Gaussian-Det: Learning Closed-Surface Gaussians for 3D Object Detection

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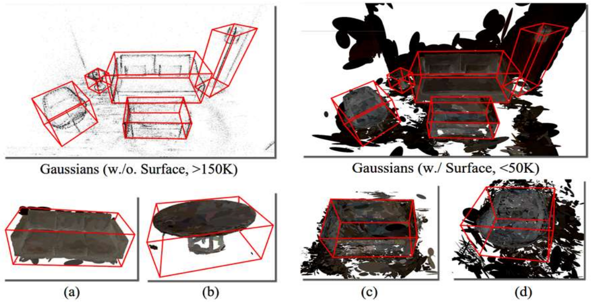
Overview

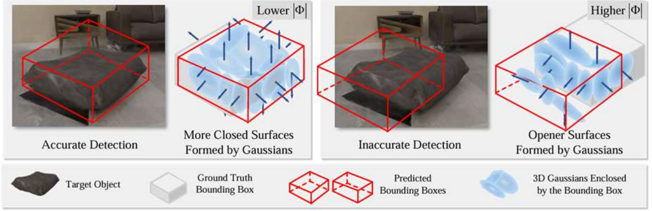
Motivation: Detect 3D objects with posed multi-view images. Use 3D Gaussians as neural scene representations for detection



Problems: GS inherently introduce outliers, leading to degradation when directly utilizing point-cloud based detectors.

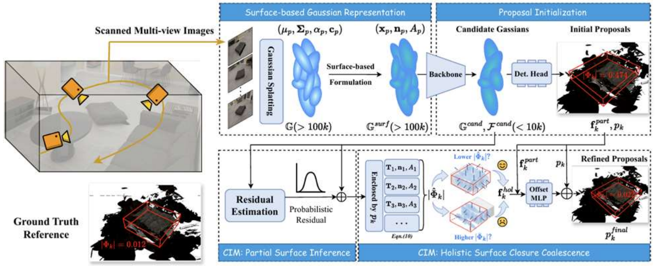
Methods: 3DGS as surface representations. We use normal n (shortest axis) and area A (largest cross-section area of 3D Gaussian Ellipsoid) of Gaussians to represent theobject as an additional guidance for detection.

Method



Goal: Find the bounding box that encloses the object without outliers.

Closed Surface: Objects are enclosed by a series of surfaces, which is an inherent property.



$$\Phi = \oiint_S \mathbf{T} \cdot \mathbf{n} dS = 0 \qquad \oiint_S \mathbf{T} \cdot \mathbf{n} dS = \iiint_V \nabla \cdot \mathbf{T} dV \overset{\nabla \cdot \mathbf{T}=0}{=} 0.$$

$$\hat{\Phi}_k = \sum \mathbf{T} \cdot \mathbf{n}_i A_i$$

Closure: If T is a constant vector field, then the surface integral over a closed region equals zero. We discretize integral for all Gaussians within a proposal. The value is defined as closure.

Experiments

Quantitative Comparisons:

Methods	3D-FRONT				ScanNet			
	AR_{25}	AR_{50}	AP_{25}	AP_{50}	AR_{25}	AR_{50}	AP_{25}	AP_{50}
ImVoxelNetRukhovich et al. (2022b)	88.3	71.5	86.1	66.4	51.7	20.2	37.3	9.8
NeRF-RPN Hu et al. (2023)	96.3	69.9	85.2	59.9	89.2	42.9	55.5	18.4
NeRF-MAE† Irshad et al. (2024)	97.2	74.5	85.3	63.0	**92.0**	39.5	57.1	17.0
G-VoteNet Qi et al. (2019)	81.5	61.6	73.0	49.6	78.5	34.2	66.8	18.2
G-GroupFree Liu et al. (2021)	84.9	63.7	72.1	45.1	75.2	37.6	60.1	20.4
G-FCAF3D Rukhovich et al. (2022a)	89.1	56.9	73.1	35.2	90.2	42.4	63.7	18.5
G-BRNet Xu et al. (2022b)	89.7	75.3	88.2	71.0	71.1	32.2	63.1	19.3
Gaussian-Det (Ours)	**97.9**	**82.3**	**96.7**	**77.7**	87.3	**43.0**	**71.7**	**24.5**

Qualitative Comparisons: