RT-NeRF: Real-Time On-Device Neural Radiance Fields Towards Immersive AR/VR Rendering

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EFFICIENT AND INTELLIGENT COMPUTING

NeRF: A Tool to Generate Novel Views

- Neural Radiance Fields (NeRF) can generate **arbitrary new views** of a specific scene **given sparsely sampled scene images**

Inputs: Sparsely sampled views

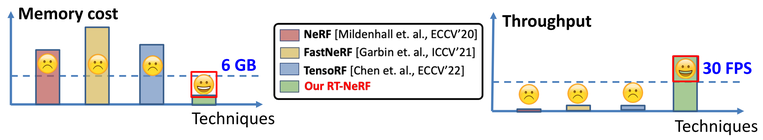
Outputs: Images of any new view

Real-Time NeRF Is Increasingly Demanded

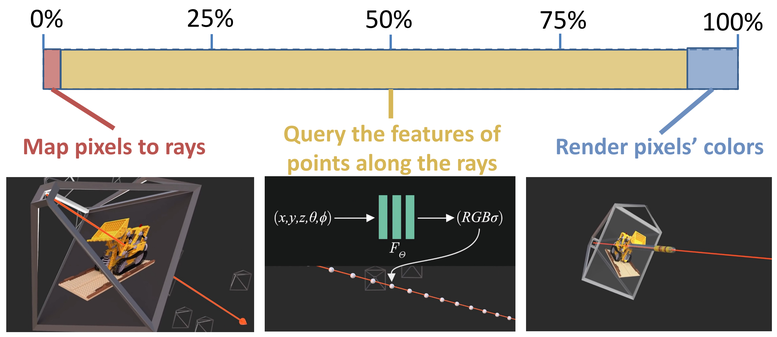
Virtual Meetings | Metaverse | Autonomous Driving Simulation

SOTA Efficient NeRF's Limitations

- **Limitation 1**: **Large memory** requirement
- **Limitation 2**: **Low throughput**



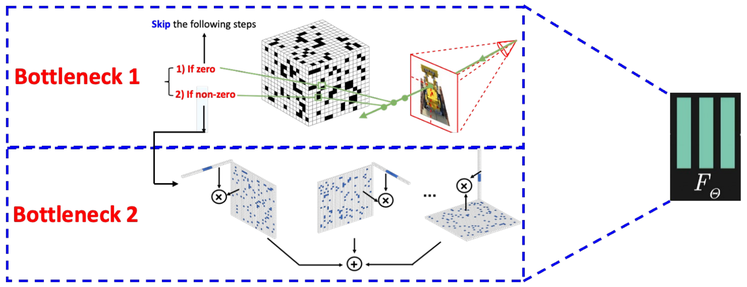
Contribution 1: Analyze the Efficiency Bottleneck



Source: [Mildenhall et. al., ECCV'20]

Contribution 2: Identify Two Key Bottlenecks

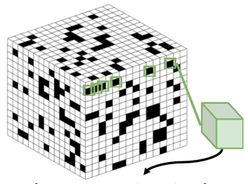
- Dominant step: Query the features of points along the rays
  - **Bottleneck 1 - Locate pre-existing points**
  - **Bottleneck 2 - Compute points' embeddings**



Overview of the Proposed RT-NeRF

To Alleviate Bottleneck 1
(Locate the Pre-Existing Points)

