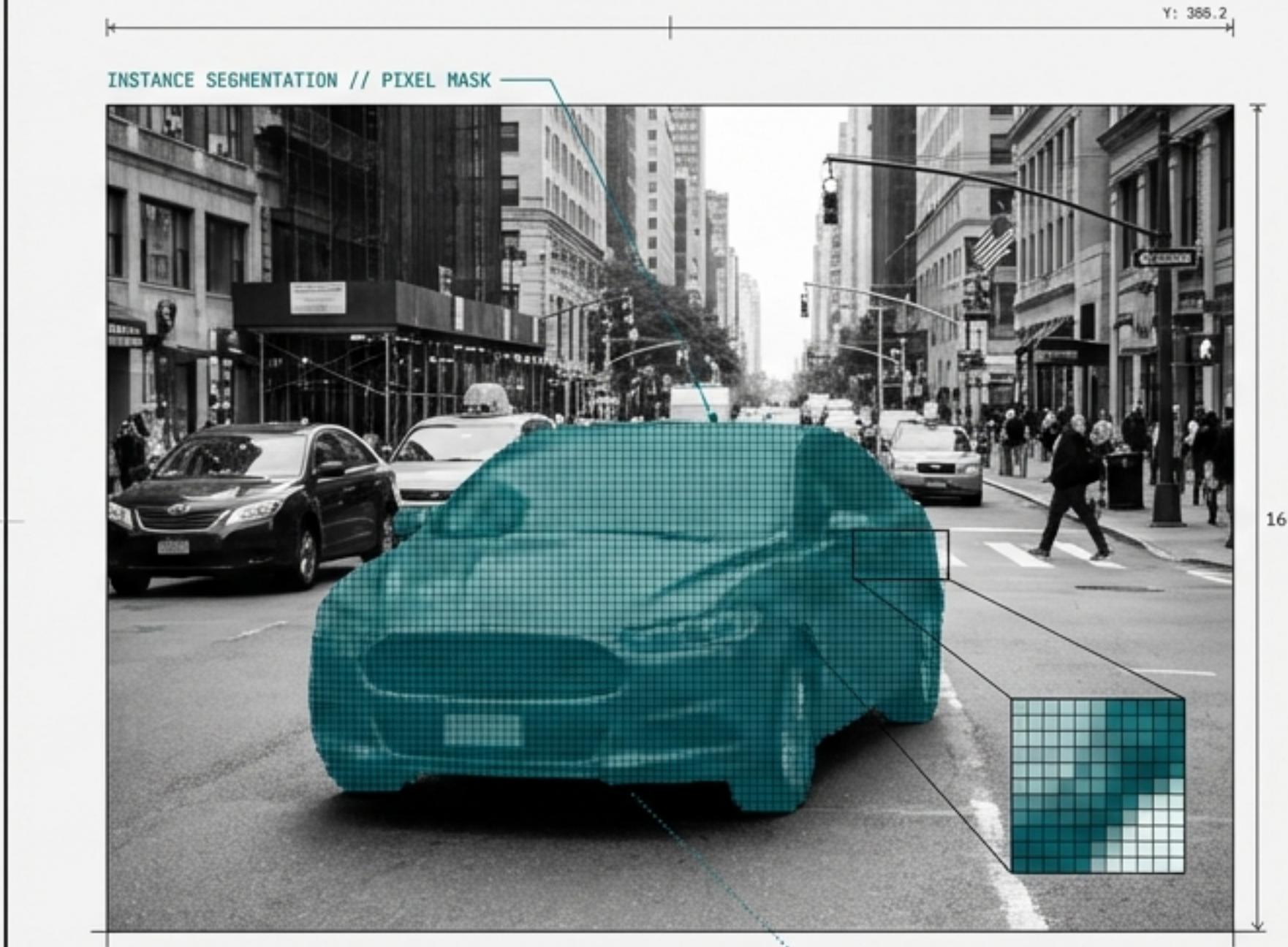


OBJECT DETECTION // BOUNDING BOX
CLASS: PASSENGER VEHICLE
CONFIDENCE: 98.7%



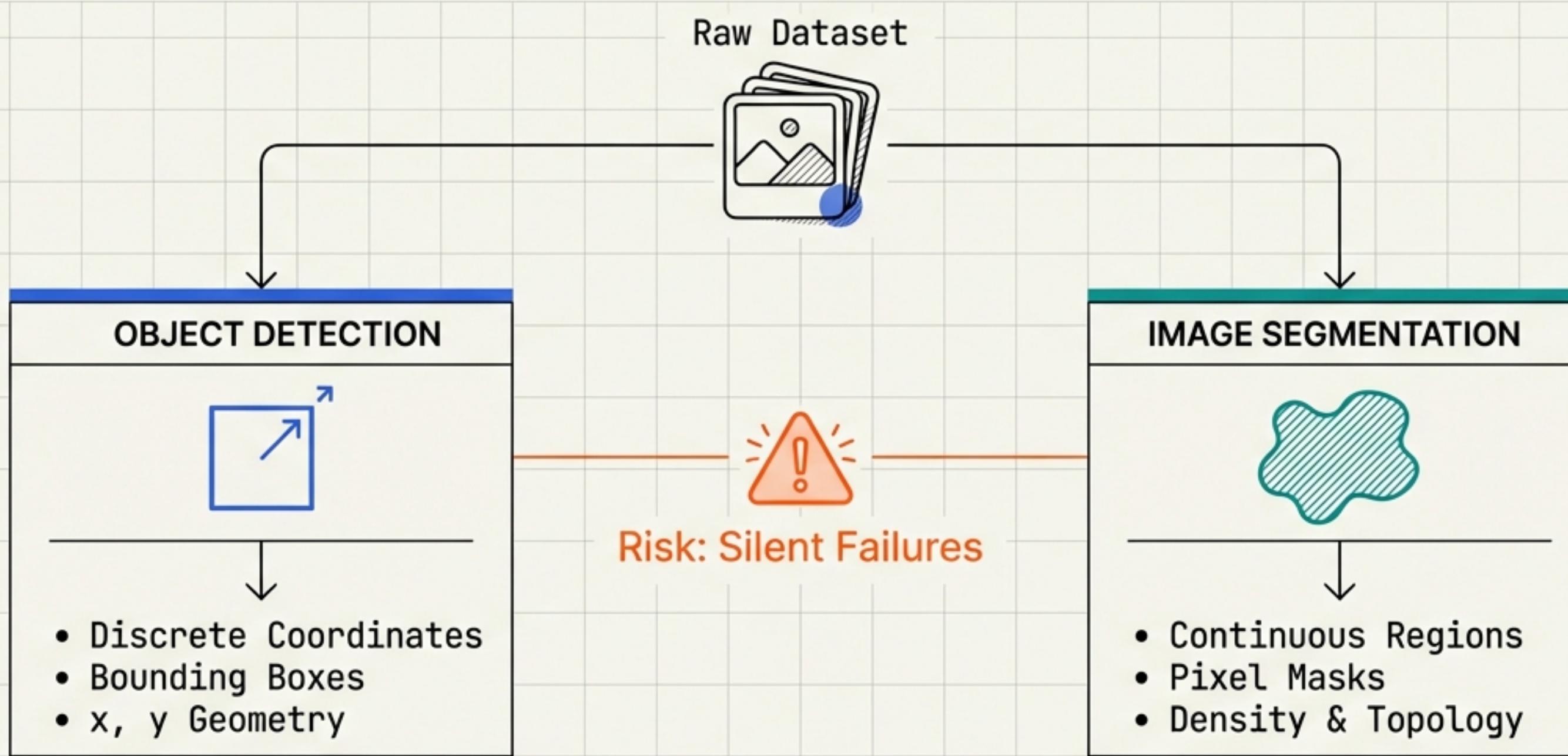
INSTANCE SEGMENTATION // PIXEL MASK
SEGMENT ID: 004A
AREA: 12,458 PI3ELS
MASK DENSITY: HIGH

THE GEOMETRY OF VISION

Analytical Frameworks for Detection and Segmentation

Vision EDA: Analyzing Label Quality

Standard image checks are insufficient. The workflow must bifurcate based on the target label logic.



