SymmNeRF: Learning to Explore Symmetry Prior for Single-View View Synthesis

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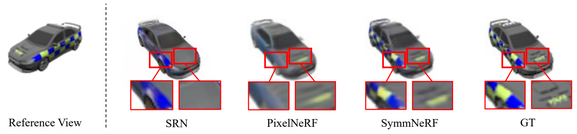
ACCV 2022 Macau

Problem Statement

Goal: Our goal is to synthesize novel views of object categories from a single image.



Motivation:

- Existing methods fail to recover fine details in single-view view synthesis due to the limited information a single view can provide.
- Explicitly injecting symmetry priors into NeRF benefits single-view view synthesis.

Key Contributions:

- We propose SymmNeRF, a NeRF-based framework for single-view view synthesis. By introducing symmetry priors into NeRF, SymmNeRF can synthesize high-quality novel views with fine details regardless of pose transformation.
- We combine local features with global conditioning via hypernetworks and achieve significant improvement.
- Given only a single input image, SymmNeRF demonstrates significant improvement over state-of-the-art methods on synthetic and real-world datasets and show good generalization when applied to unseen objects.

Methodology

Encoding Holistic Representations: The image encoder network f is responsible for mapping the input image $\mathcal{I}_i$ into the latent code $\mathbf{z}_i$:

$$f : \mathbb{R}^{H\times W\times 3} \to \mathbb{R}^k, \quad \mathcal{I}_i \mapsto f(\mathcal{I}_i) = \mathbf{z}_i.$$

Extracting Symmetric Features: We obtain symmetric features by projecting the symmetric point $\mathbf{X}'$ to the 2D location $\mathbf{x}'$ on the image plane using camera parameters, followed by bilinearly interpolating between the pixelwise features on the feature volume $\mathbf{F}$ extracted by the image encoder network f.

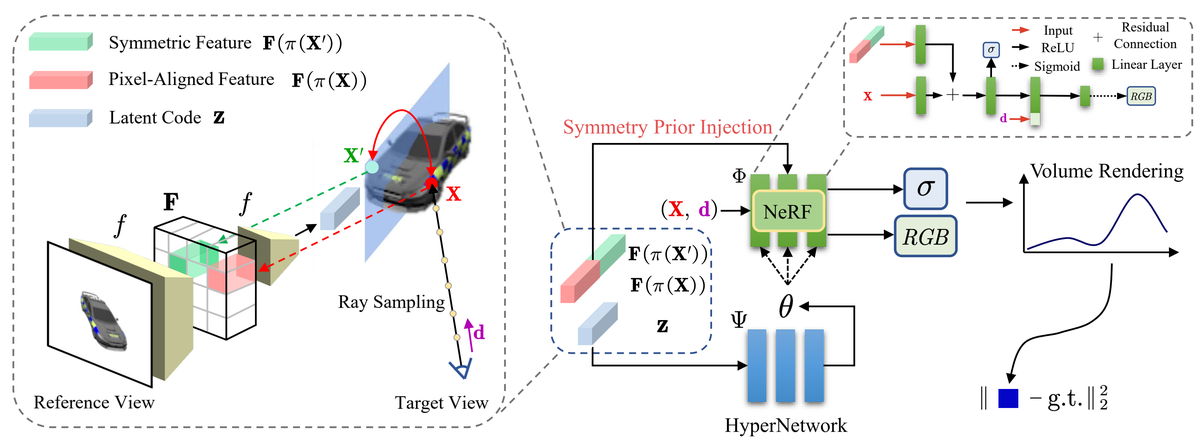
Generating Neural Radiance Fields: We generate a specific neural radiance field by mapping a latent code $\mathbf{z}_i$ to the weights θ_i of the neural radiance field using the hypernetwork Ψ:

$$\Psi : \mathbb{R}^k \to \mathbb{R}^l, \quad \mathbf{z}_i \mapsto \Psi(\mathbf{z}_i) = \theta_i.$$

Injecting Symmetry Prior: Given a reference image with known camera parameters, for a single query point location $\mathbf{X} \in \mathbb{R}^3$ on a ray $\mathbf{r} \in \mathbb{R}^3$ with unit-length viewing direction $\mathbf{d} \in \mathbb{R}^3$, SymmNeRF predicts the color and density at that point in 3D space:

$$\Phi : \mathbb{R}^{m_\mathbf{X}} \times \mathbb{R}^{m_\mathbf{d}} \times \mathbb{R}^{2n} \to \mathbb{R}^3 \times \mathbb{R},$$
$$\Phi(\gamma_\mathbf{X}(\mathbf{X}), \gamma_\mathbf{d}(\mathbf{d}), \mathbf{F}(\pi(\mathbf{X})), \mathbf{F}(\pi(\mathbf{X}'))) = (\mathbf{c}, \sigma).$$

