GeRaF: Neural Geometry Reconstruction from Radio Frequency Signals

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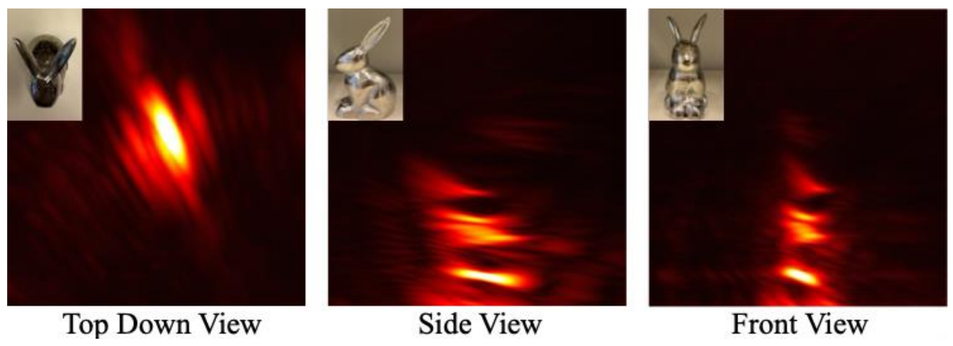
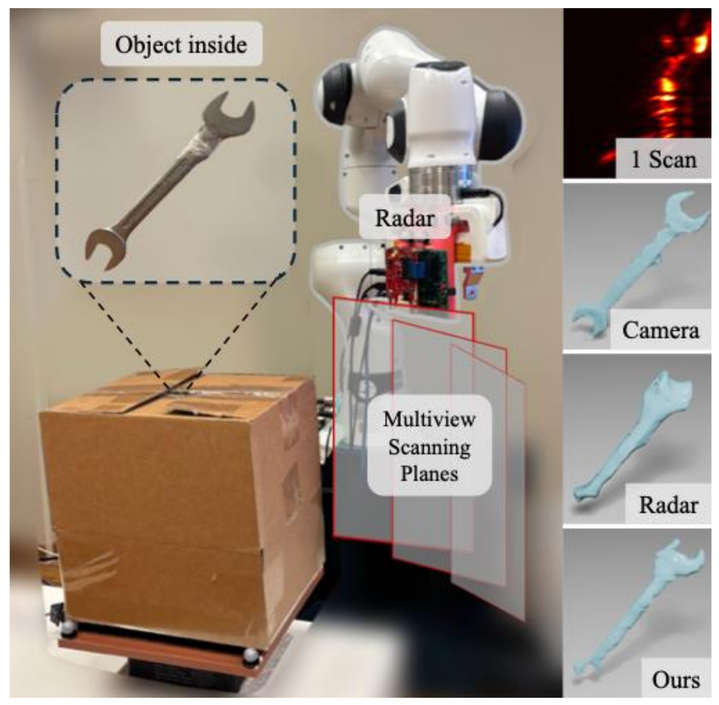
Radio frequency offers advantages to vision in many scenarios

Radio frequency…
- Can see through occlusions
- Works regardless of visibility
- Safe for humans!