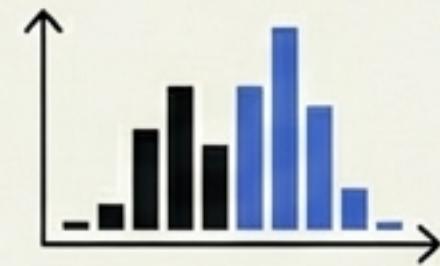
Neglecting task-specific EDA leads to ‘Silent Failures’—where valid images train invalid models due to anchor mismatches or pixel class imbalance.

The Gatekeeper Checks: Universal Foundations

Before defining the task, every dataset must pass these hygiene validations to prevent data leakage.

01

Image Quality



Check brightness & blur.
Inspect Exif tags.

02

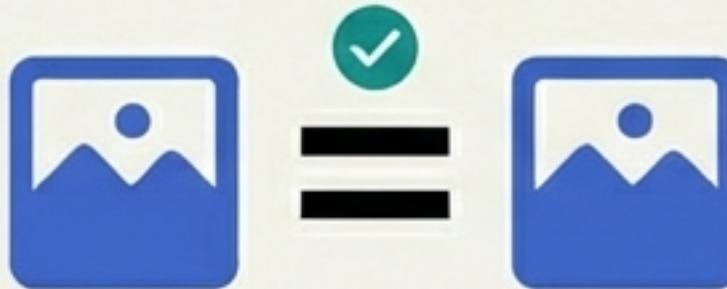
Dimensionality



Identify extreme aspect ratios (panoramas)
to prevent destructive resizing.

03

Duplicate Detection



Hash images to remove duplicates.
Prevent Train/Val leakage.

04

Visual Validation

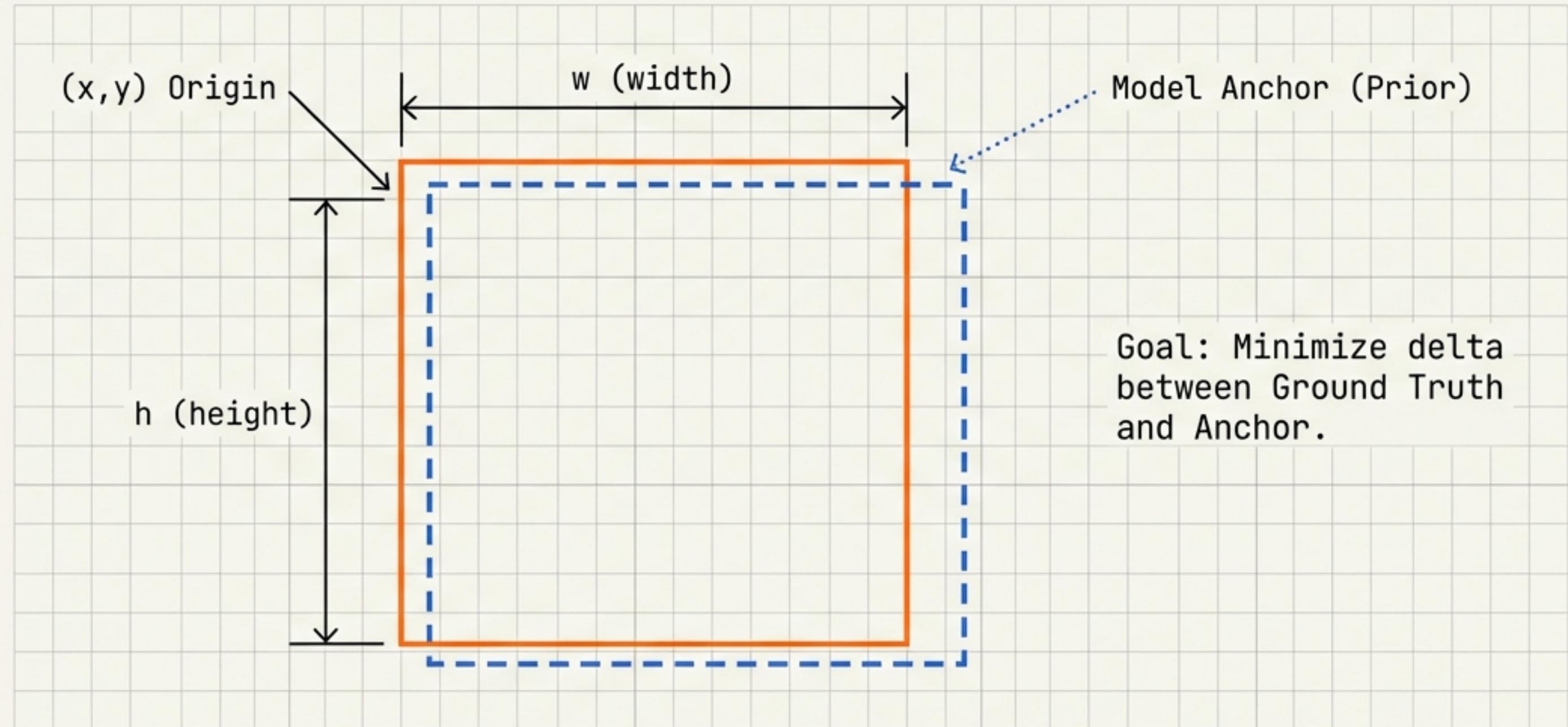


Manually inspect samples for annotation
errors (e.g., mislabeled background).

