AirBrain — LiDAR 3D Obstacle Detection

Real-time helicopter collision prevention using deep learning on LiDAR point clouds

Team AirBrain
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APPROACH

PointNetSegV4 — Point-wise segmentation + geometric clustering + bounding box estimation.

HDF5 → Sph→Cart → PointNet Seg → DBSCAN → PCA BBox → NMS+Filter

- **Input:** 5 features/point (x, y, z, reflectivity, distance)
- **Backbone:** Multi-scale encoder (64→128→256→512→1024) + skip connections
- **Output:** 5-class segmentation (background + 4 obstacle classes)

FINAL MODEL

1,882,693 parameters

Property	Value
Architecture	PointNetSegV4 (multi-scale skip connections)
Format	PyTorch (.pt) + ONNX (0.03 MB)
Training	A100 80GB, 282 min total (5 iterations)
Inference	~1.3 min / 100 frames (T4 GPU)

TRAINING CHOICES

Choice	Why
Class-balanced sampling	Only 5% of points are obstacles — forced 50/50 ratio, equal per class
Focal Loss (γ=2)	Reduces background contribution, focuses on rare classes
Cosine warm restarts	Escapes local minima — best model at epoch 253
Drop augmentation (0-50%)	Simulates reduced density for 25/50/75% robustness
Validation: scene_8	Highest class diversity (entropy 4.72) among 10 scenes

MODELS TESTED

Ver.	Params	Key Change	Obs. mIoU
v1	116K	Baseline PointNet-lite	0.054
v2	116K	+ Focal Loss	0.027
v3	454K	+ Balanced sampling	0.168
v4	1.88M	+ Larger backbone, class-balanced	0.205
v5	**1.88M**	**+ Fine-tuning, drop augment 50%**	**0.212**

Key insight: balanced sampling (v3) = single biggest gain (+0.14 mIoU).

POST-PROCESSING (V7.3)

- **Per-class point confidence:** antenna 0.40, cable 0.27, pole 0.25, turbine 0.30
- **DBSCAN:** per-class eps/min_samples tuned from GT stats
- **Geometric reclassification:** elongated antenna → cable, large antenna → turbine
- **Per-class box confidence:** antenna 0.70, cable 0.55, pole 0.45, turbine 0.60
- **Cable merging:** collinear clusters within 15° / 10m gap
- **Size filter + NMS:** min points, max dim per class, IoU > 0.3

Calibrated on scene_8: 485 pred vs 506 GT boxes (ratio 0.96x). Optional TTA (4x Z-rotation).

RESULTS (V7.3 ON SCENE_8 VALIDATION)

Class	Seg. IoU	Pred	GT	Ratio
Antenna	0.310	81	111	0.73x
Cable	0.397	295	285	1.04x
Electric Pole	0.004	53	40	1.33x
Wind Turbine	0.136	56	70	0.80x
Total	**0.212**	**485**	**506**	**0.96x**

Density	Boxes	Retention
100%	487 (4.9/fr)	100%
75%	459 (4.6/fr)	94.3%
50%	406 (4.1/fr)	83.4%
25%	387 (3.9/fr)	**79.5%**

All 4 classes detected at all densities. Cable: 88% at 25%.