However…
- Low spatial resolution
- Huge computational complexity

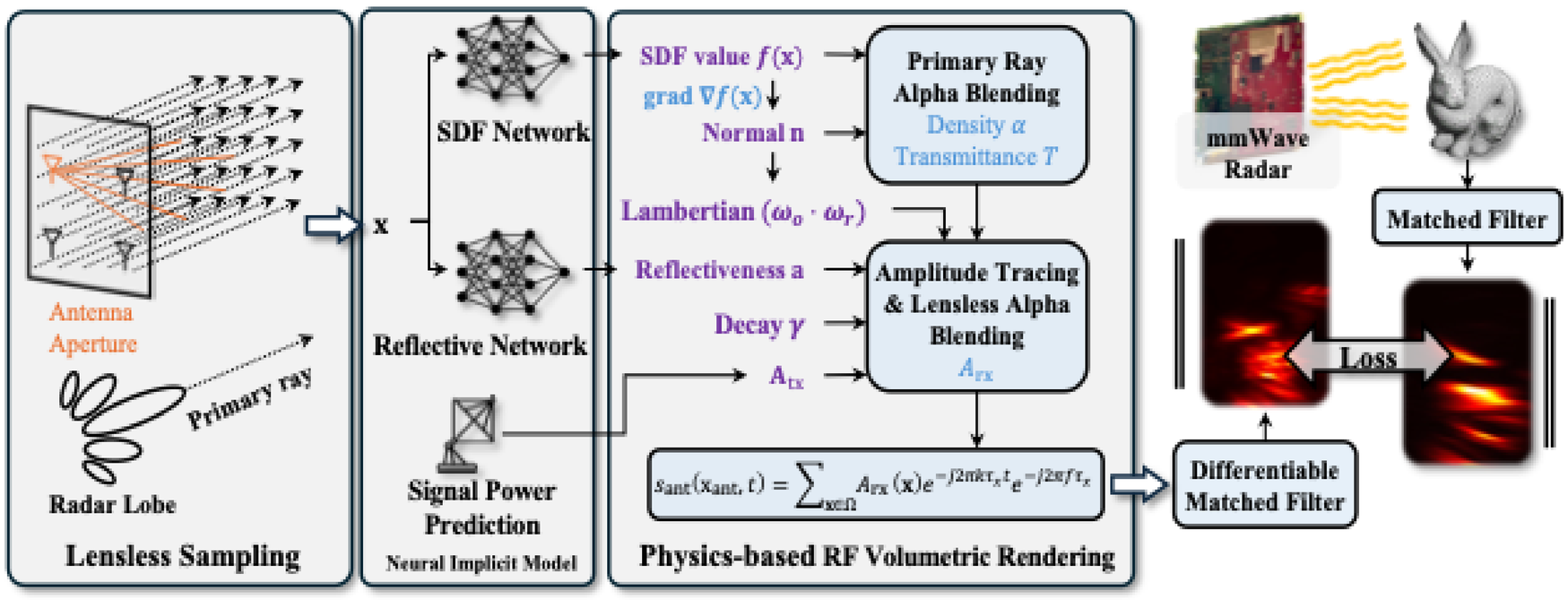
Radio Frequency (RF) heatmaps are not informative enough





Our System: Multiplane radar image scans to enable 3D reconstruction

GeRaF Overview



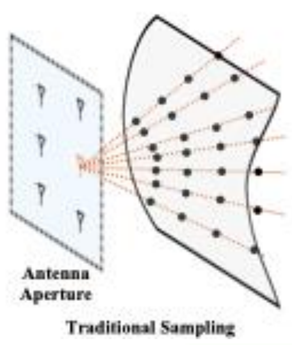
Challenges in RF Implicit Models

1) Use *lensless imaging* models instead of the pinhole model
2) Dominated by *specular reflections* instead of diffused reflections
3) RF rendering has huge *computational complexity*

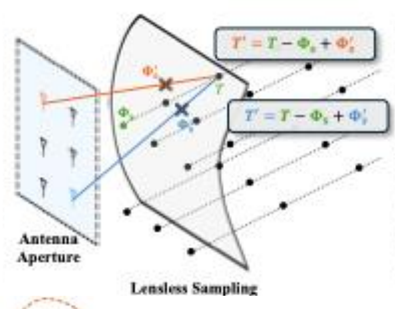
GeRaF is composed of: (1) **Lensless sampling** to replace ray-based sampling methods commonly used in vision. (2) A **neural implicit model** predicts geometry, reflectivity, and power. (3) **RF volumetric rendering** simulates physical signal propagation. (4) **Matched filtering** produces radio frequency power images (heatmaps). (5) An **L2 loss** compares the rendered and ground truth power for end-to-end training.

