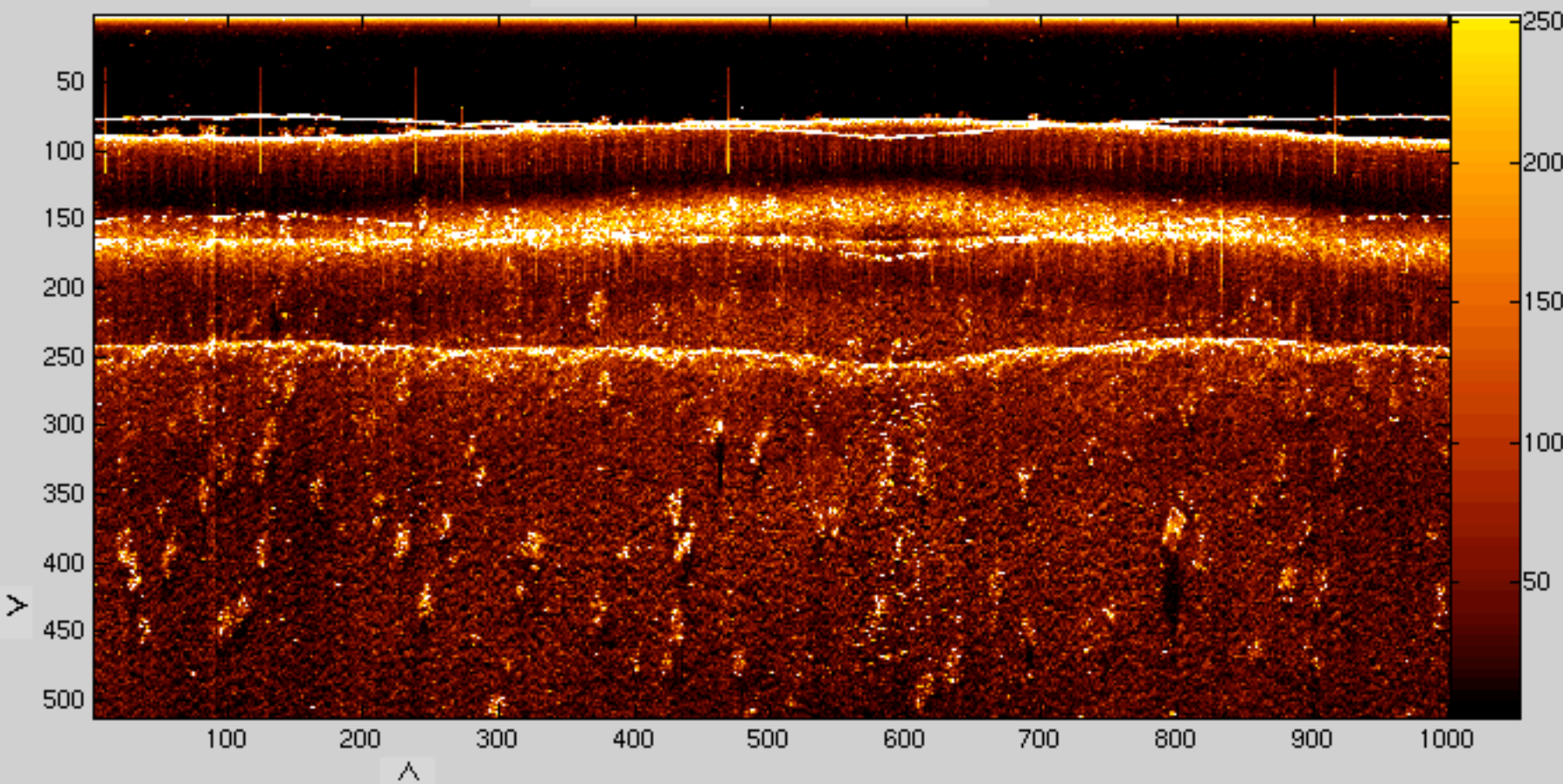
Filter(s) used: brightspot.m thintargets.m

Ground truth verification: target confirmed, listed at (111,284)

Target 1 ☒

Projections

01FEB032A_RIGHT.PGM



Navigation and Control Buttons:

- 14 LOAD EXIT
- LAST NEXT
- NAVSEA [dropdown arrow]
- PROCESS SCORE
- Settings Info

PROCESSING DETAILS:

2 targets detected in 4.03 s.

Generating group projections took 3.5 s.

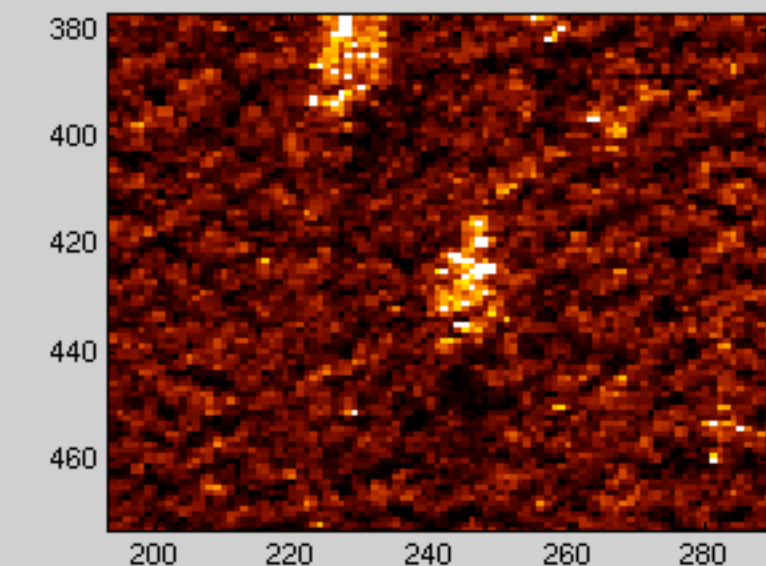
brightspot.m took 0.1 s and found 1 target.

boxtargets.m took 0.2 s and found 1 target.

thintargets.m took 0.18 s and found 0 targets.

Ground truth lists 1 target.

Found 1 ground truth target and 1 false alarm.



TARGET 1 DETAILS

Location: (241,425)

Present in segment:

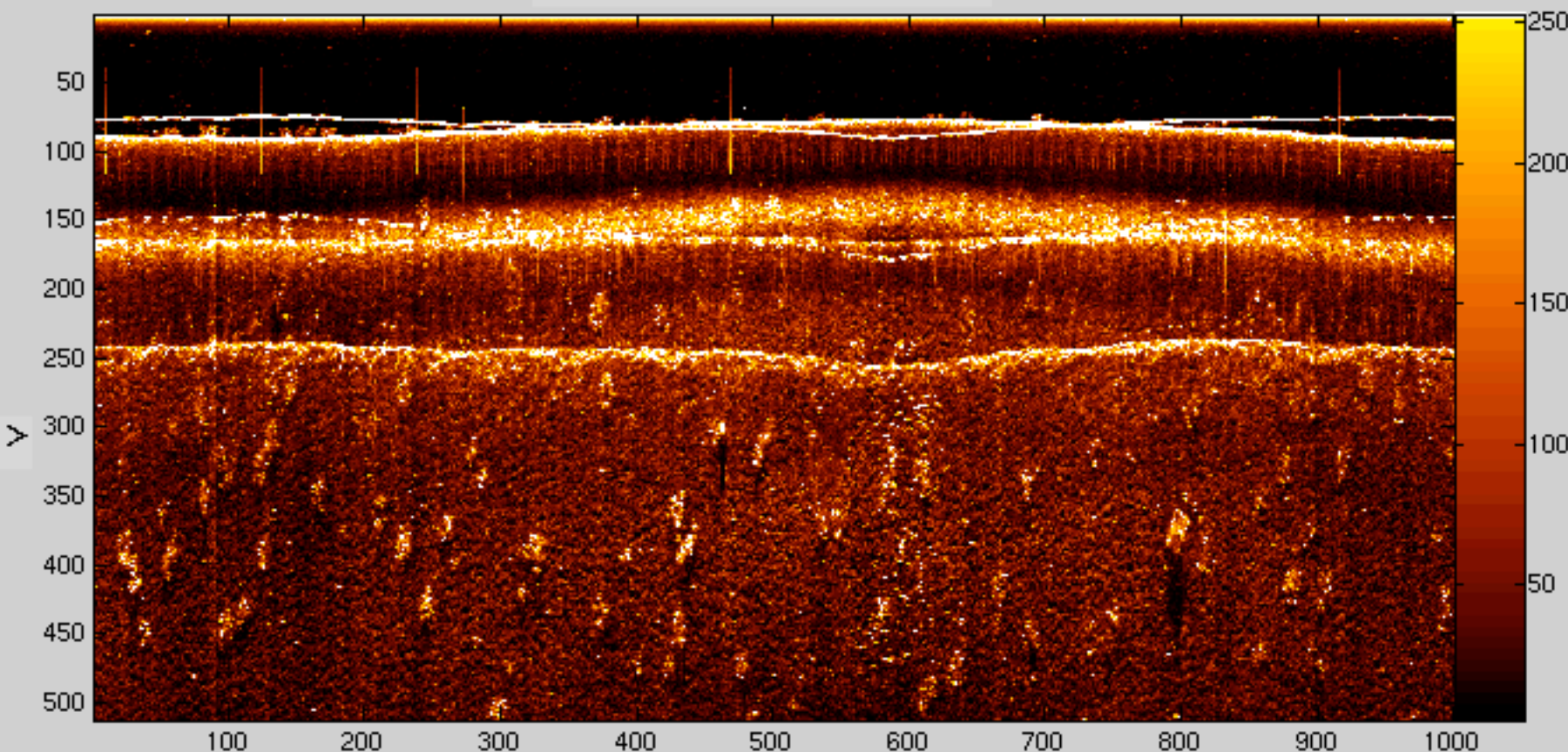
Filter(s) used: boxtargets.m

Ground truth verification: target not confirmed

Target 1 [dropdown arrow]

Projections

01FEB032A_RIGHT.PGM



Navigation and Control Buttons:

- LAST, NEXT, NAVSEA, Settings, Info
- 14, LOAD, EXIT, PROCESS, SCORE

PROCESSING DETAILS:

2 targets detected in 4.03 s.