Object Detection Strategy: Geometry & Coordinates

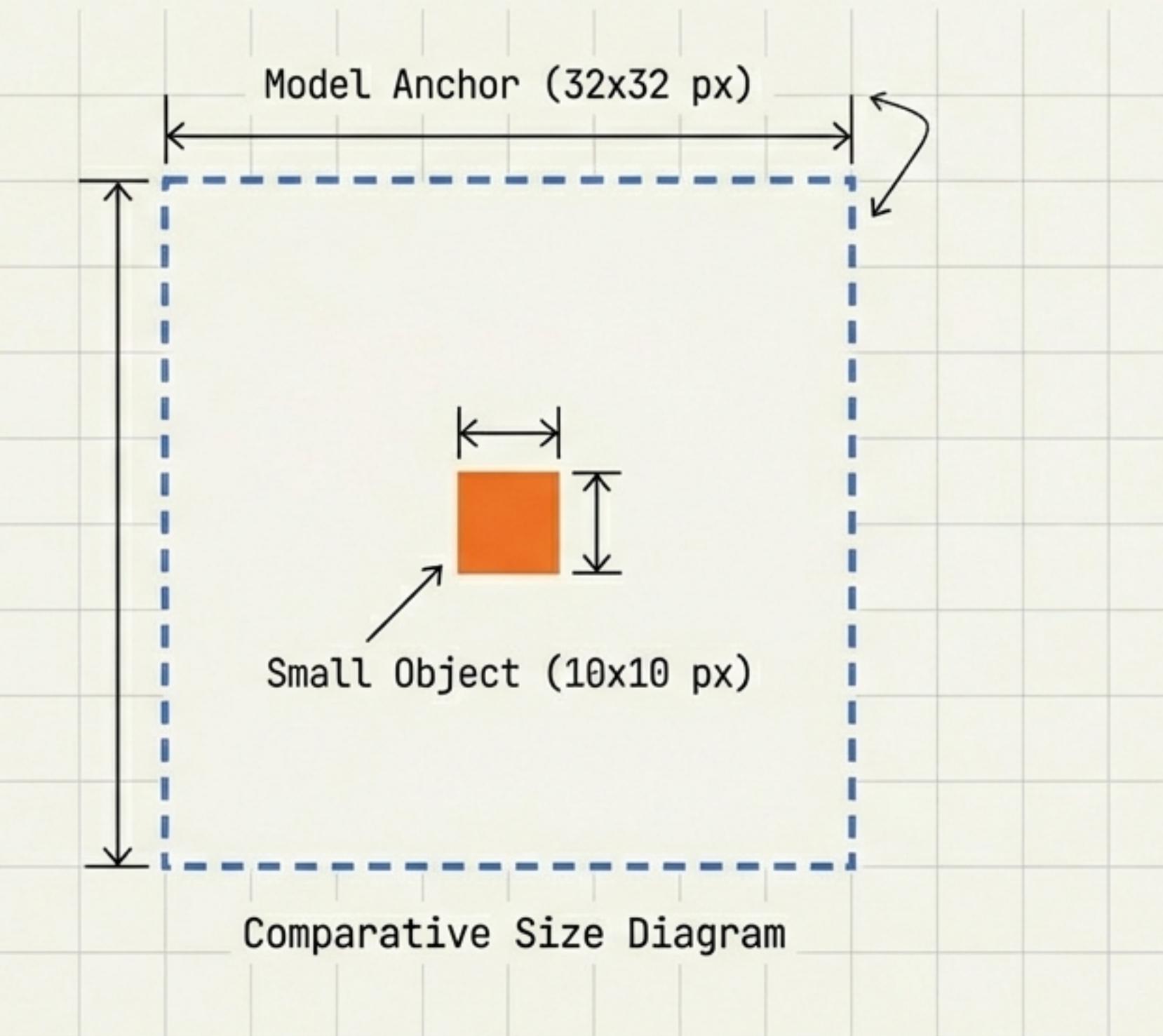
The unit of analysis is the ANCHOR. The label is defined by discrete coordinates.

The unit of analysis is the ANCHOR. The label is defined by discrete coordinates.



The Anchor Box Trap

When Priors Contradict Data



THE MECHANISM:

Detection models use 'priors' to propose regions. They match via Intersection over Union (IoU).

THE RISK:

If Object < Anchor, IoU approaches 0.
Result: The model treats the object as background.

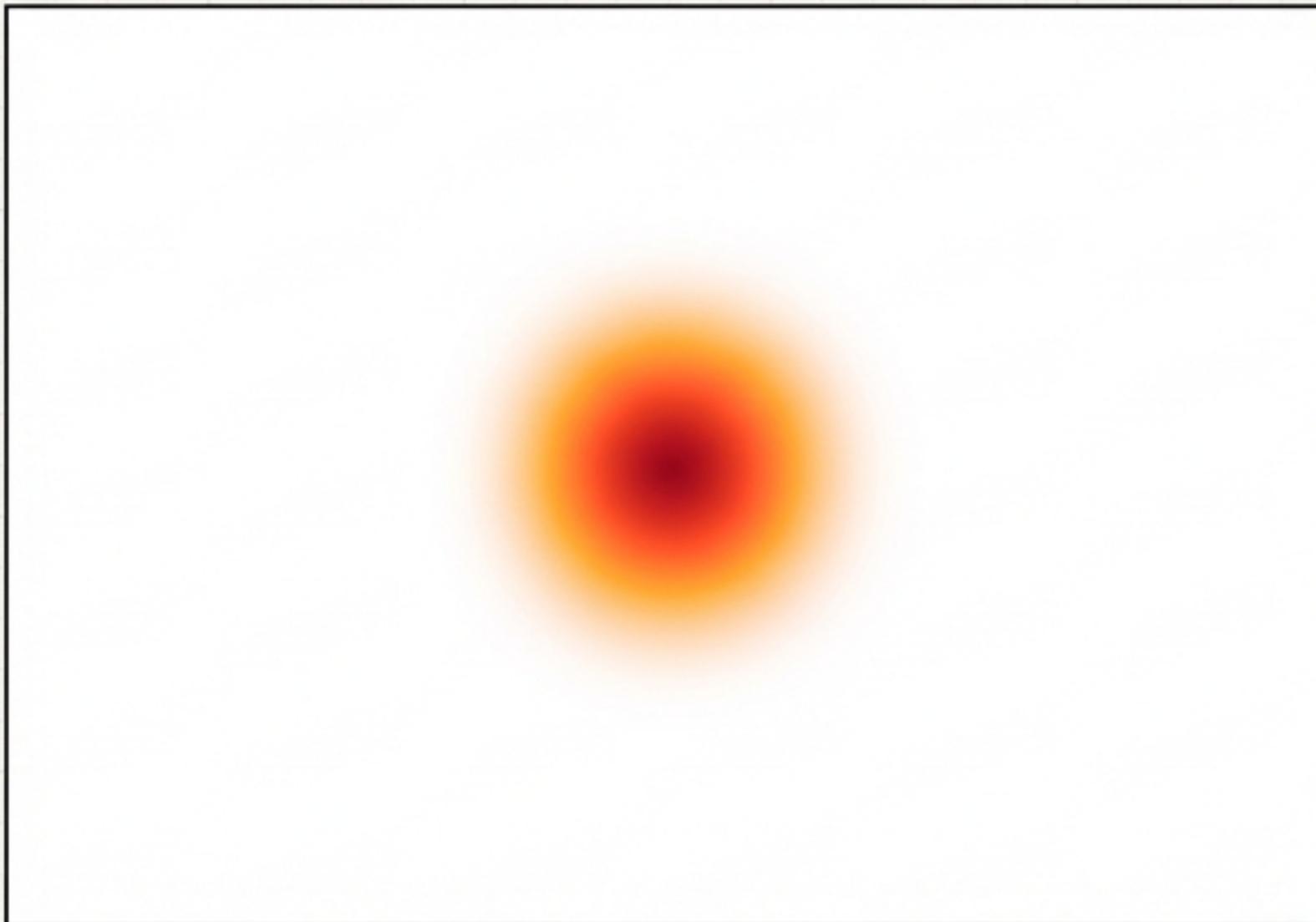
ACTION:

Recalibrate anchor scales to match dataset distribution.

