TAD-GS

Temporally Aware Densification for Dynamic 3D Gaussian Splatting

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Project page

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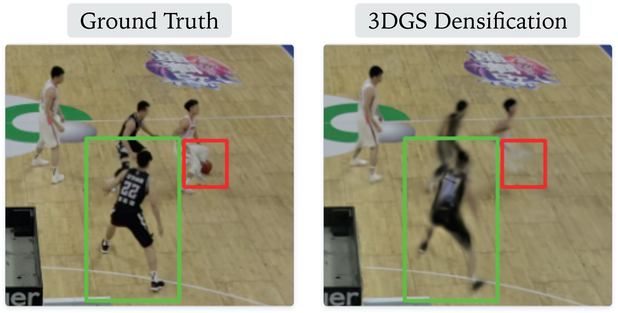
1. Densification in Dynamic 3DGS

- Dynamic 3DGS methods still inherit **static 3DGS Densification**, leading to **sparse gradient** supervision and **blurry reconstructions** in **moving regions**.



2. Analyzing Densification for Dynamic Gaussian

- **Densification criterion:** a Gaussian is densified if its averaged positional gradient $\bar{g}$, accumulated over N iterations, exceeds a pre-defined threshold τ_{pos}.
- Dynamic Gaussians typically have a **shorter temporal lifespan** to represent **complex motion**. For a dynamic Gaussian, the gradient signal $\bar{g}$ decomposes as:

$$\bar{g}_i = \frac{1}{N} \sum_{t \in \text{visible}} g_i(t) + \frac{1}{N} \sum_{t \notin \text{visible}} g_i(t)$$

$\downarrow$ Vanishes *(small numerator, large denominator)* — $\downarrow$ Vanishes *(not visible)*

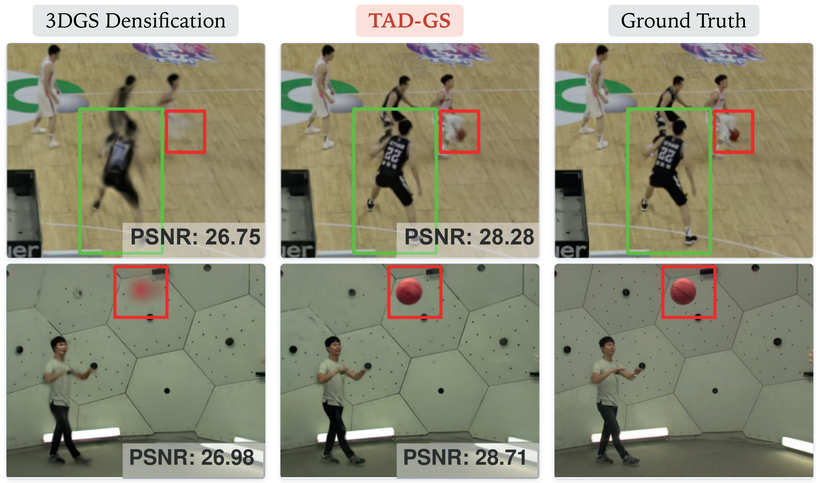
$\bar{g}_i$ rarely exceeds τ_{pos}, and dynamic Gaussians remain un-densified.

3. Prior Work on Dynamic Densification

	Visibility-aware gradient accumulation	Lifespan-adaptive densification threshold	Enhanced local motion modelling
SaRO-GS	✗	✓	✗
Anchored-4DGS	✗	✓	✗
Ours	✓	✓	✓

Our Proposed Solution: We redesign densification criterion based on **Gaussian visibility** and **temporal lifespan**, also enhancing **local motion modeling** for effective densification of dynamic Gaussians.

