Efficient Neural Radiance Fields for Real-Time 3D Scene Reconstruction on Consumer Grade Hardware

Abstract:
Neural Radiance Fields (NeRF) have revolutionized 3D reconstruction by synthesizing high-fidelity novel views from a set of 2D images. However, standard NeRF implementations require substantial computational resources, making them impractical for real-time applications on consumer-grade hardware. We explore efficient NeRF variants optimized for consumer grade hardware. We first implement a baseline NeRF model trained on the synthetic Blender Dataset and analyze its reconstruction quality. We then extend this work by incorporating Instant-NGP (Instant Neural Graphics Primitives) to significantly reduce training time, enabling real-time rendering without sacrificing visual fidelity. Additionally, we introduce a novel depth-to-mesh pipeline, converting NeRF-generated depth maps into 3D point clouds and surface reconstructions using Open3D. Finally, we evaluate the impact of real-world datasets captured from mobile devices, comparing the reconstruction quality, training efficiency, and model performance across different NeRF architectures. Our results demonstrate that optimized NeRF implementations can achieve high-quality 3D reconstructions of consumer hardware, making real-time NeRF applications more accessible.

Phase 1 midterm:

- Review the original NeRF paper and Fast-NeRF variants: Mip-NeRF, Instant-NGP, NeRF-SH
- Test and train NeRF or TinyNeRF on my machine with the Blender Dataset or the LLFF dataset
- Time permitting: analyze performance with Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE), and Structural Similarity Index (SSIM)

Phase 2 final:

- Use coarse-to-fine training for better results
- Implement hierarchical volume sampling for better convergence
- Capture a real world dataset with my phone of common and more interesting objects
- Use a pre-trained NeRF model and refine it with real world scenes
- Render novel views from depth maps to a 3D mesh using Open3D