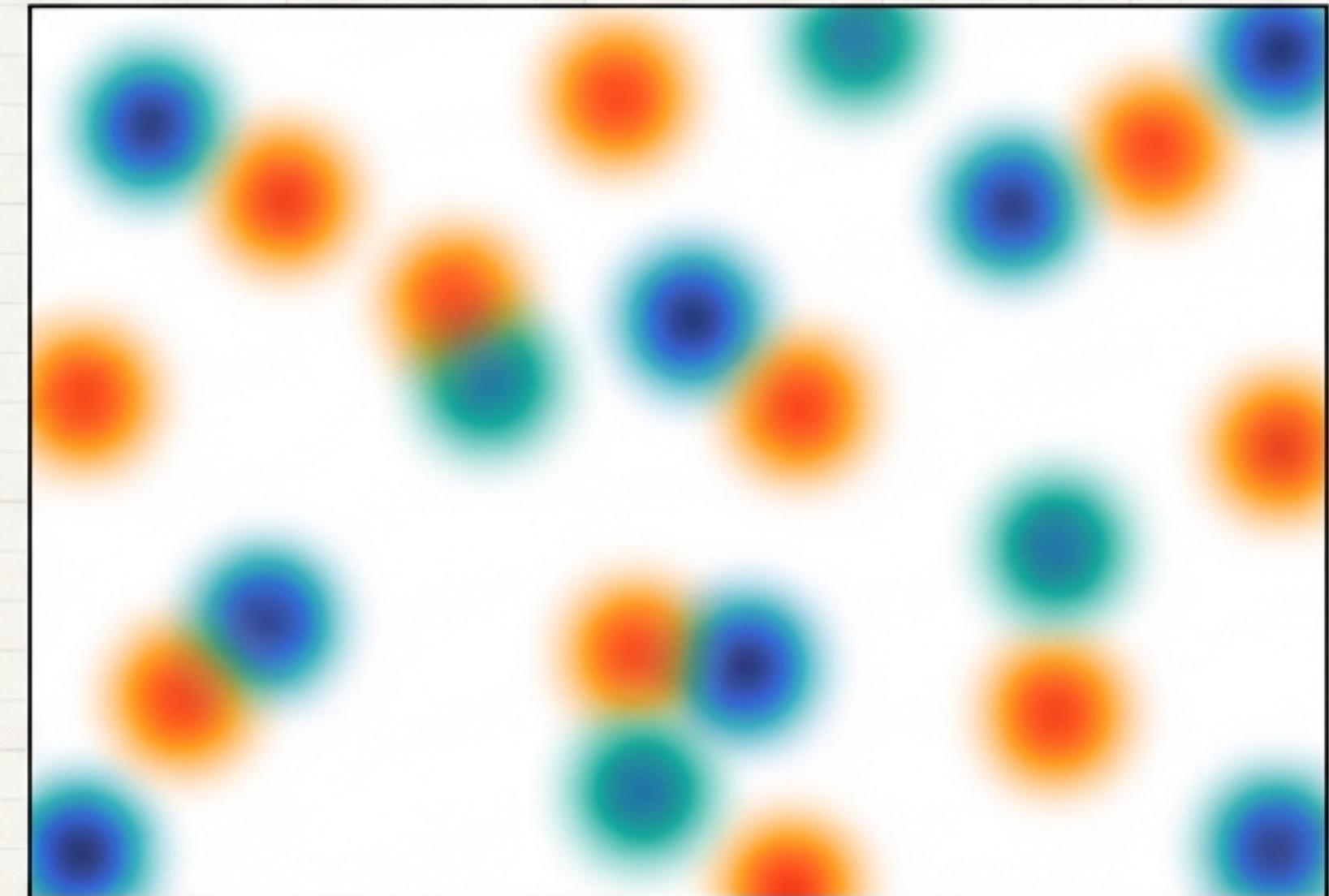
Spatial Analysis: Verifying Location Diversity

Centroid Heatmaps detect “Center Bias”—where models fail to detect objects at the periphery.