Framework



More details at: https://github.com/xingyi-li/SymmNeRF

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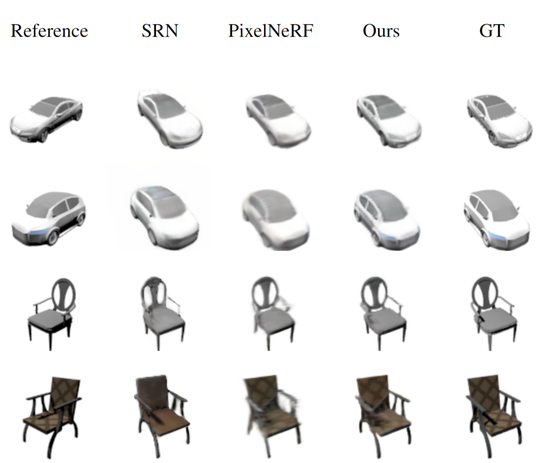
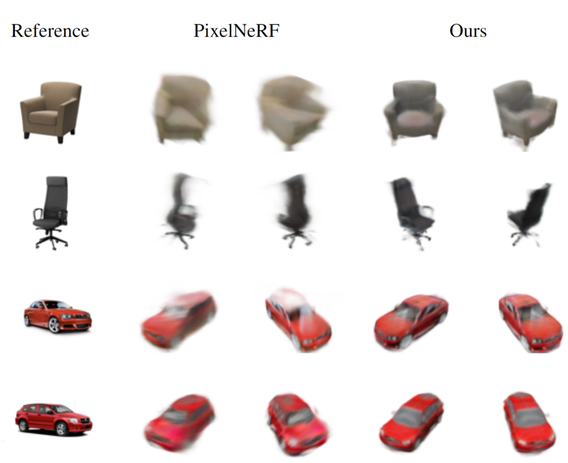
Experiments

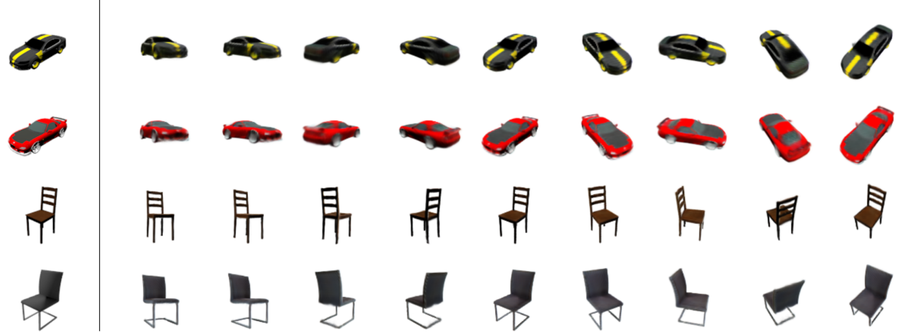
Qualitative comparisons on "Cars" and "Chairs":



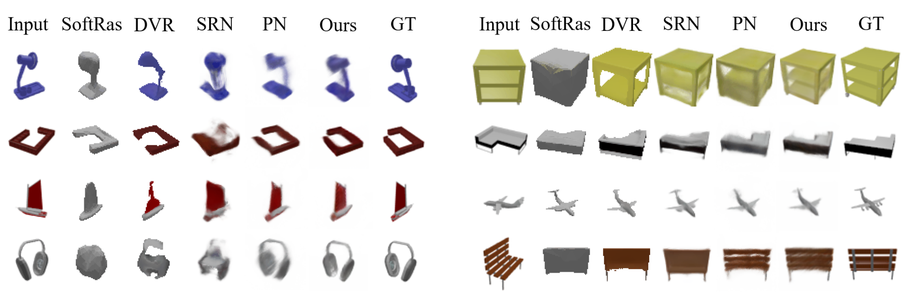
Qualitative comparisons on real-world datasets:



Novel view synthesis on "Cars" and "Chairs" of ShapeNet-SRN dataset:



Qualitative comparisons on ShapeNet-NMR dataset under category-agnostic single-view reconstruction setting:



Acknowledgments

This work is supported in part by the National Natural Science Foundation of China (Grant No. U1913602). This study is also supported under the RIE2020 Industry Alignment Fund – Industry Collaboration Projects (IAF-ICP) Funding Initiative, as well as cash and in-kind contribution from the industry partner(s).