Improving the Detection of Explosive Hazards with LIDAR-Based Ground Plane Estimation

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SPIE Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XXI

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Outline



- LIDAR Point Clouds
- Individual Sensing Modalities
 - Forward Looking Ground Penetrating Radar
 - Synthetic Aperture Acoustic
 - LIDAR Magnitude Response
- Ground Plane Estimation
 - Target Prediction Filtering
- Sensor Fusion





- Laser-based range finder
- Creates massive point clouds (195 million points)
- How can LIDAR help with target detection?





Ambient Occlusion Filter

Magnitude Response



Traditional Workflow

- Used with FLGPR and SAA to produce a set of hit locations
- A size-contrast filter is applied to each beamformed image
- Resulting peaks are used as hits
- Use mean-shift to combine hits from multiple frames



LIDAR Magnitude

- LIDAR magnitude response is much lower when reflecting off of targets
- Threshold all points above 0.2
- Use mean-shift to cluster the remaining points
- Cluster size reflects density and is used as hit confidence









Individual Modality Scores



Hand-Labeled "Ground" Truth





- Train a NN classifier to learn what is ground and what is not
- Hand-labeled 10m x 10m LIDAR patch with approx. 1.5 million points
- Region is divided into 10cm x 10cm grid cells



Minimum Point Raster Image

• Save the point with the lowest elevation in each grid column



Feature Extraction



Ground Plane Interpolation

- Threshold and erode high-confidence ground locations from the classifier output
- Use this mask to initialize the ground plane model from the minimum point raster image
- Fill in remaining locations with linear interpolation



Interpolated Ground Plane: Ginterp



Ground Plane Classifier Output: Gour



Estimated Ground Plane Mask: Gest



Height Range Thresholding

- Threshold the region based on the difference between the ground plane and maximum point raster image
- Remove hits that could not come from above-ground





Maximum Point Raster Image: Pmax

Filtering Mask h, = 5 cm



Filtering Mask h, = 15 cm



Filtering Mask h, = 10 cm

Filtering Mask h, = 20 cm







Filtering Results



Backbone Lane: Filtered Sparse Hits $h_t = 15$ cm 1 0.9 0.8 0.7 Detection Rate 0.6 0.5 0.4 0.618 FLGPR 0.3 0.696 FLGPR Filtered 0.653 SAA 0.2 0.783 SAA Filtered 0.507 LIDAR 0.1 0.528 LIDAR Filtered 0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04 0.045 0.05 0 False Alarm Rate (FA/m²)

1 0.9 0.8 0.7 Detection Rate 0.6 0.5 0.4 0.618 FLGPR 0.3 - 0.651 FLGPR Filtered 0.653 SAA 0.2 0.689 SAA Filtered 0.507 LIDAR 0.1 0.526 LIDAR Filtered 0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04 0.045 0.05 0 False Alarm Rate (FA/m²)



Backbone Lane: Filtered Sparse Hits h, = 10 cm

Dense Confidence Surface

- Instead of returning a sparse set of hit locations, generate a dense confidence surface from the output of the sizecontrast filter
- Confidence points are aggregated like LIDAR points
- Each sensing modality produces a confidence surface raster image
- Normalize each surface by dividing by the mean





Sensor Fusion



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- Surfaces are fused with a weighted average ۲
- Non-maximum suppression is used to generate a hit list for scoring •



0.5

Target #9: FLGPR



Target #15: FLGPR



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0	0 1	0	
	Target #15: SAA		Tar
2			
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1.0			-
1		0.5	

rget #1: LIDAR



3

2

3

2

rget #9: LIDAR



get #15: LIDAR



Target #1: Fused



Target #9: Fused



Target #15: Fused









Backbone Lane: Confidence Surface Hits h, = 10 cm







Conclusion



- LIDAR can augment existing workflows
 - Independent sensing modality
 - Improved scene understanding
- Ground plane estimation
 - Filter prediction locations based on environment
- Sensor Fusion
 - Create a confidence surface for each modality
 - Generate predictions from the combined surface