Generating group projections took 3.5 s.

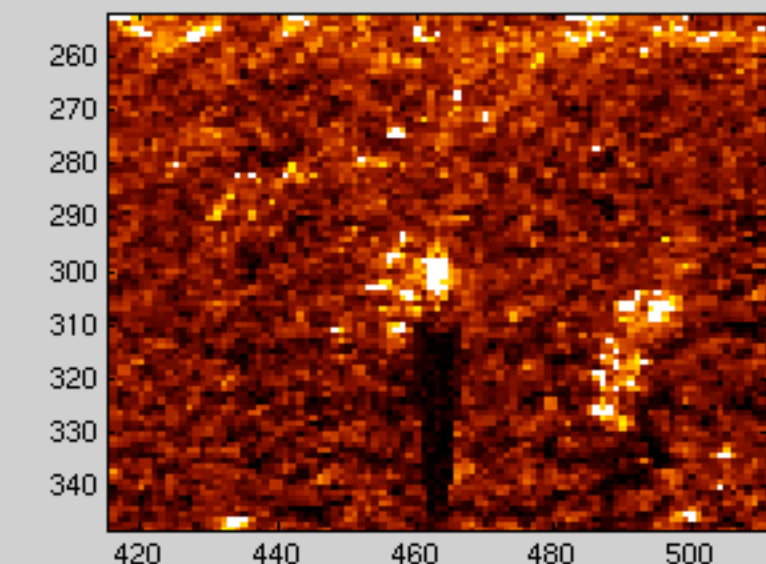
brightspot.m took 0.1 s and found 1 target.

boxtargets.m took 0.2 s and found 1 target.

thintargets.m took 0.18 s and found 0 targets.

Ground truth lists 1 target.

Found 1 ground truth target and 1 false alarm.



TARGET 2 DETAILS

Location: (463,300)

Present in segment:

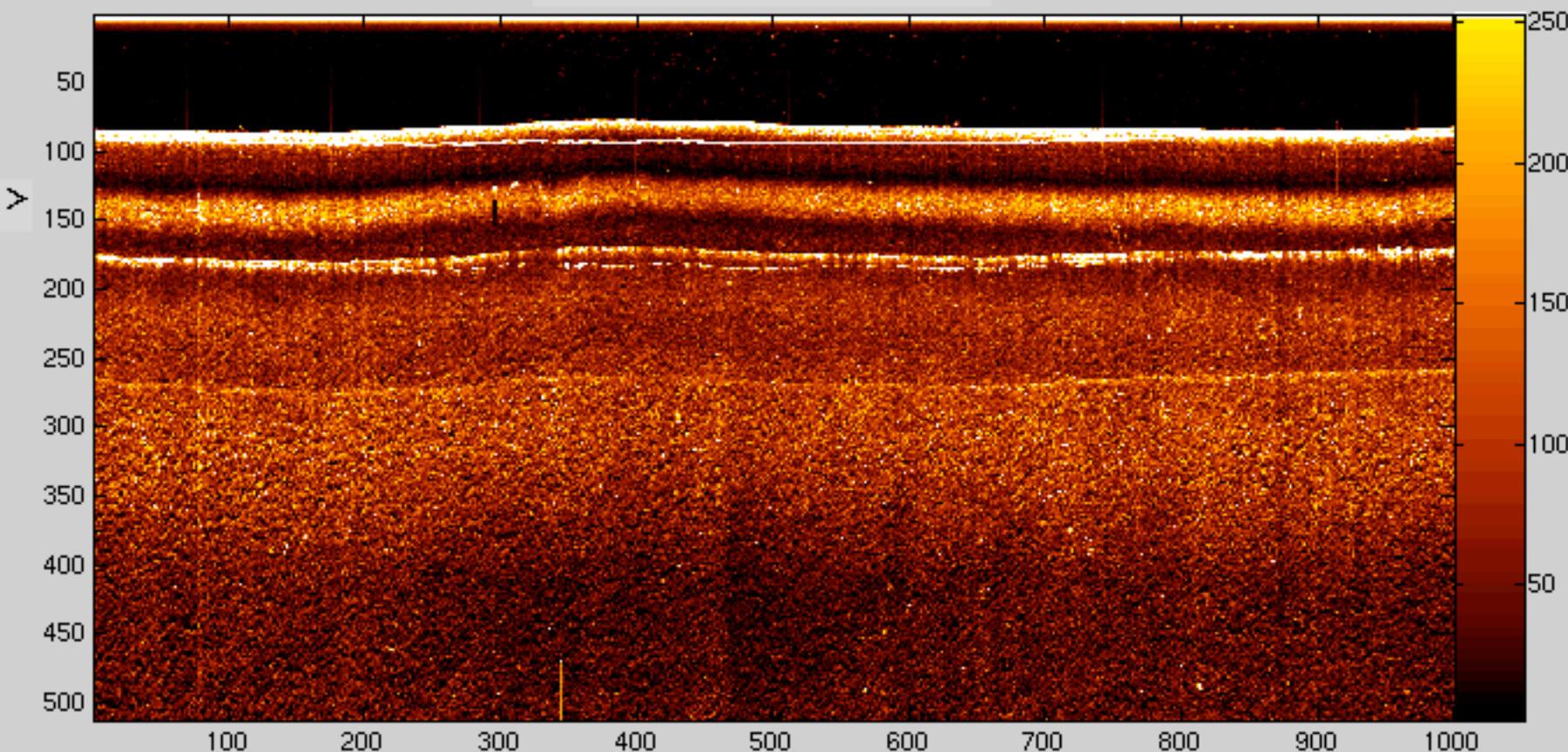
Filter(s) used: brightspot.m

Ground truth verification: target confirmed, listed at (463,300)

Target 2

Projections

01FEB032_RIGHT.PGM



Navigation and Control Buttons:

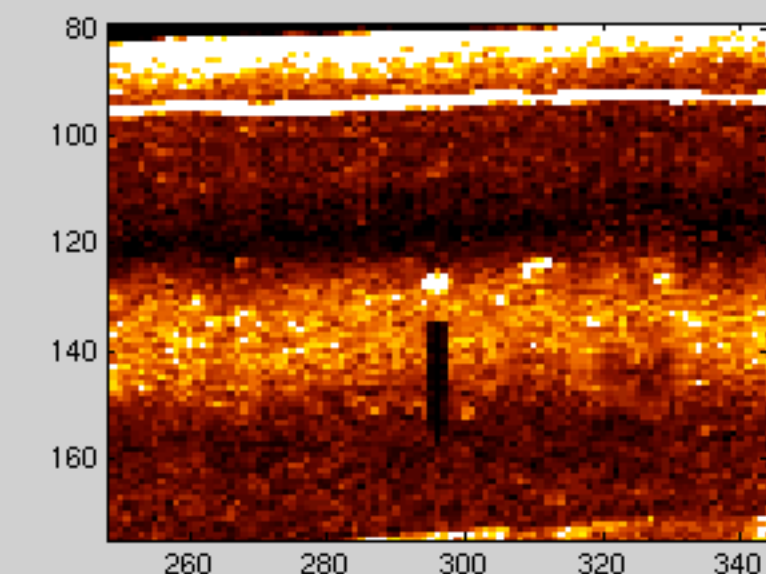
- LAST, NEXT, NAVSEA, Settings, Info
- 16, LOAD, EXIT, PROCESS, SCORE

PROCESSING DETAILS:

1 target detected in 3.77 s.
 Generating group projections took 3.22 s.
 brightspot.m took 0.08 s and found 1 target.
 boxtargets.m took 0.08 s and found 0 targets.
 thintargets.m took 0.34 s and found 1 target.

Ground truth lists 1 target.