BAD: Center Bias



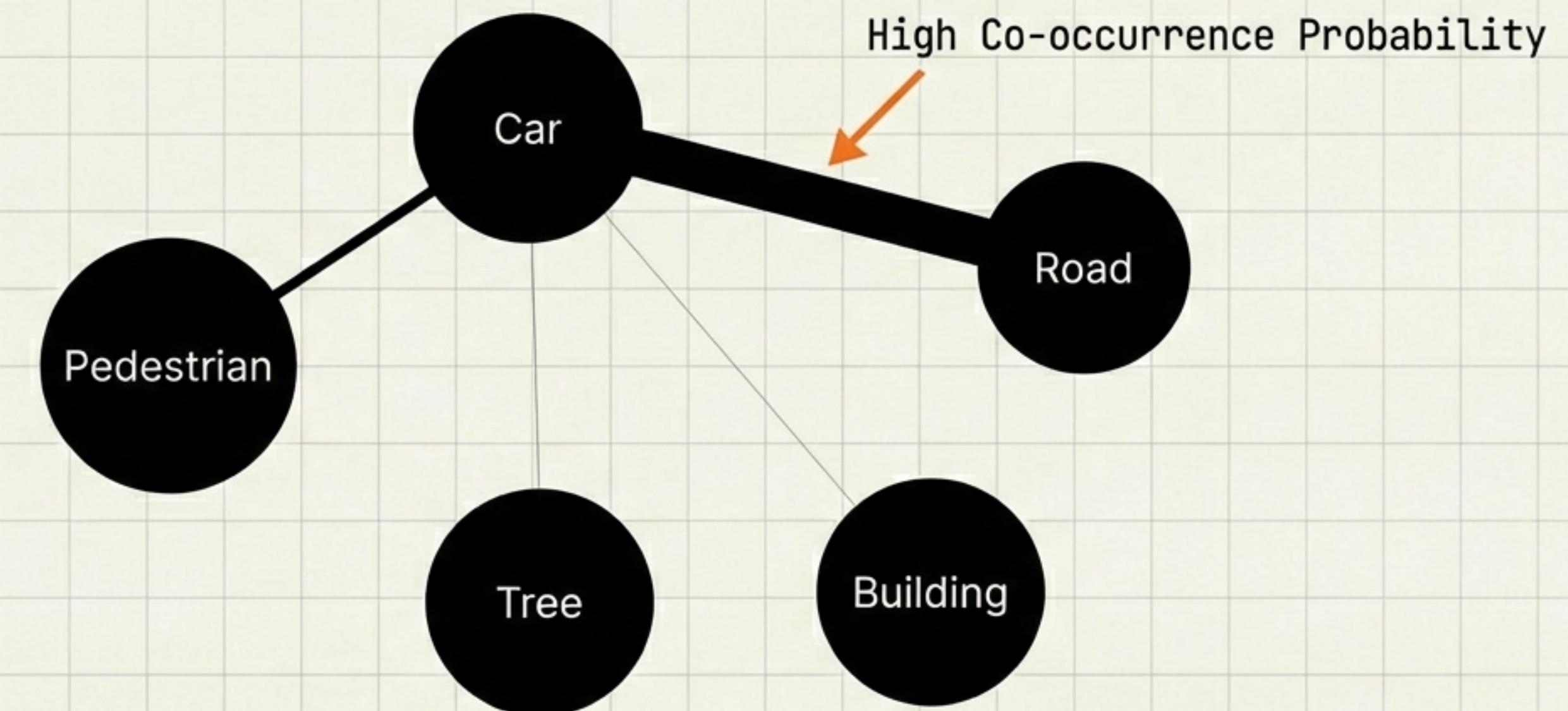
GOOD: Distributed



Plot centroids of all bounding boxes to visualize spatial distribution.

Co-occurrence and Contextual Overfitting

Analyzing which classes appear together helps identify biases. If 'Car' always equals 'Road', the model overfits to context.

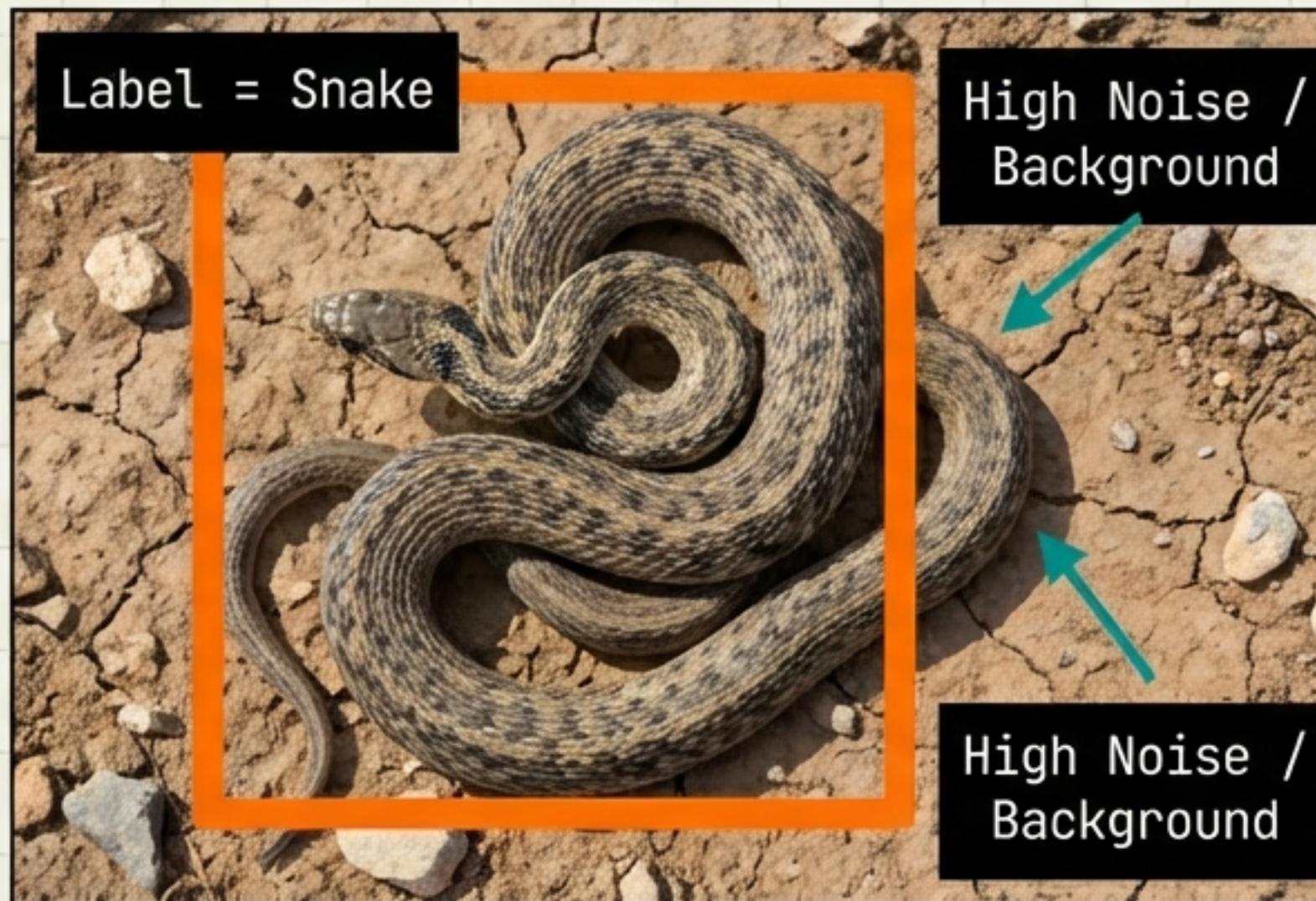


Visual: Co-occurrence Network

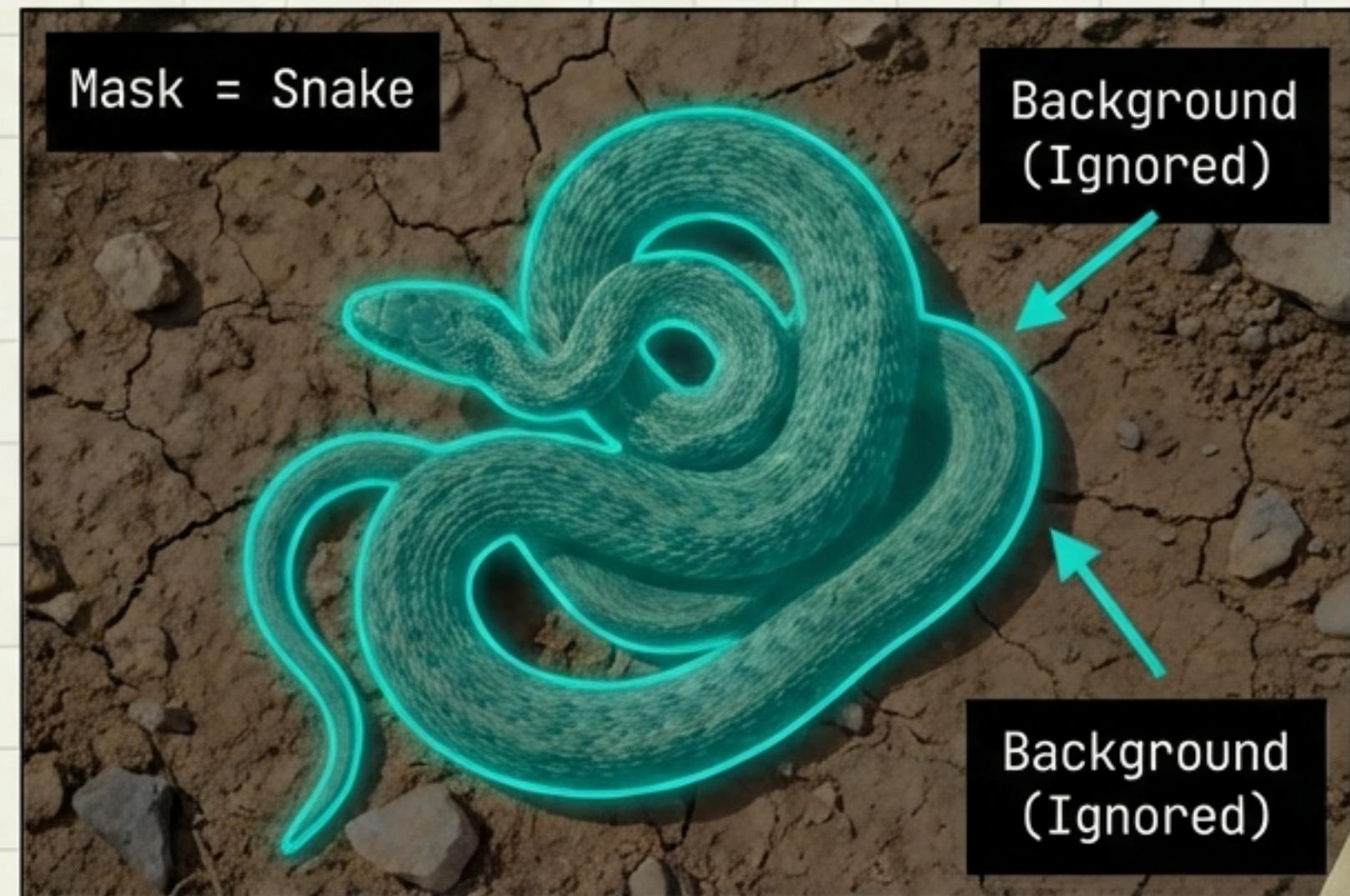
Segmentation Strategy: Density & Topology