Computation Optimization

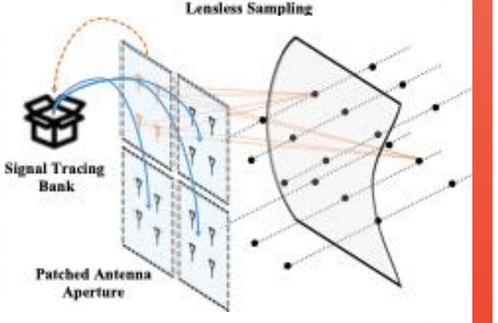
Naïve sampling: traces rays across the entire space for each antenna, resulting → highest computational complexity

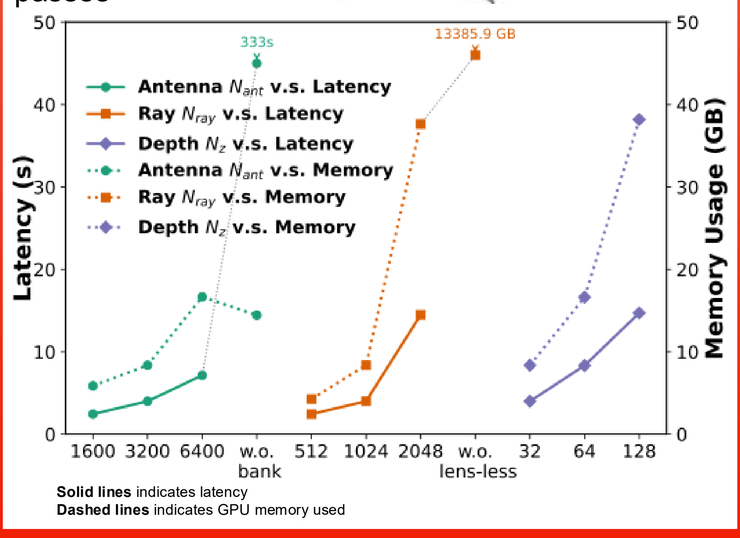


Lensless sampling: samples points along the radar's primary direction and reuses network predictions across antennas



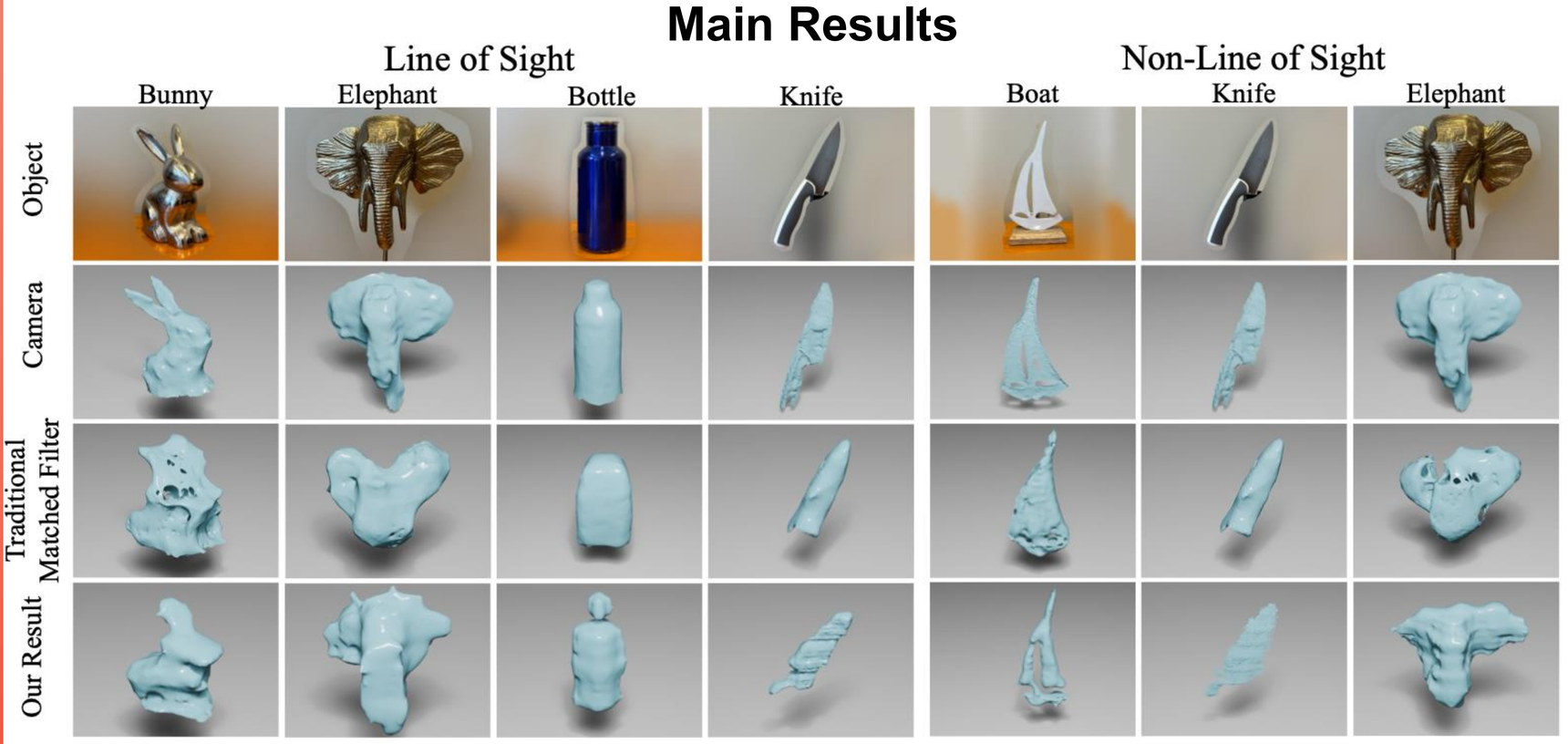
Signal Tracing Bank: subset of antennas is processed in each iteration, reducing computation for forward/backward passes