Found 1 ground truth target and 0 false alarms



TARGET 1 DETAILS

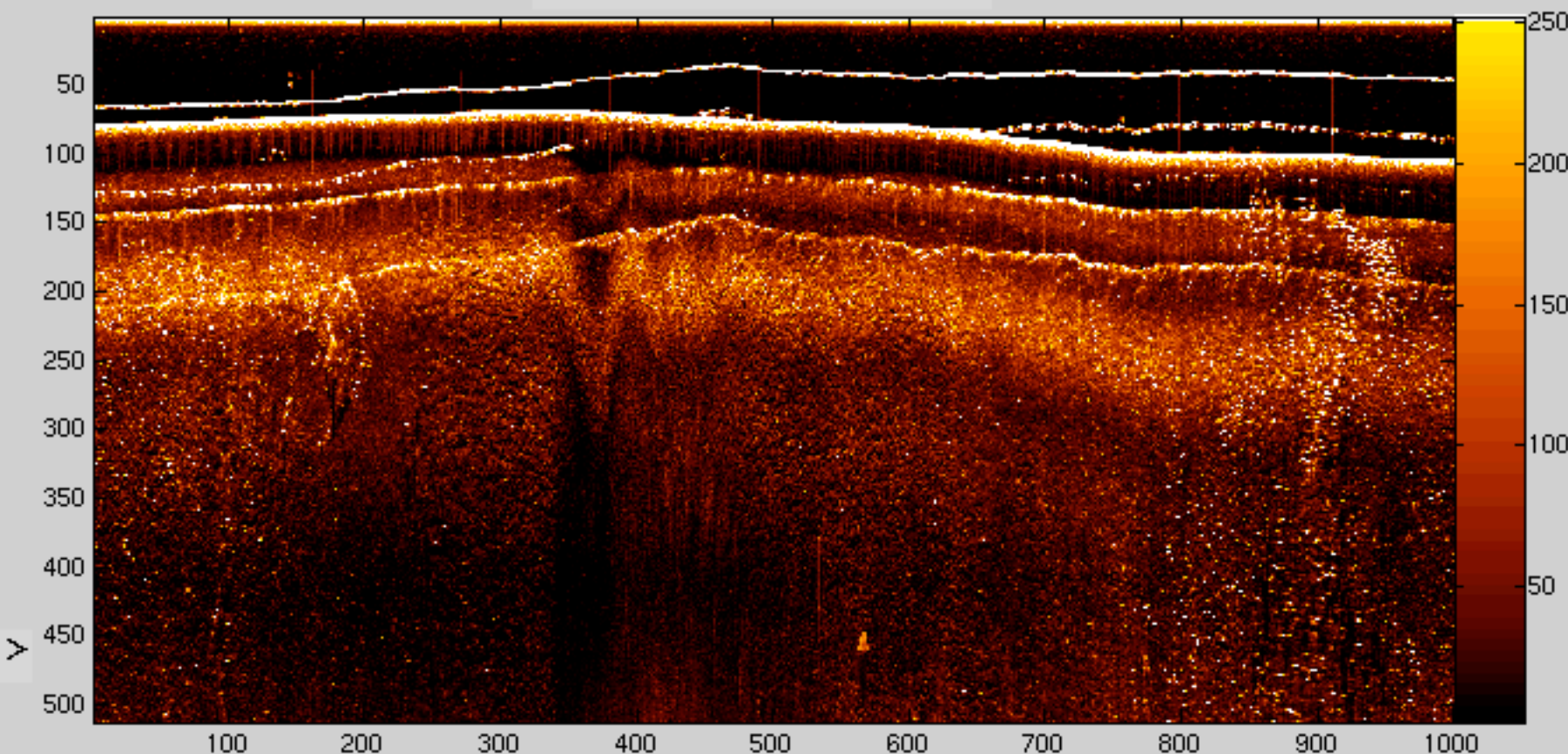
Location: (296,127)
 Present in segment: (229,95)
 Filter(s) used: brightspot.m thintargets.m

Ground truth verification: target confirmed, listed at (295,127)

Target 1

Projections

01FEB039A_LEFT.PGM



Navigation and Control Buttons:

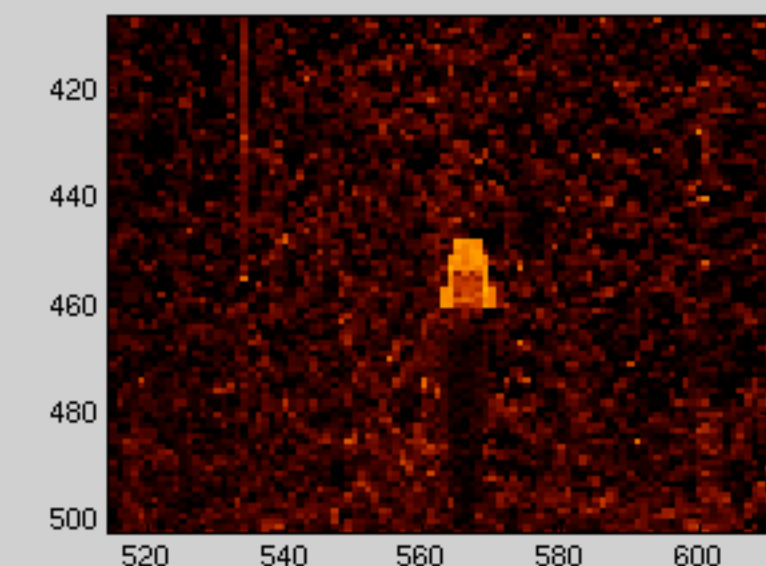
- LAST, NEXT, NAVSEA, Settings, Info
- 23, LOAD, EXIT, PROCESS, SCORE

PROCESSING DETAILS:

1 target detected in 3.73 s.
 Generating group projections took 3.19 s.
 brightspot.m took 0.08 s and found 0 targets.
 boxtargets.m took 0.2 s and found 1 target.
 thintargets.m took 0.23 s and found 0 targets.

Ground truth lists 1 target.

Found 1 ground truth target and 0 false alarms



TARGET 1 DETAILS

Location: (562,454)

Present in segment: (533,417)

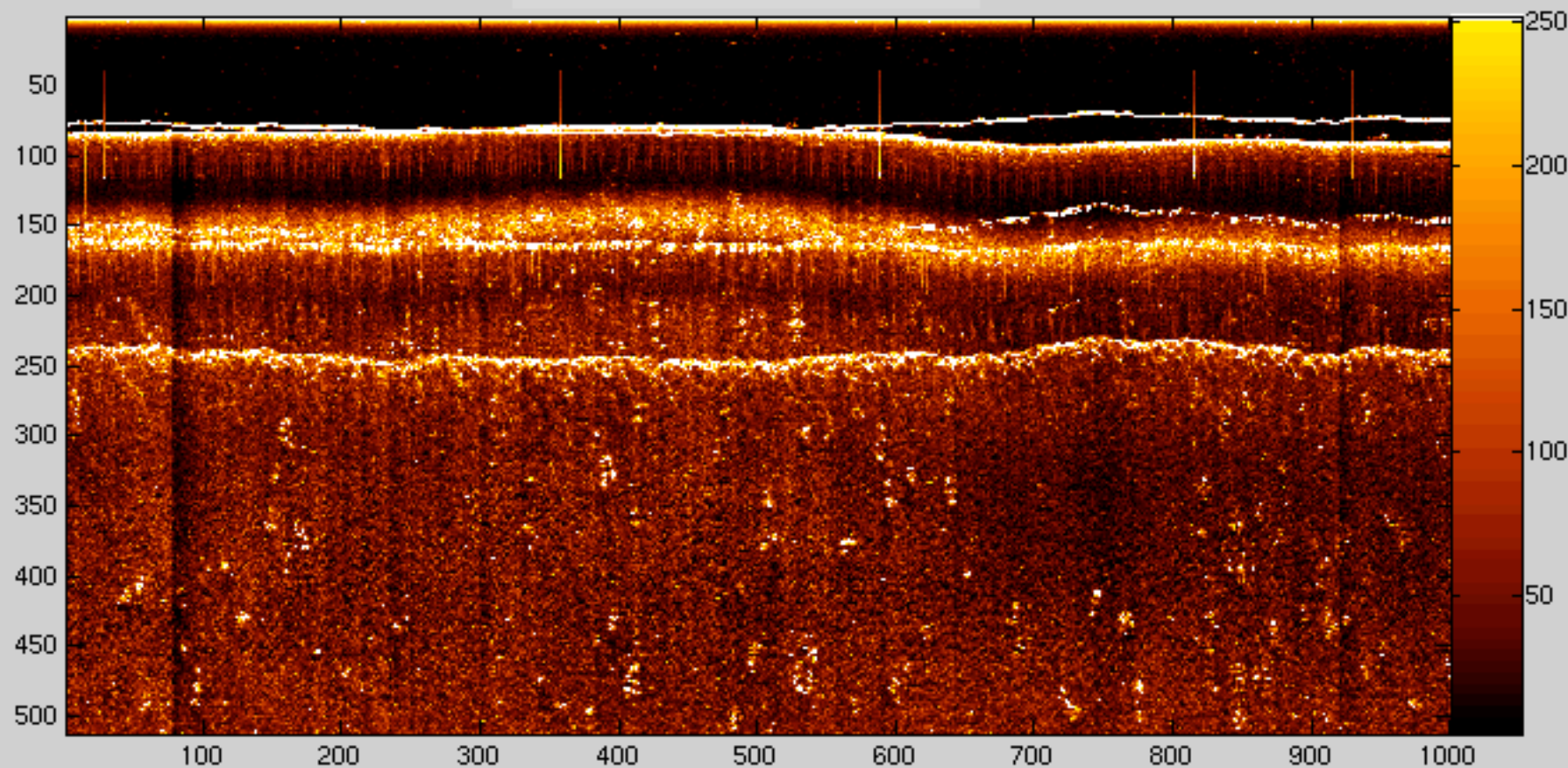
Filter(s) used: boxtargets.m

Ground truth verification: target confirmed, listed at (566,454)

Target 1

Projections

01FEB041A_RIGHT.PGM



Navigation and Control Buttons:

- LAST
- NEXT
- NAVSEA
- Settings
- Info
- 26
- LOAD
- PROCESS
- EXIT
- SCORE

PROCESSING DETAILS:

0 targets detected in 3.87 s.

Generating group projections took 3.1 s.

brightspot.m took 0.06 s and found 0 targets.

boxtargets.m took 0.23 s and found 0 targets.

thintargets.m took 0.42 s and found 0 targets.

