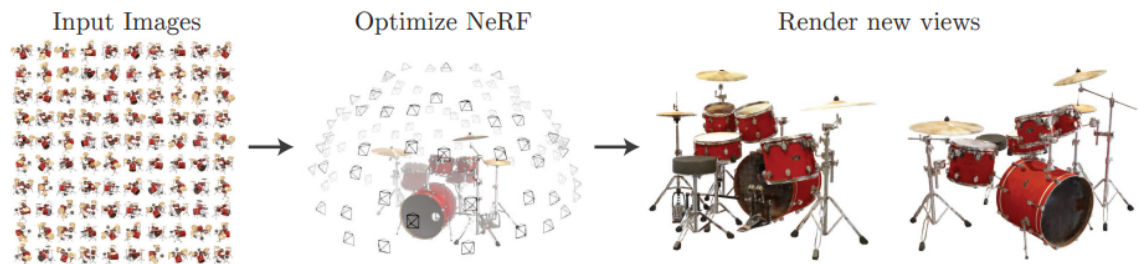# NeRF Design Document

Problem: View synthesis — Given an input image, synthesizing new images of the same object or scene observed from arbitrary viewpoint.

Current solution: NeRF — ECCV 2020, UC Berkeley

- Neural radiance field — SOTA method for view synthesis, can also create 3D models
- "Optimizes underlying continuous scene function using a sparse set of input views"

- Achieved through clever data representation
  - Input: 5D coordinate of $(x, y, z, \theta, \varphi)$
    - Spatial location + Viewing direction (Camera pose)
  - Output: Volume density and view-dependent radiance at that spatial location
- Uses fully-connected deep network (MLP)
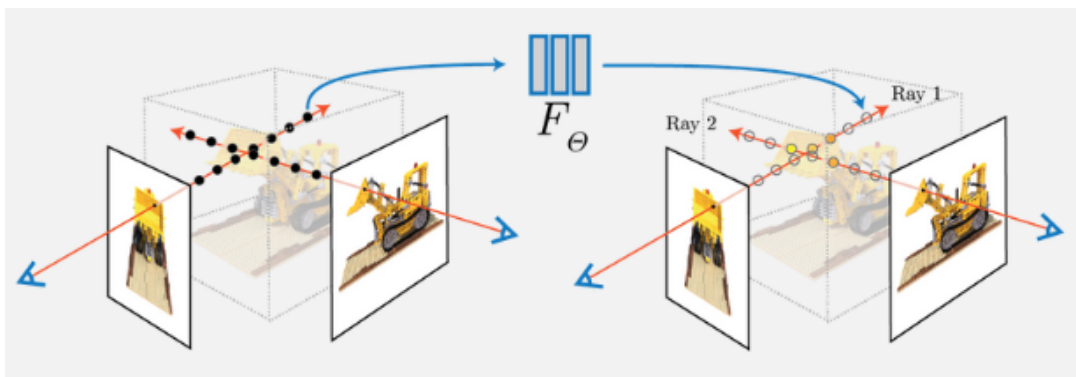
What makes NeRF so good?

- Methodology sounds simple but is *significantly* better than past approaches to view synthesis
    - 50+ papers at CVPR 2022 using NeRF
- View synthesis is useful for many fields, as synthetic data can be utilized for any CV application
- NeRF can create 3D models of objects based on images
    - Can include scene information such as occlusion
    - Can be converted to mesh

Bottlenecks/Avenues for NeRF:

- Training time/efficiency:
    - Original NeRF uses simple MLP
    - Newer papers use better architectures
- Number of views required
    - Original NeRF requires many views (~100) for high-quality synthesis
- Scene quality and complexity
    - Large-scale scenes (important for AV!)
    - Complex scenes
        - Details, light patterns, surface textures
- Altering scenes
    - Appearance modulation
        - Changing the lighting of a scene by altering NeRF model output
    - Mixed reality
        - Adding virtual (AR) objects into real-life scenes, taking advantage of NeRF occlusion information, etc.
- Applications of NeRF in other areas that are relevant to WATonomous:
    - Object detection and tracking: Since NeRF produces full 3D models, can be done with NeRF
    - NICE-SLAM: Doing SLAM with NeRF-inspired architecture, resulting in more robust, scalable and efficient SLAM

WATonomous-related areas that I think are worth exploring:

- Improving on scene rendering for autonomous vehicles
- Related work: Block-NeRF (Waymo, CVPR 2022)
- Rendering dynamic objects
    - Important for AV — moving cars, pedestrians, etc.
    - Otherwise limited to closed-loop simulation tasks
- Temporal inconsistencies
    - Handling events such as construction work
- Real-time rendering
    - For more complex applications, such as live rendering on a moving car, real-time rendering is important
        - Reducing computational expense