The unit of analysis shifts from discrete objects to continuous regions. We measure coverage, not coordinates.

Left side (Detection)



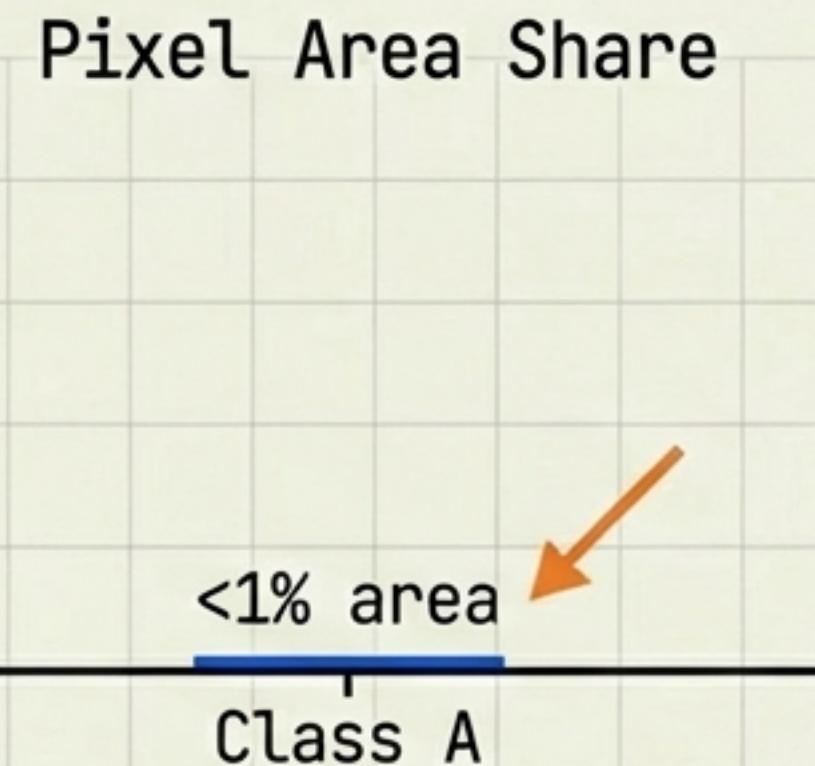
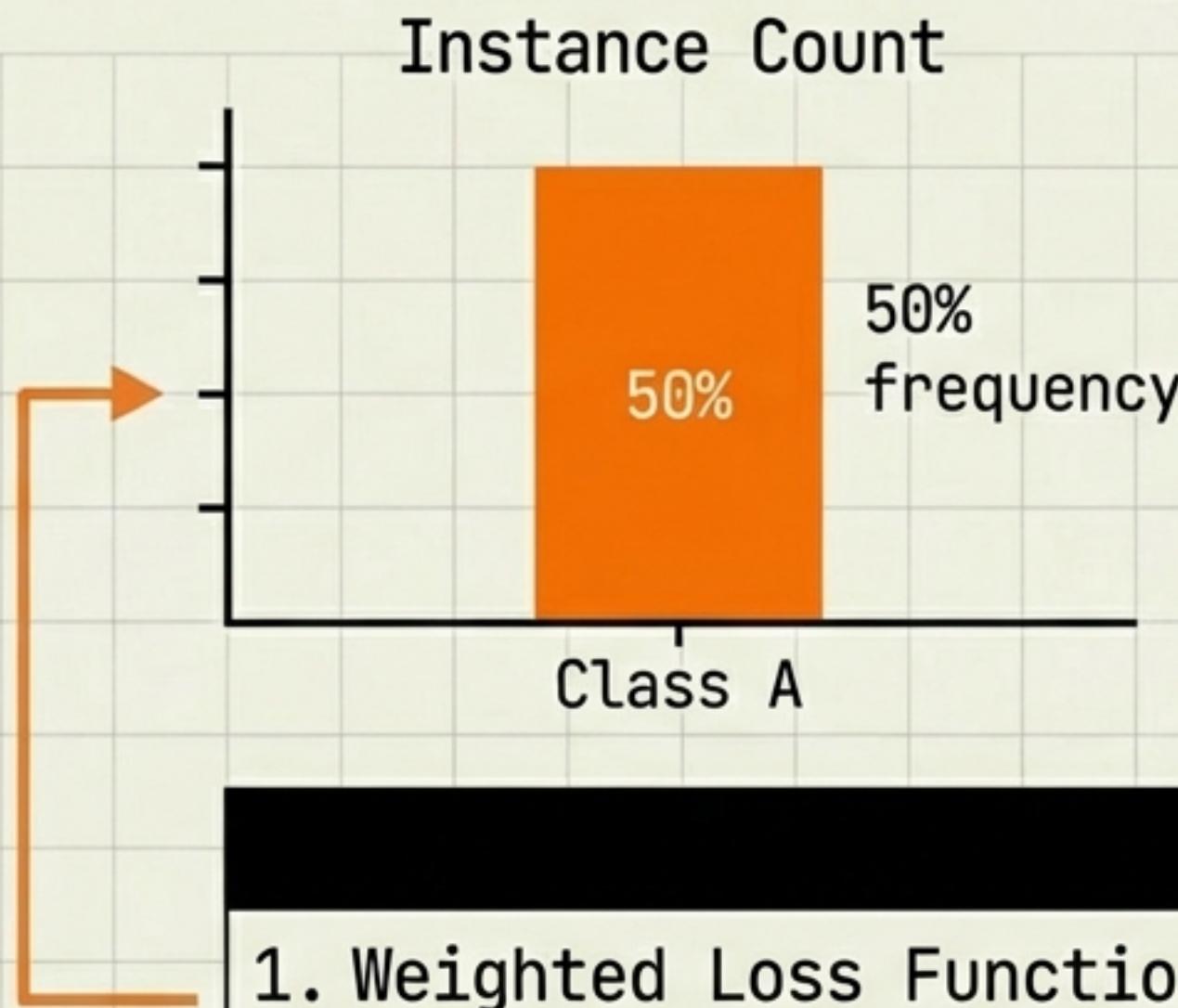
Right side (Segmentation)



Metric Shift: Coordinates (x, y) -> Pixel Density & Mask Integrity.