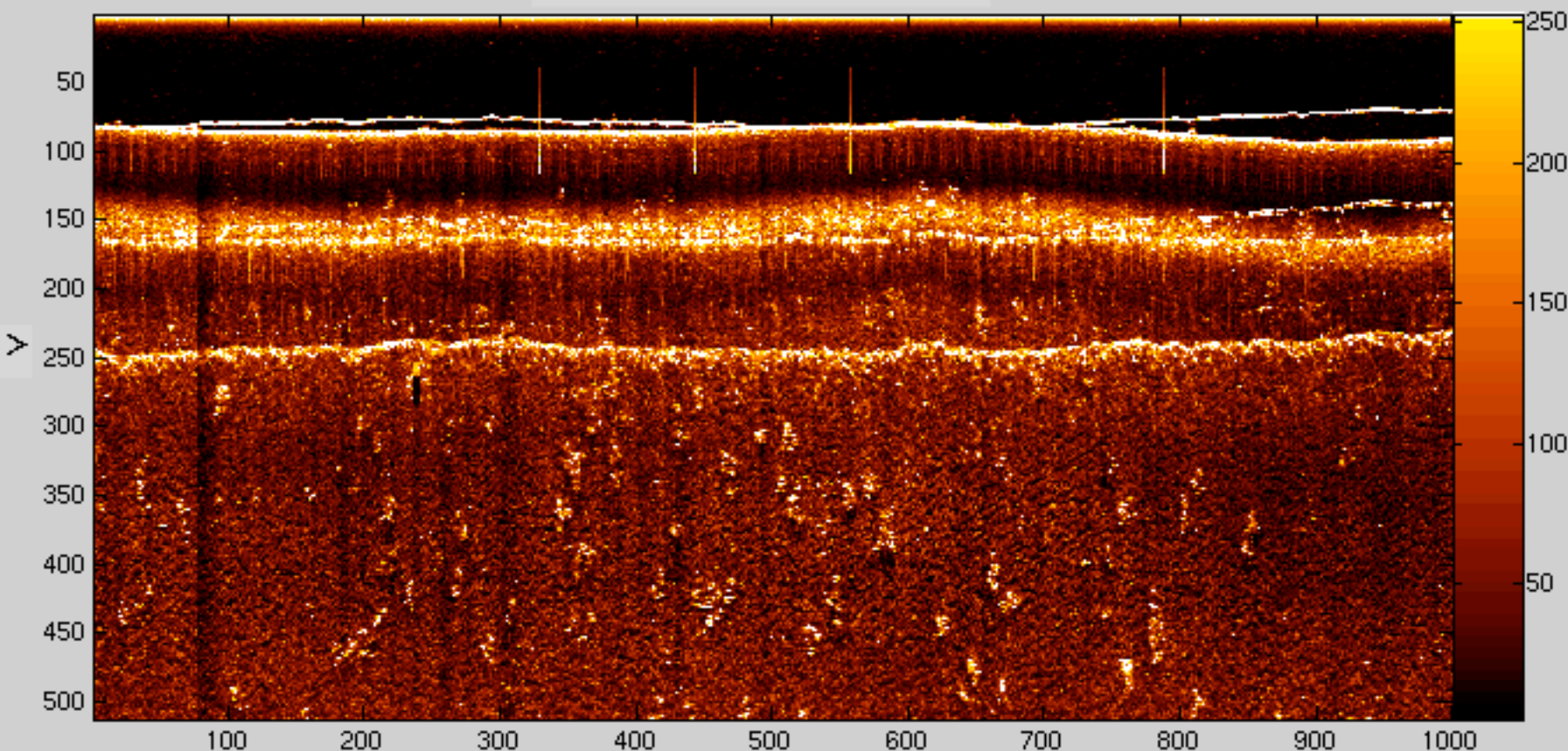
Ground truth lists 0 targets.

Found 0 ground truth targets and 0 false alarms

Figure 1: Underwater Mine Detection

File Edit View Insert Tools Desktop Window Help

01FEB044A_RIGHT.PGM



Navigation and Control Buttons:

- LAST, NEXT, NAVSEA, Settings, Info
- 28, LOAD, EXIT, PROCESS, SCORE

PROCESSING DETAILS:

2 targets detected in 4.03 s.

Generating group projections took 3.34 s.

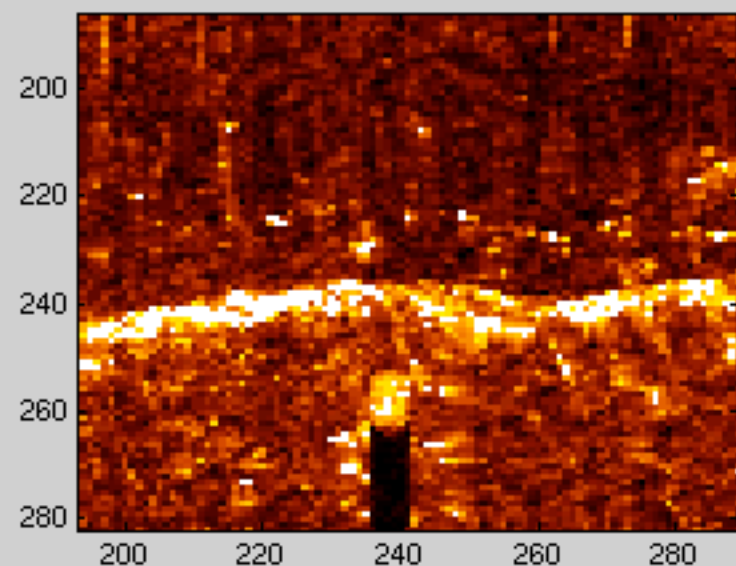
brightspot.m took 0.1 s and found 1 target.

boxtargets.m took 0.17 s and found 0 targets.

thintargets.m took 0.38 s and found 1 target.

Ground truth lists 1 target.

Found 1 ground truth target and 1 false alarm.



TARGET 1 DETAILS

Location: (241,234)

Present in segment:

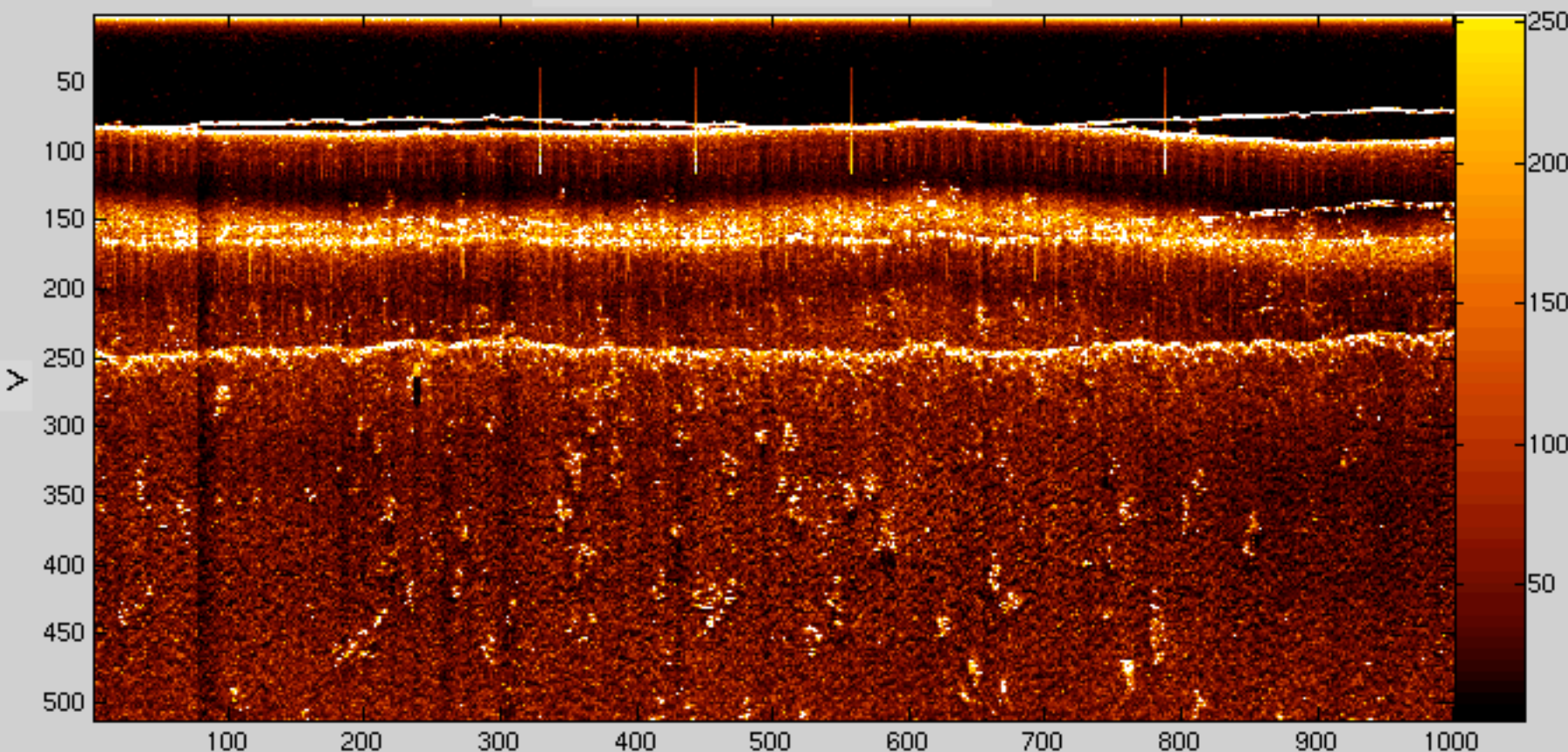
Filter(s) used: thintargets.m

Ground truth verification: target not confirmed

Target 1

Projections

01FEB044A_RIGHT.PGM



Navigation and Control Buttons:

- LAST, NEXT, NAVSEA, Settings, Info
- 28, LOAD, EXIT, PROCESS, SCORE

PROCESSING DETAILS:

2 targets detected in 4.03 s.

Generating group projections took 3.34 s.