Propose a New Efficient Rendering Pipeline

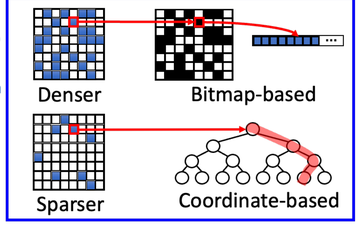


Only query points in the cube

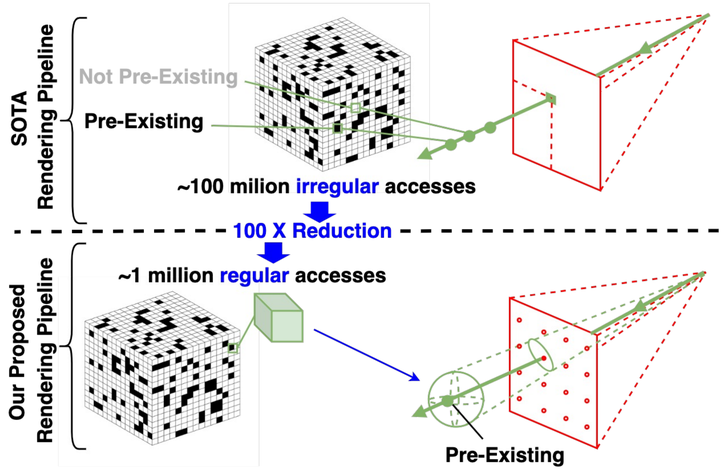
Co-Design

To Alleviate Bottleneck 2
(Compute Points' Embeddings)

Propose a Hybrid Sparse Encoding Scheme & Bi-Direction Trees



Contribution 3: Efficient Rendering Pipeline



Contribution 4: Hybrid Sparse Encoding

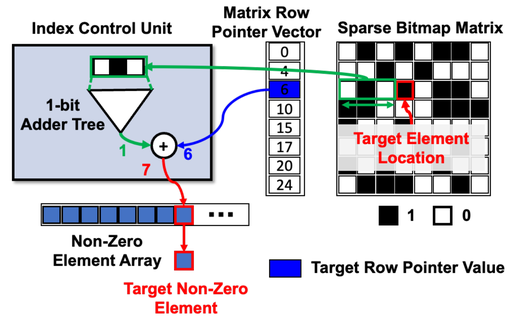
- For **dense** (< 80% sparsity) matrices

Encoding Scheme	Storage Size (↓)	Decoding Throughput (↑)	Resource Utilization (↑)
Bitmap -based	★★★	★	★★★
Our proposed	★★★	★★★	★★★

- For **sparse** (≥ 80% sparsity) matrices

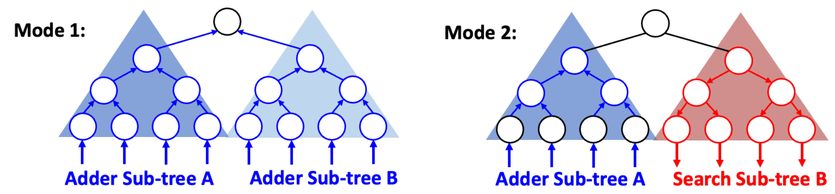
Encoding Scheme	Storage Size (↓)	Decoding Throughput (↑)	Resource Utilization (↑)
Coordinate -based	★★★	★★★	★
Our proposed	★★★	★★★	★★★

Contribution 5: Improved Bitmap-Based Encoding Scheme to Boost Throughput

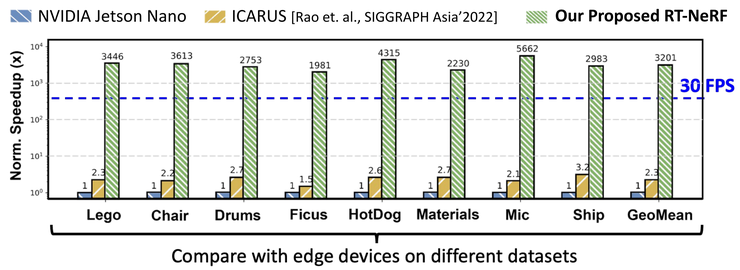


- **Cycle 1:** Check the bitmap matrix element 1 or 0
- **Cycle 2:** Sum up 1-bit bitmap vector and then add the row pointer value
- **Cycle 3:** Fetch the target non-zero element

Contribution 6: Bi-Direction Trees to Boost Utilization



RT-NeRF's Speedup Over Baselines



Our RT-NeRF framework has delivered **the first real-time** neural rendering solution suited for edge applications