The Pixel Imbalance Problem

A class can be frequent (High Count) but invisible (Low Pixel Area).



The Fix

1. Weighted Loss Functions (Prioritize minority pixels).
2. Custom Cropping (Resample to increase density).

Visual: Pixel Density Comparison

Boundary Complexity & Mask Integrity

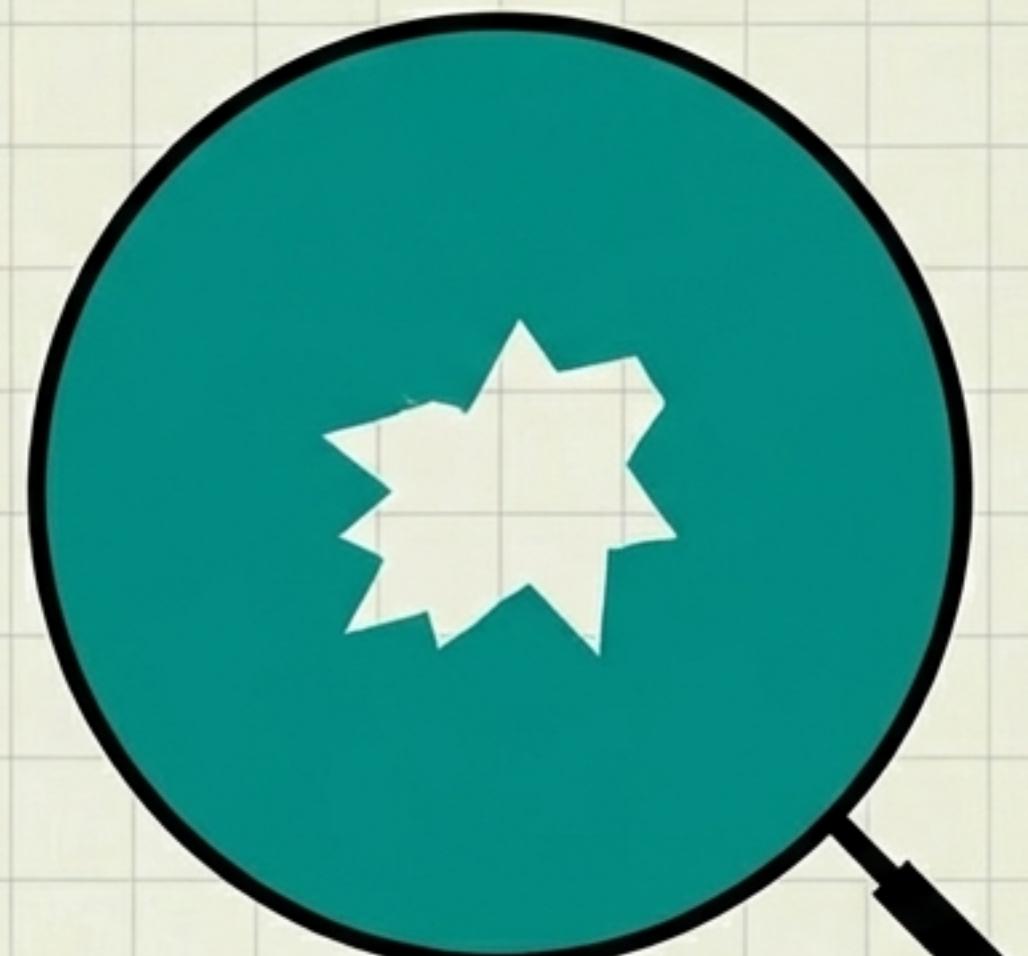
Segmentation fails if edges are undefined or masks are corrupted.

High Complexity



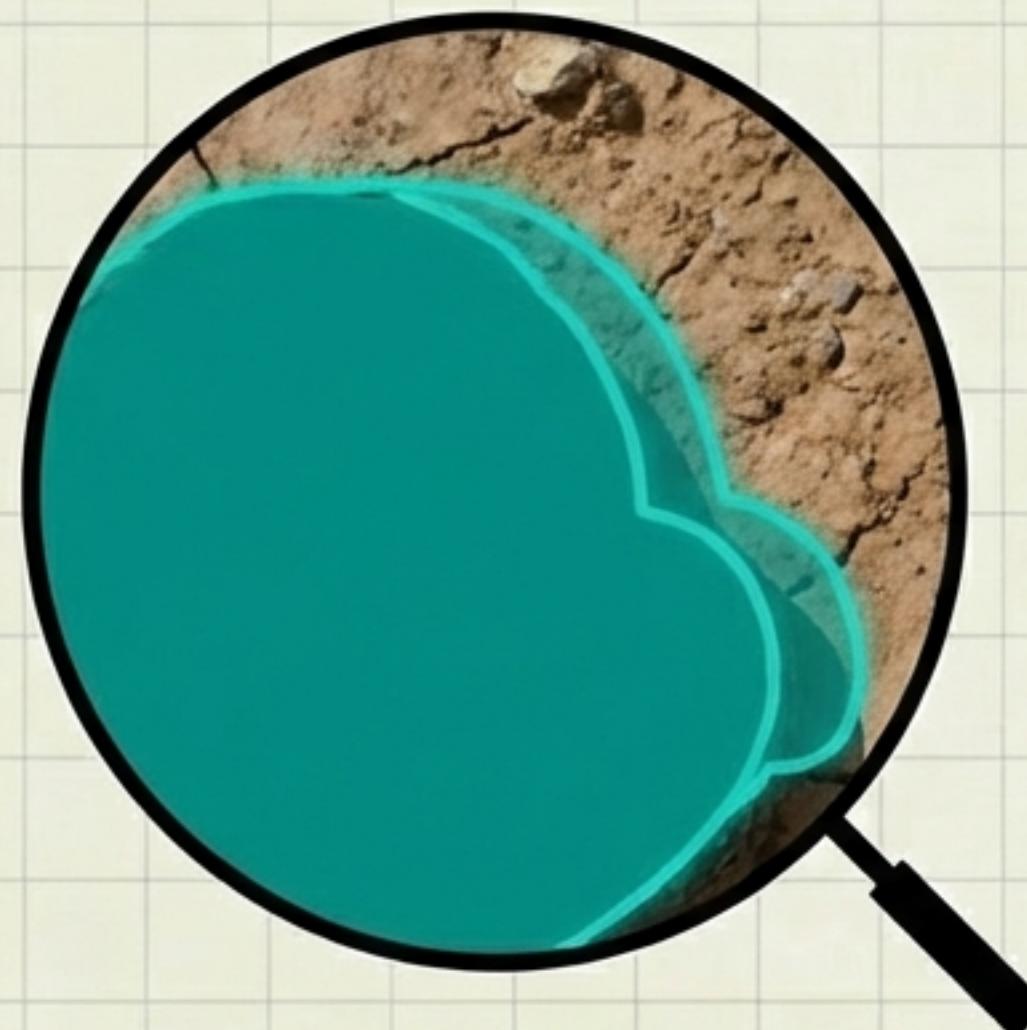
Requires high resolution.