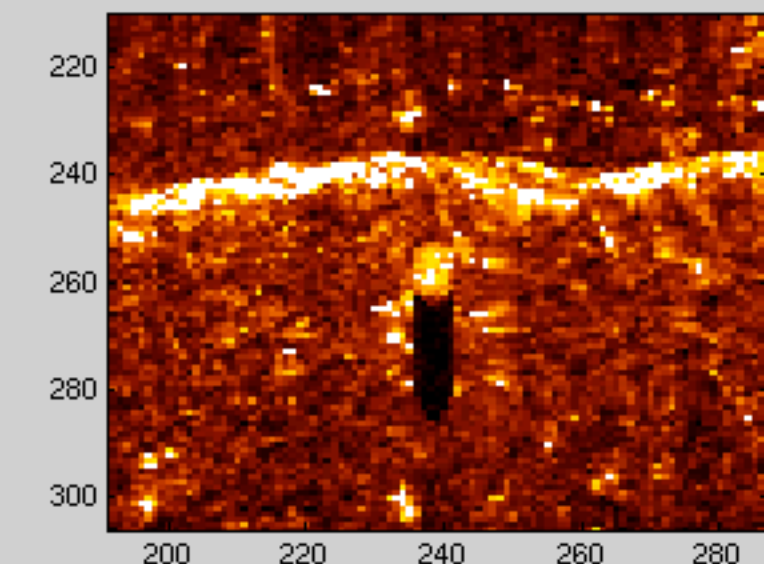
brightspot.m took 0.1 s and found 1 target.

boxtargets.m took 0.17 s and found 0 targets.

thintargets.m took 0.38 s and found 1 target.

Ground truth lists 1 target.

Found 1 ground truth target and 1 false alarm.



TARGET 2 DETAILS

Location: (239,258)

Present in segment:

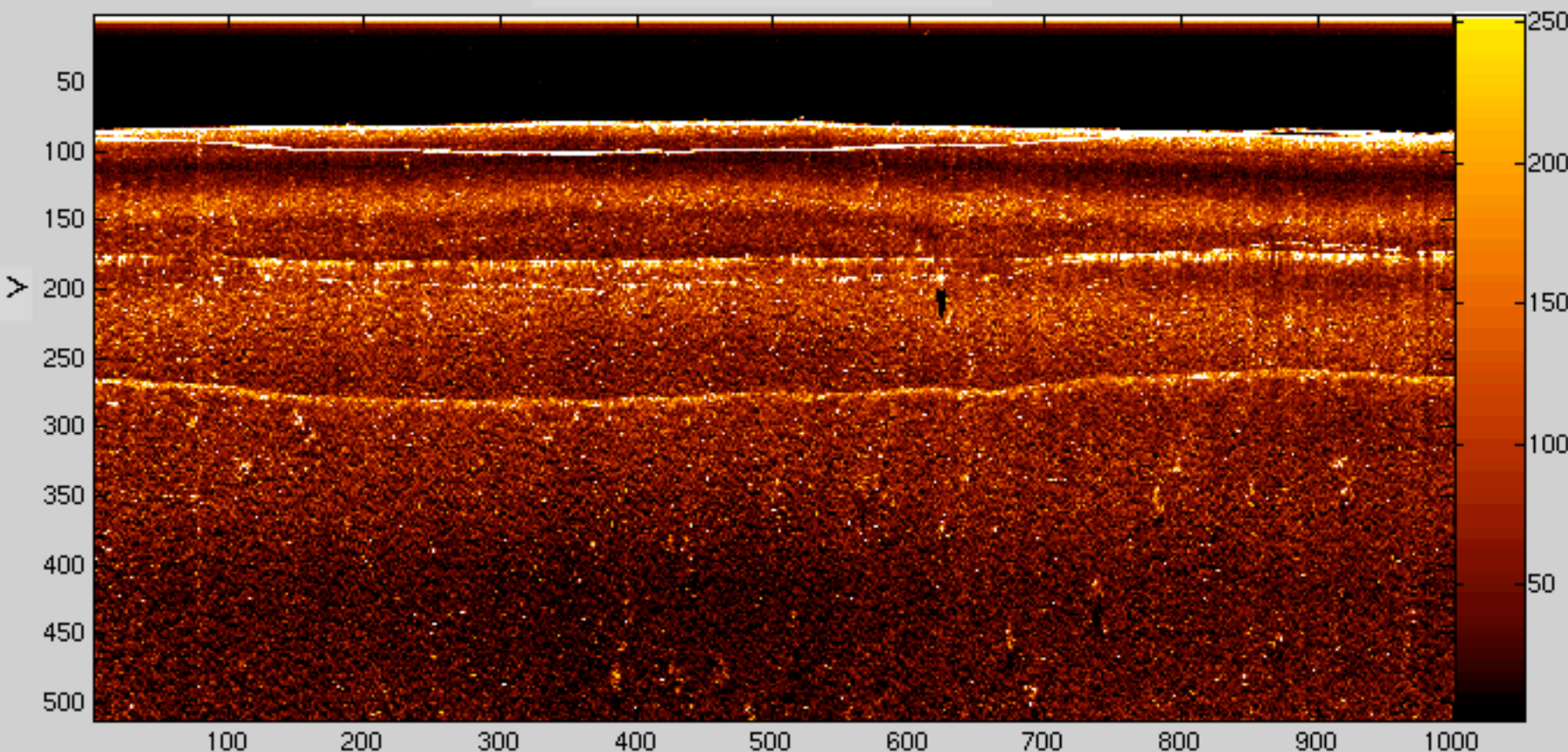
Filter(s) used: brightspot.m

Ground truth verification: target confirmed, listed at (239,258)

Target 2

Projections

01 FEB046_LEFT.PGM



Navigation and Control Buttons:

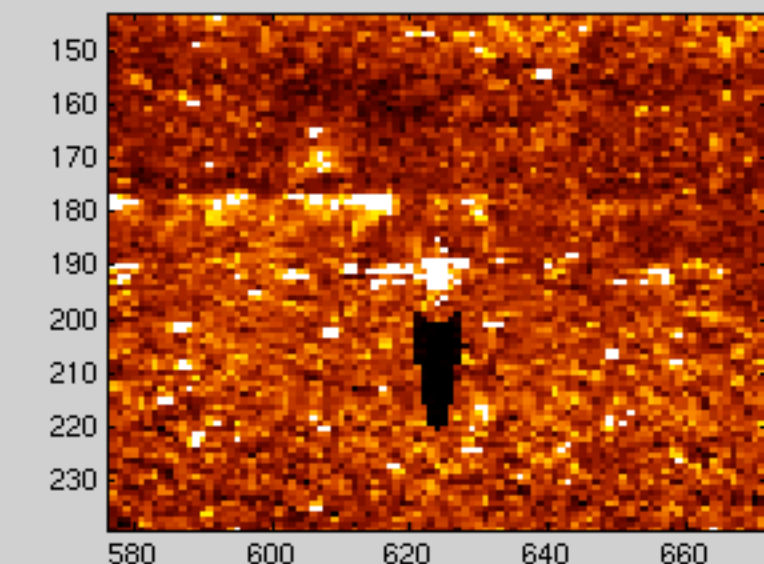
- LAST, NEXT, NAVSEA, Settings, Info
- 29, LOAD, EXIT, PROCESS, SCORE

PROCESSING DETAILS:

1 target detected in 3.77 s.
 Generating group projections took 3.16 s.
 brightspot.m took 0.1 s and found 1 target.
 boxtargets.m took 0.17 s and found 0 targets.
 thintargets.m took 0.29 s and found 0 targets.

Ground truth lists 1 target.

Found 1 ground truth target and 0 false alarms



TARGET 1 DETAILS

Location: (624,191)

Present in segment:

Filter(s) used: brightspot.m

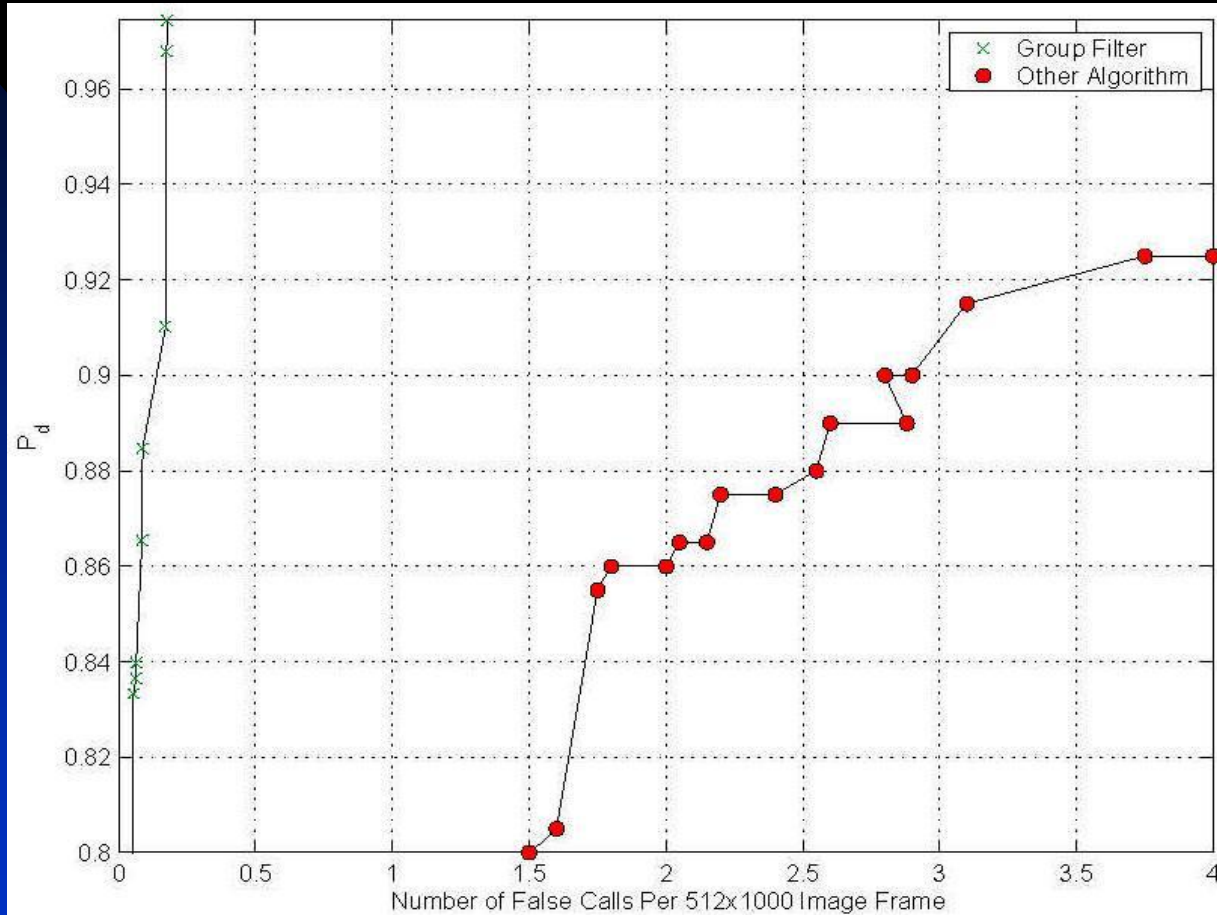
Ground truth verification: target confirmed, listed at (624,191)

