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

- **Point confidence:** softmax < 0.3 → background
- **DBSCAN:** per-class eps/min_samples tuned from GT stats
- **Cable merging:** collinear clusters within 15° / 10m gap
- **Box confidence:** mean softmax ≥ 0.6 per box
- **Size filter:** min points + max dim per class
- **NMS:** IoU > 0.3 suppression within each class

Reduced from 244 to 5.2 boxes/frame (GT: 5.1). Optional TTA (4x Z-rotation).

RESULTS & DENSITY ROBUSTNESS

Class	Seg. IoU
Antenna	0.310
Cable	0.397
Electric Pole	0.004
Wind Turbine	0.136
Obstacle mIoU	**0.212**

Density	Boxes	Retention
100%	508 (5.1/fr)	100%
75%	542 (5.4/fr)	107%
50%	477 (4.8/fr)	94%
25%	339 (3.4/fr)	67%