Artifact: Hole



Disjointed Topology.

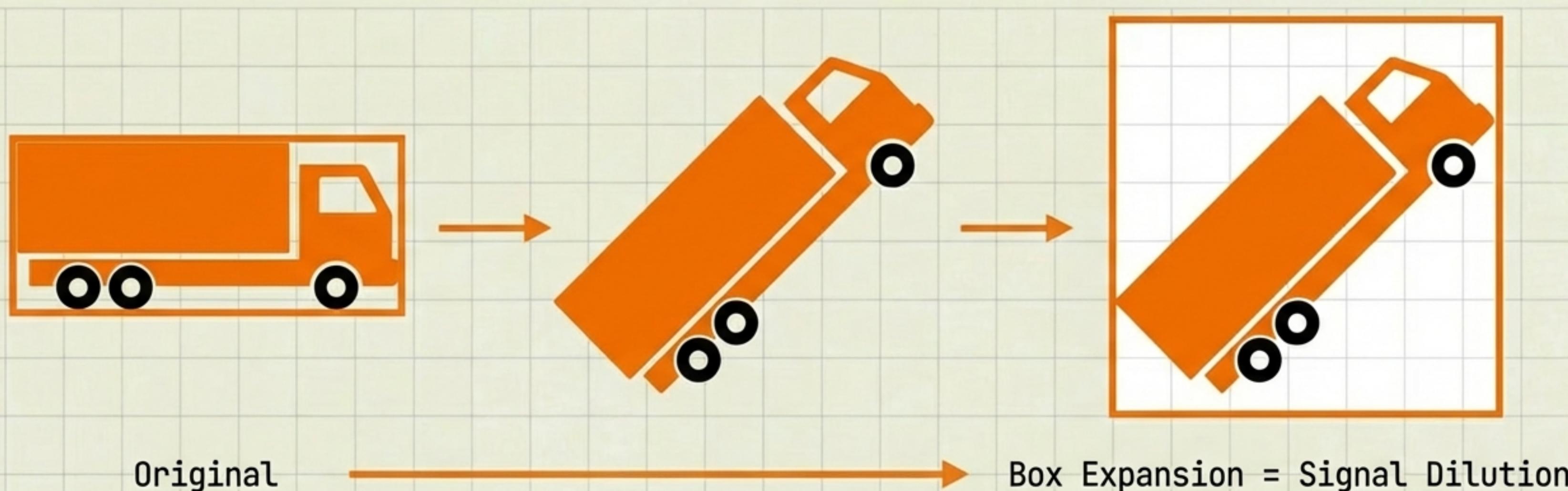
Artifact: Bleed



Poor Alignment.

The Risks of Spatial Augmentation

Rotation helps generalization but can destroy label integrity.



Original

Box Expansion = Signal Dilution

WARNING: Avoid rotation in detection unless using oriented bounding boxes or non-destructive angles (90/180).

Precision Strategies for Small Objects

The Compounding Failure of Resizing and Anchoring.

High-Res Image (1080p)

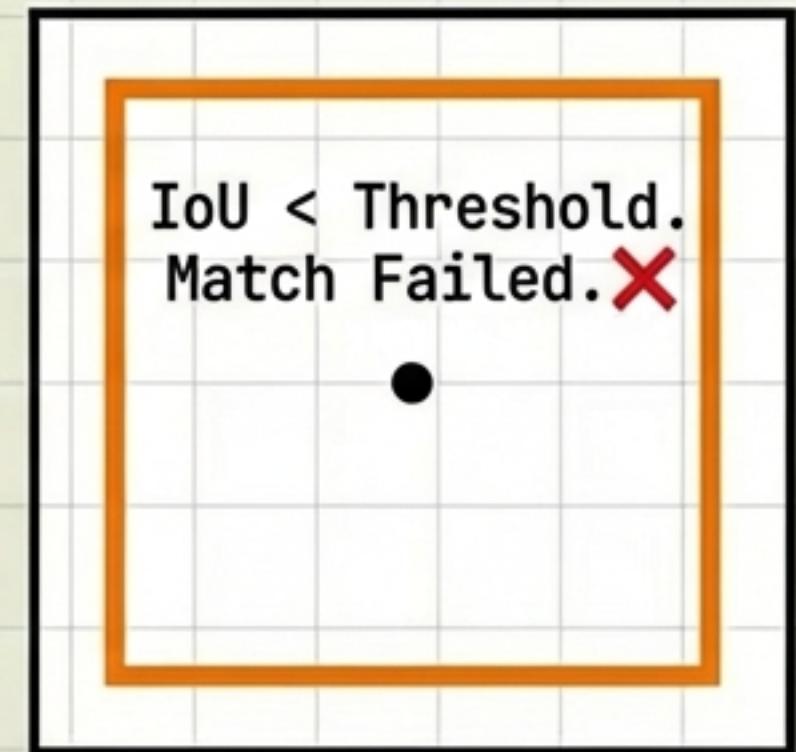


Destructive
Resizing

Low-Res Image (256p)

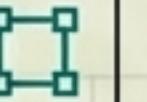


Smallest Anchor Box



STRATEGIC TAKEAWAY: Match anchors to the SMALLEST ground truth.
Avoid destructive resizing.

Framework Comparison

Metric	Object Detection (OD) 	Image Segmentation (IS) 
Primary Unit	Discrete Box	Continuous Mask
Label Metrics	Coordinates (x,y)	Pixel Count / Density
Imbalance Type	Count-based	Pixel-area-based
Spatial Check	Centroid Heatmap	Mask Occupancy %
Model Alignment	Anchor Matching	Boundary Complexity
Key Risk	Small Object Loss	Fine Detail Loss

The Practitioner's Checklist

PHASE 1: DIAGNOSIS

- Plot aspect ratio distribution vs. Anchor Defaults.
- Generate centroid heatmaps for center-bias.
- Calculate pixel-area ratios for invisible classes.

PHASE 2: INTERVENTION

- Recalibrate anchor scales for small objects.
- Implement weighted loss for low-density masks.
- Verify rotation augmentations visually.

GREAT MODELS START WITH CURATED DATA.

Visualize. Measure. Recalibrate.

Technical Reference Series. End of Part 1.