Target 1

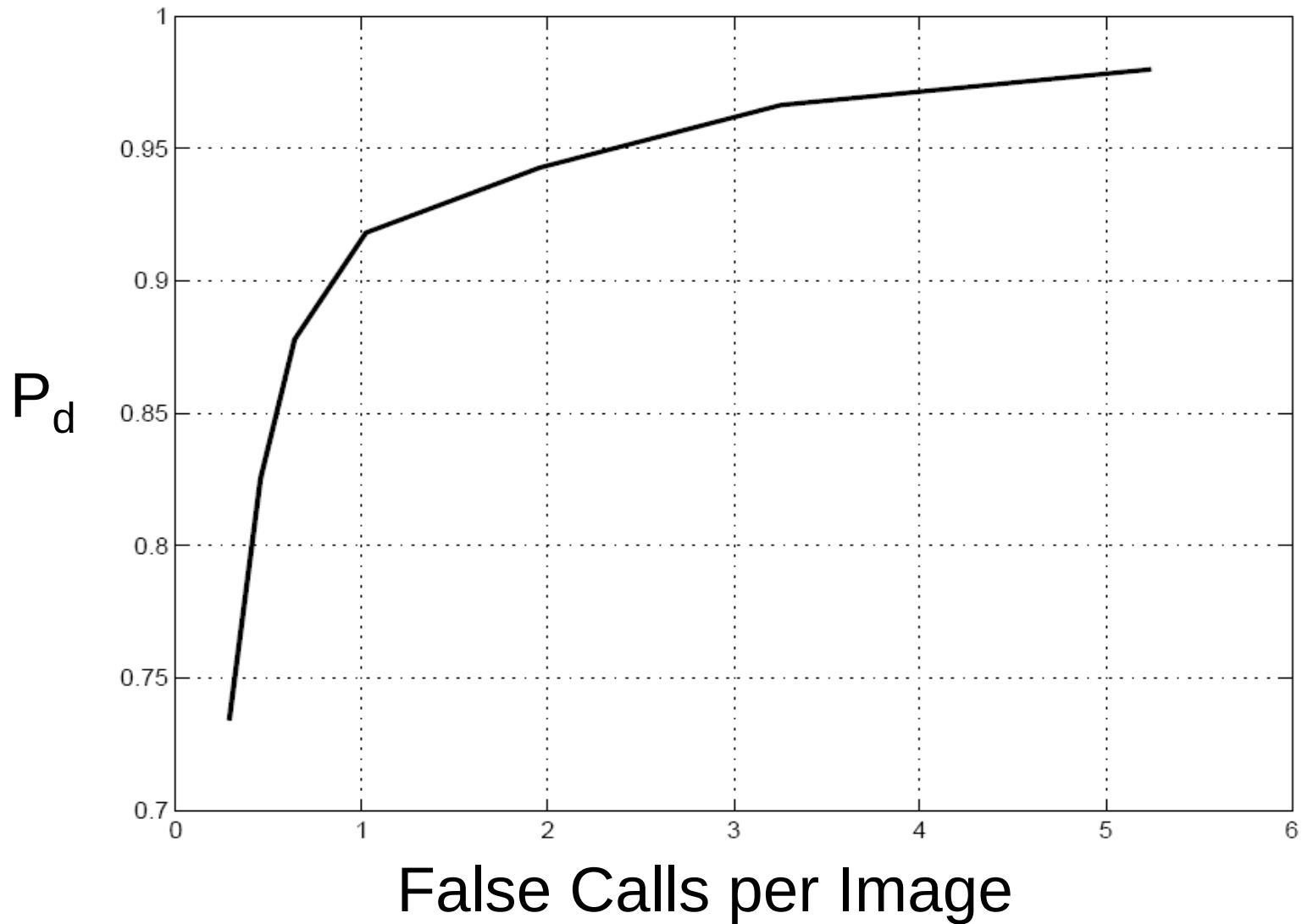
Projections



Performance Comparison



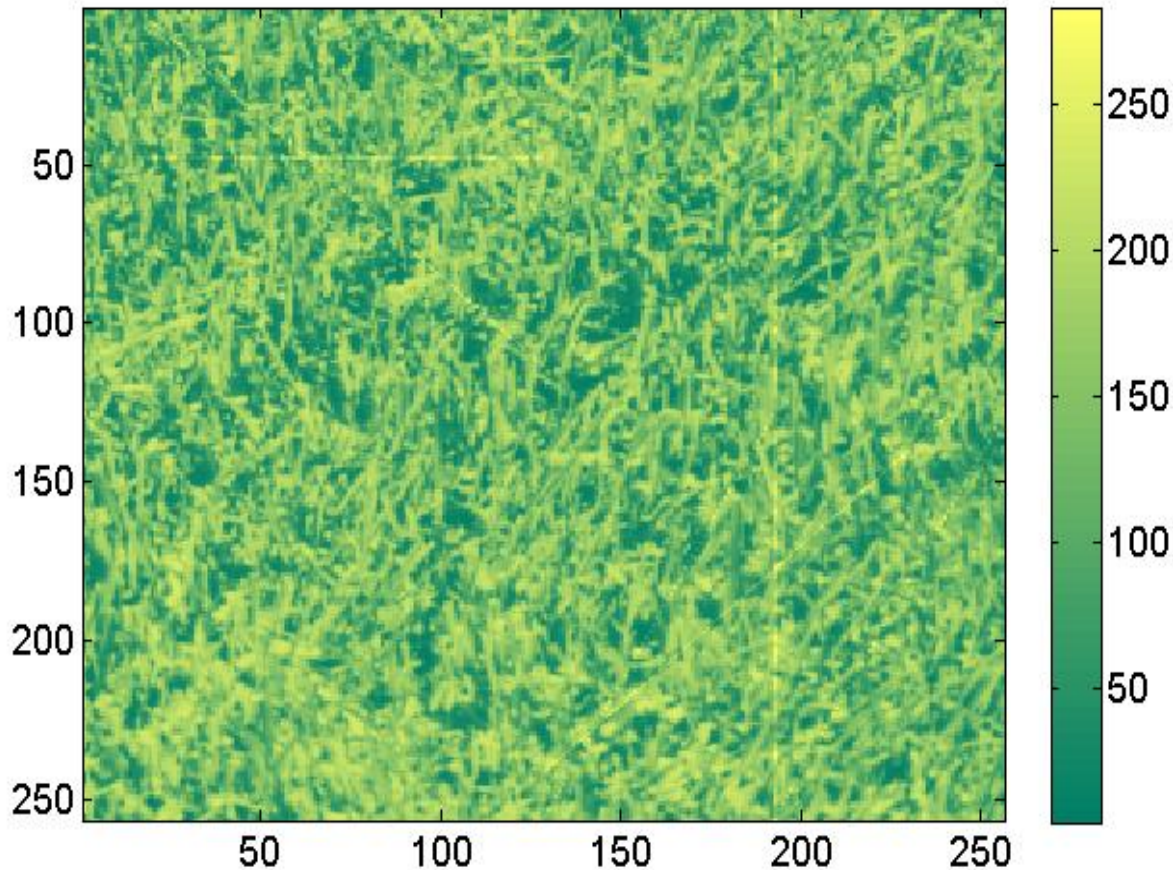
SAS Mine-Like Object Detection ROC Curve





Thin Line Detection

Grass field with embedded lines



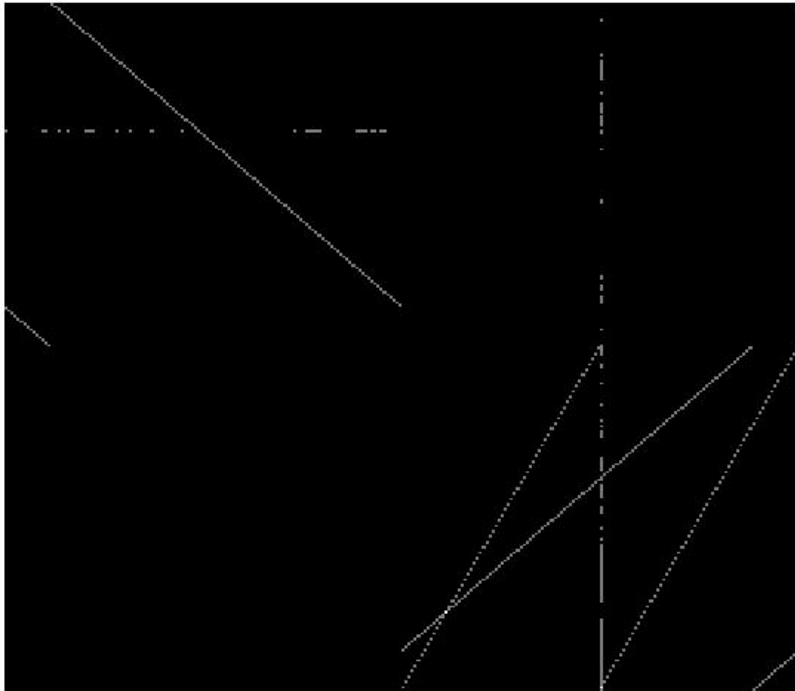
- Six single pixel lines embedded in noisy background (web photo of grass from Google).
- Lines in 4 orientations, intensity = 50.