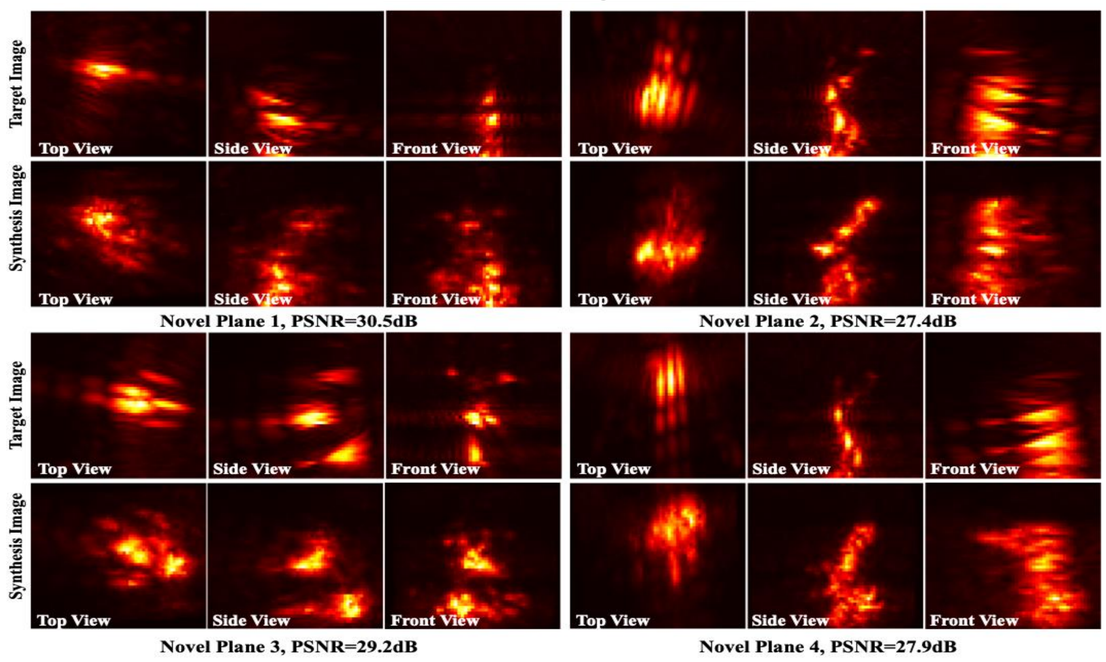


Solid lines indicates latency
Dashed lines indicates GPU memory used

Main Results



New View Synthesis



With and without Radio Physics