4. Temporally Aware Densification



TAD-GS (Ours)

Densification Criterion

$$\frac{\sum_{t \in \mathcal{N}} \sigma_i(t)\, g_i(t)}{\sum_{t \in \mathcal{N}} \sigma_i(t)} > \tau_{\text{pos}} \cdot \left(\frac{1}{1 + \beta\,(1 - \bar{\psi}_i)} \right)^{\alpha}$$

Visibility Aware Densification (VAD)

- Visibility-weighted gradient accumulation
- **Avoids gradient dilution** for dynamic Gaussians

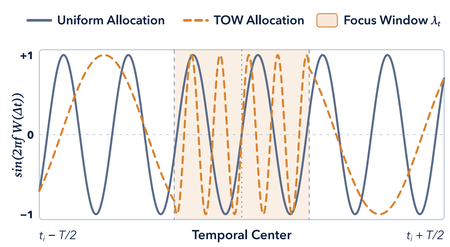
$\sigma_i(t)$: visibility

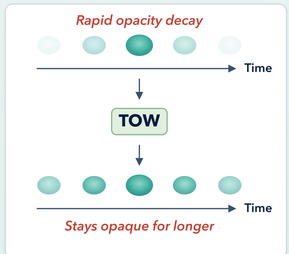
Temporally Adaptive Thresholding (TAT)

- Lifespan-aware thresholding
- **Relaxes threshold bar** for dynamic Gaussians

$\bar{\psi}_i$: temporal lifespan

Temporal Offset Warping (TOW)

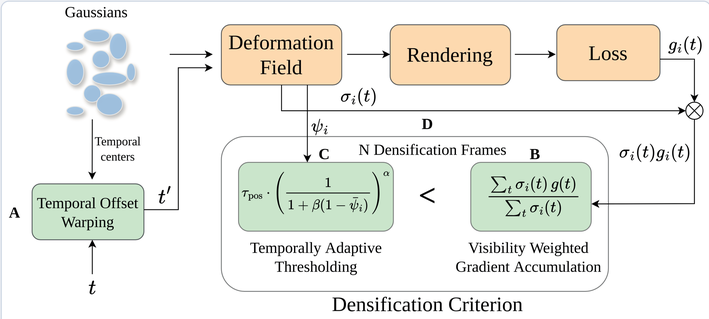




- Stretches time near center, shrinks it farther away
- Enhances Fourier-basis deformation modelling

- Improves local motion modelling
- Increases Gaussian lifespan
- Improves gradient accumulation of dynamic Gaussians

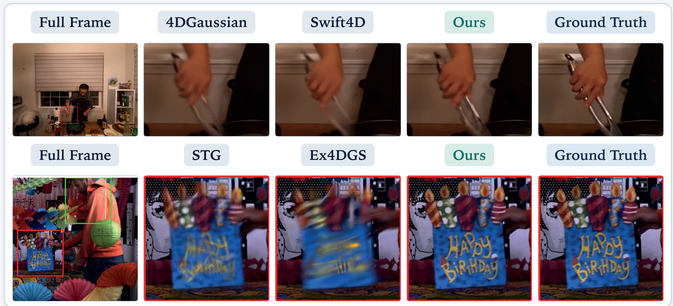
5. TAD-GS Pipeline



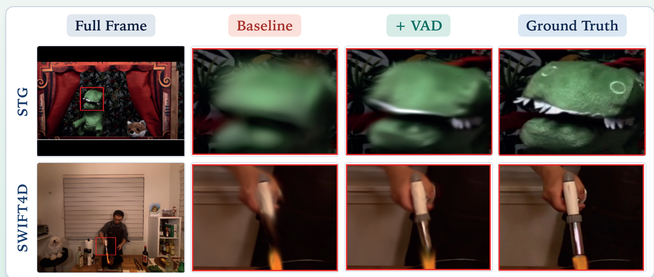
$g_i(t)$ Positional Gradient — $\sigma_i(t)$ Gaussian Opacity at time t — ψ_i Temporal Scale — t' Warped Time

6. Results

Method	Neural 3D Video PSNR↑	Neural 3D Video M-PSNR↑	Neural 3D Video M-SSIM↑	Interdigital PSNR↑	Interdigital M-PSNR↑	Interdigital M-SSIM↑
4DGaussian	31.21	22.67	0.784	26.74	18.09	0.520
STG	31.40	22.61	0.792	33.45	27.14	0.860
Ex4DGS	31.45	23.40	0.814	32.44	26.15	0.844
Swift4D	32.12	23.74	0.835	31.62	23.01	0.741
Ours	**32.42**	**24.68**	**0.863**	**34.14**	**28.87**	**0.901**



VAD module can be easily plugged into any method to improve dynamic reconstruction.



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