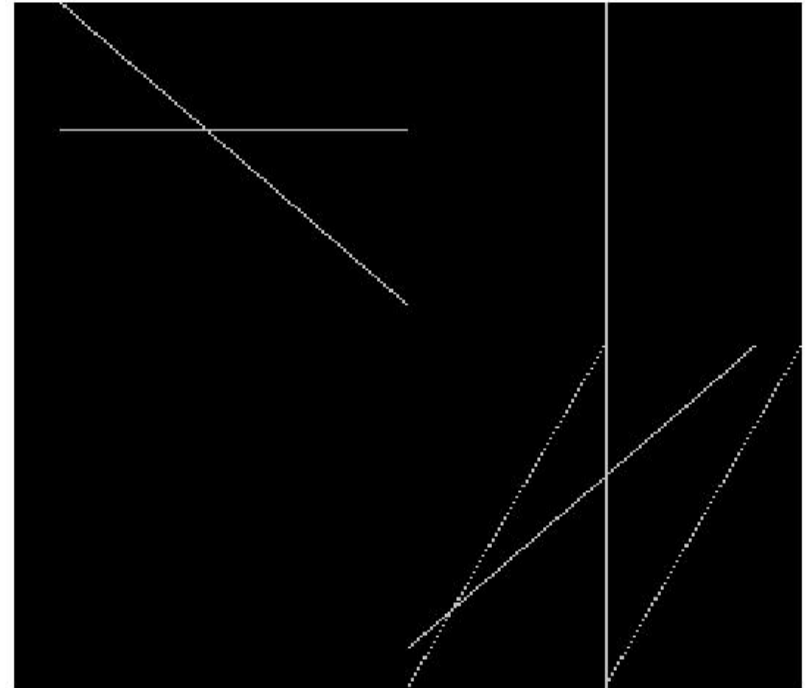


Recovered Lines

Intensity clipping of projection
results



Original embedded lines,
intensity = 50



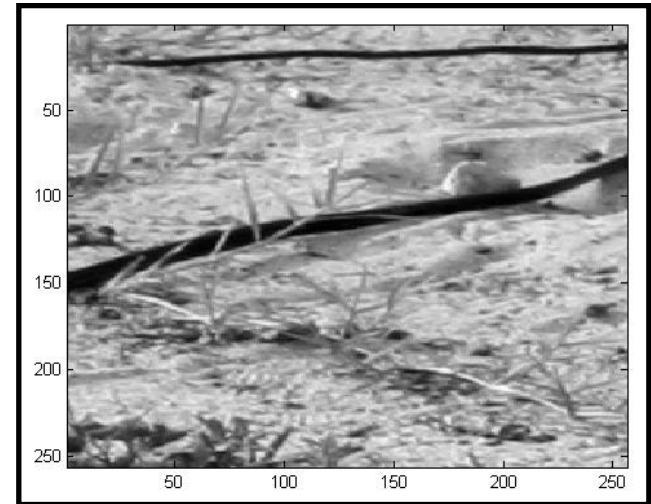


Wire Detection

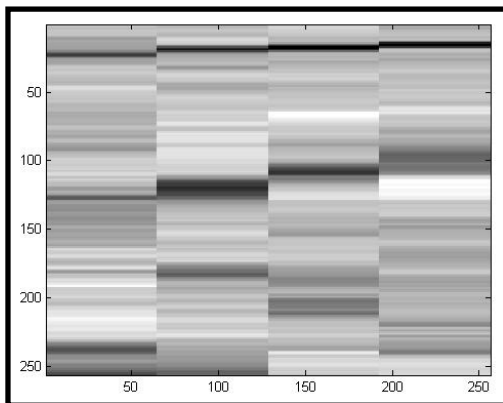
Original 2304 x 3456 pixel image



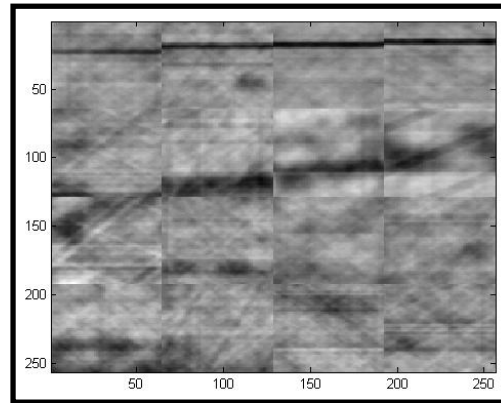
256 x 256 monochrome clip



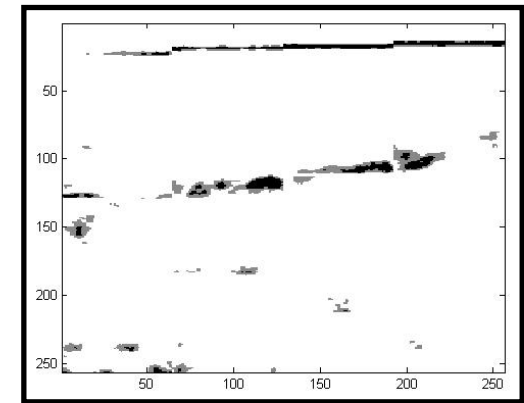
Horizontal
projection



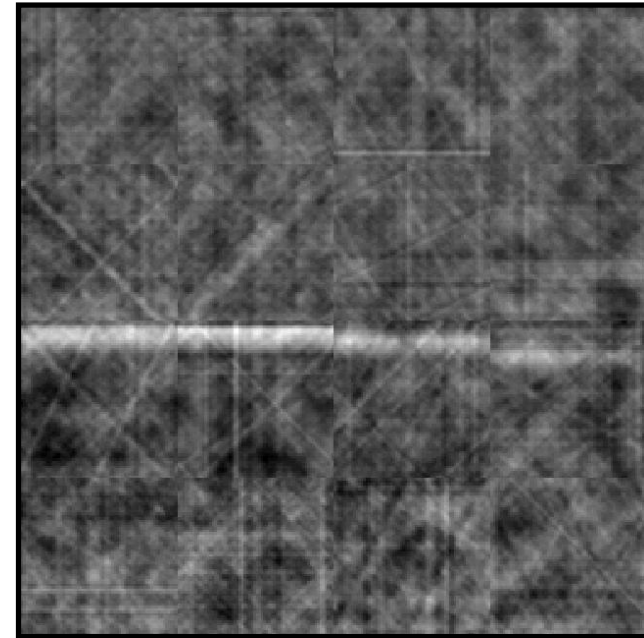
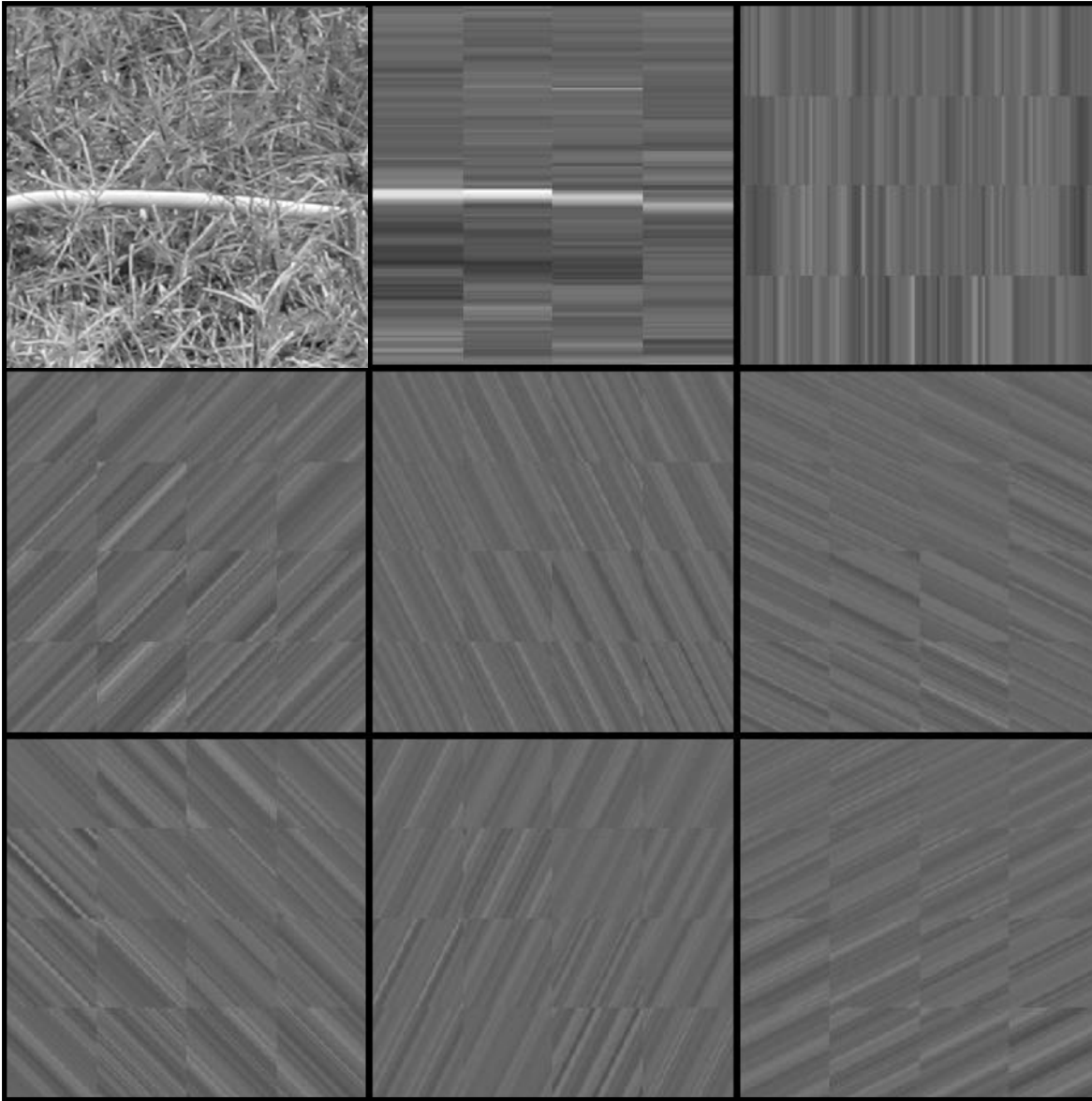
Sum of 8
projections



threshold of sum



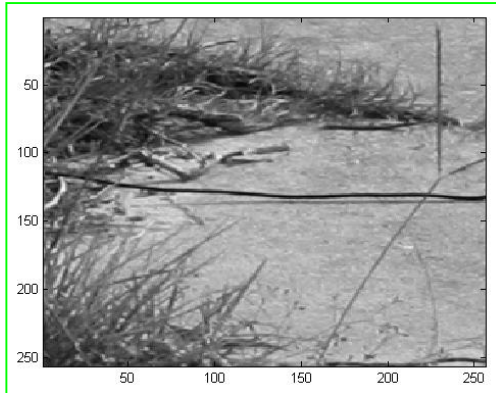
Wire Detection (2)



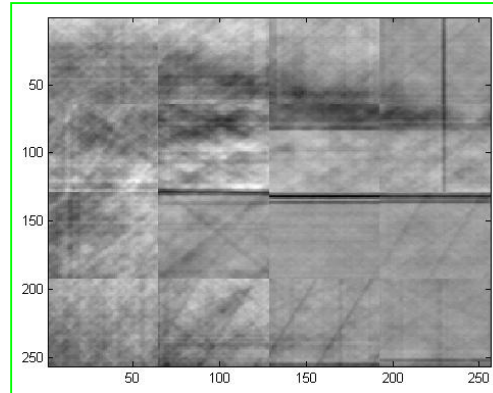
Wire Detection (3)



256 x 256 clip



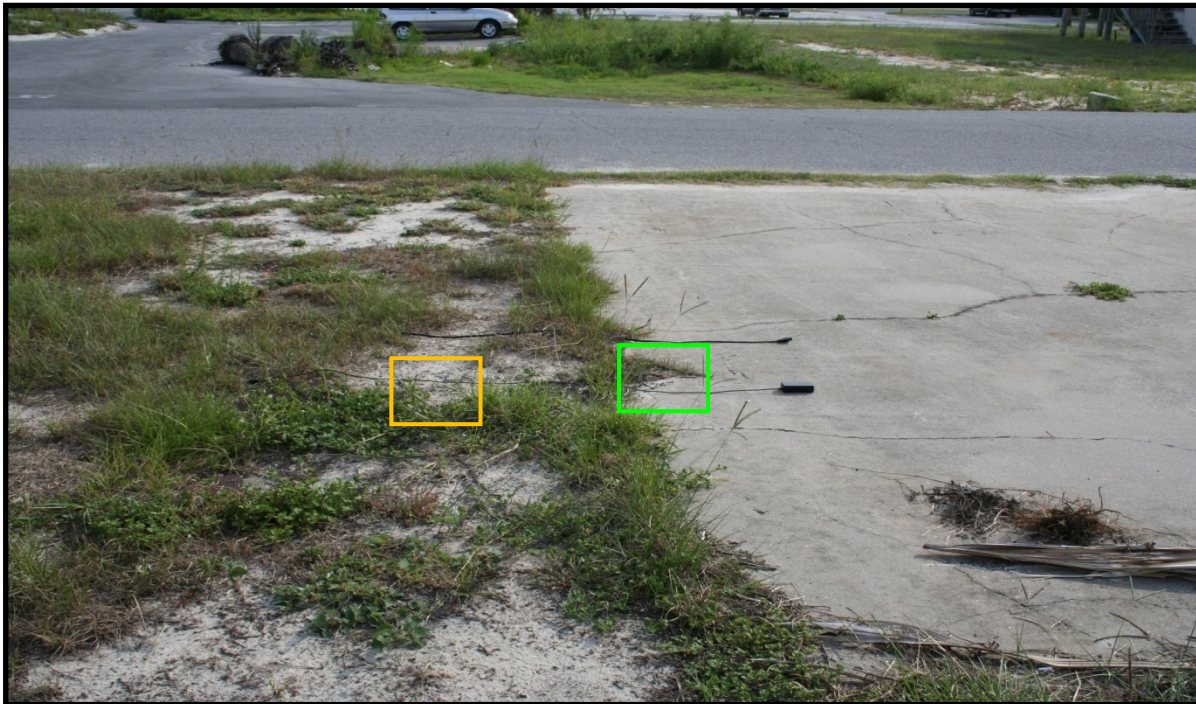
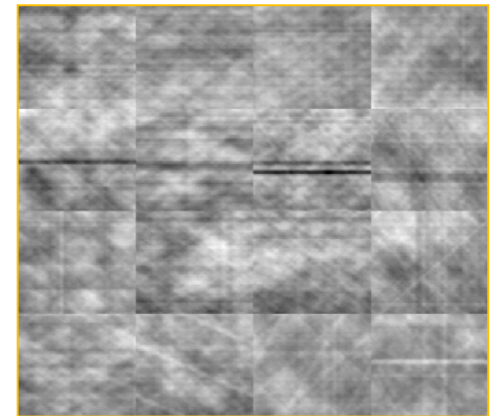
Sum of 8 projections



256 x 256 clip



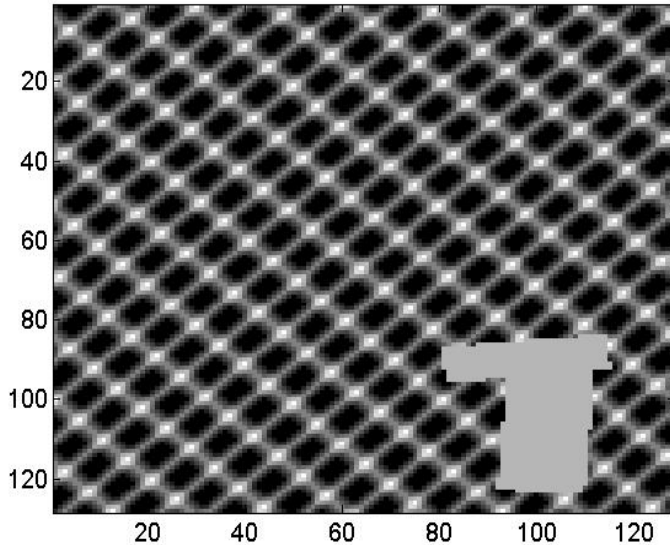
Sum of 8 projections



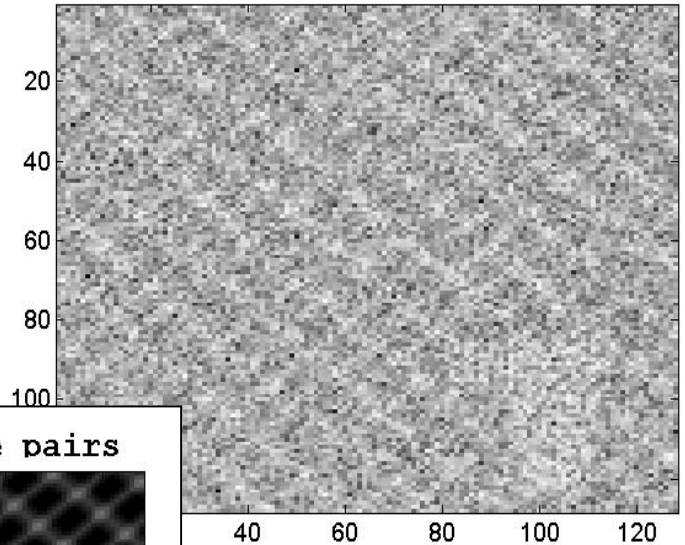


Detection in Severe Noise

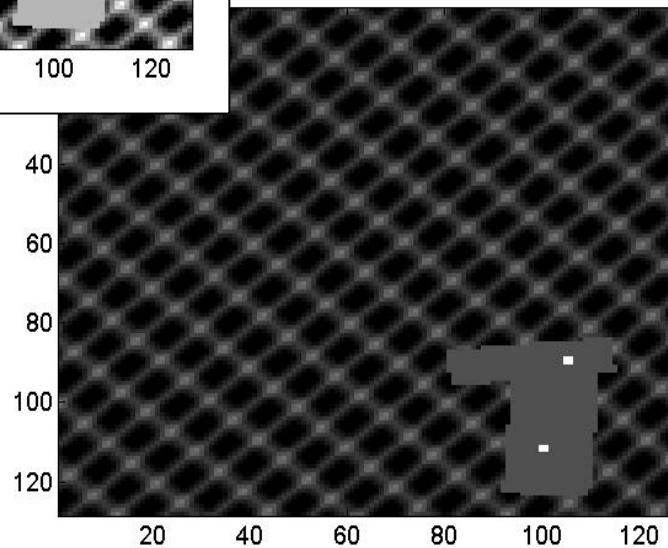
2 boxes, random size/orientation



Gaussian noise added



Output coordinate pairs



- Vertical box confidence: 3/3
- Horizontal box confidence: 3/3



