NEURAL TREE RECONSTRUCTION FOR THE OPEN FOREST OBSERVAOTRY

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ABSTRACT

The Open Forest Observatory (OFO) is a collaboration across universities and other partners to make low-cost forest mapping accessible to ecologists, land managers, and the general public. The OFO is building both a database of geospatial forest data as well as open-source methods and tools for forest mapping by uncrewed aerial vehicle. Such data are useful for a variety of climate applications including prioritizing reforestation efforts, informing wildfire hazard reduction, and monitoring carbon sequestration. In the current iteration of the OFO's forest map database, 3D tree maps are created using classical structure-from-motion techniques. This approach is prone to artifacts, lacks detail, and has particular difficulty on the forest floor where the input data (overhead imagery) has limited visibility. These reconstruction errors can potentially propagate to the downstream scientific tasks (e.g. a wildfire simulation.) Advances in 3D reconstruction, including methods like Neural Radiance Fields (NeRF) [4], produce higher quality results that are more robust to sparse views and support data-driven priors. We explore ways to incorporate NeRFs into the OFO dataset, outline future work to support even more state-of-the-art 3D vision models, and describe the importance of high-quality 3D reconstructions for forestry applications.

WHY FOREST MAPPING?

Broad-extent forest inventory data is critical for informing management of forests as our climate changes. In particular, forest density and composition can help us understand:

- Which stands are unusually dense, thus at high risk of mortality due to drought
- Carbon storage capacity of stands of trees
- The impact of various forest management techniques such as prescribed burns
- Ecosystem and biodiversity conditions
- Wildfire risk

Each of these can be additionally aided by higher quality 3D data, allowing for virtual qualitative assessment and advanced simulation.

THE OPEN FOREST OBSERVATORY

Traditional forest inventories require time-consuming ground-based surveys. The OFO greatly increases the efficiency of such data collection using drone-based data collection methods along with ML-powered algorithms to enable individuals to both collect and process the data into extensive forest inventory maps suitable for informing management decisions.

Data collected includes:

- Drone videos & photos
- Canopy and surface elevation maps
- Individual tree crown segmentation boxes and species classifications
- 3D meshes (generated via SfM)
- Measured tree diameters-at-breast-height (DBH)

ON-GOING & FUTURE WORK

We show that NeRF can produce higher fidelity reconstructions of forest data for the Open Forest Observatory, and advocate including the data in future releases for applications such as qualitative visual inspection of forests for fuel estimation and density validation (especially for carbon sequestration measurement purposes). The vanilla NeRF proof-of-concept is just a gateway to exploring NeRF-based method for forestry. On-going and future work includes

- Greatly scale up the size of the NeRF taking inspiration from other large-scale NeRF efforts [1].
- Filling in the hard-to-image understory: Trees often appear to be floating floating (Fig. 3). We are using diffusion models and other collected 2D image data to fill in the missing 3D structure similar to the approach taken in [2].
- Incorporating language models: LERF [3] allows for natural-language searching through a NeRF, which if fine-tuned on species level forest data could be very useful for finding and counting species. As we see more multi-model models that can handle question answering, we could imagine merging those with NeRF as well to give more information about the 3D environment such as stand density, basal area, or biomass, all of which are important metrics in estimating carbon sequestration and fuel sources for wildfires.
- Computer vision "Challenge Problems": We plan to curate a subset of the data collected by the OFO in the form of well-defined "challenge problems" to spur the development of new vision methods specifically designed for this high-impact application area.

PRELIMINARY RESULTS

Fig 1 & 2 (Right): A rendered view of a NeRF created from drone-captured forest imagery.

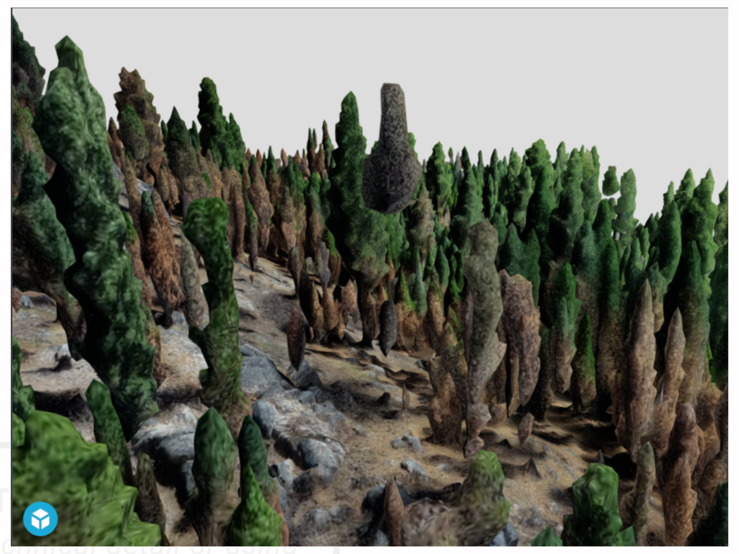

Fig. 3: A SfM reconstruction where trees are floating off the ground.

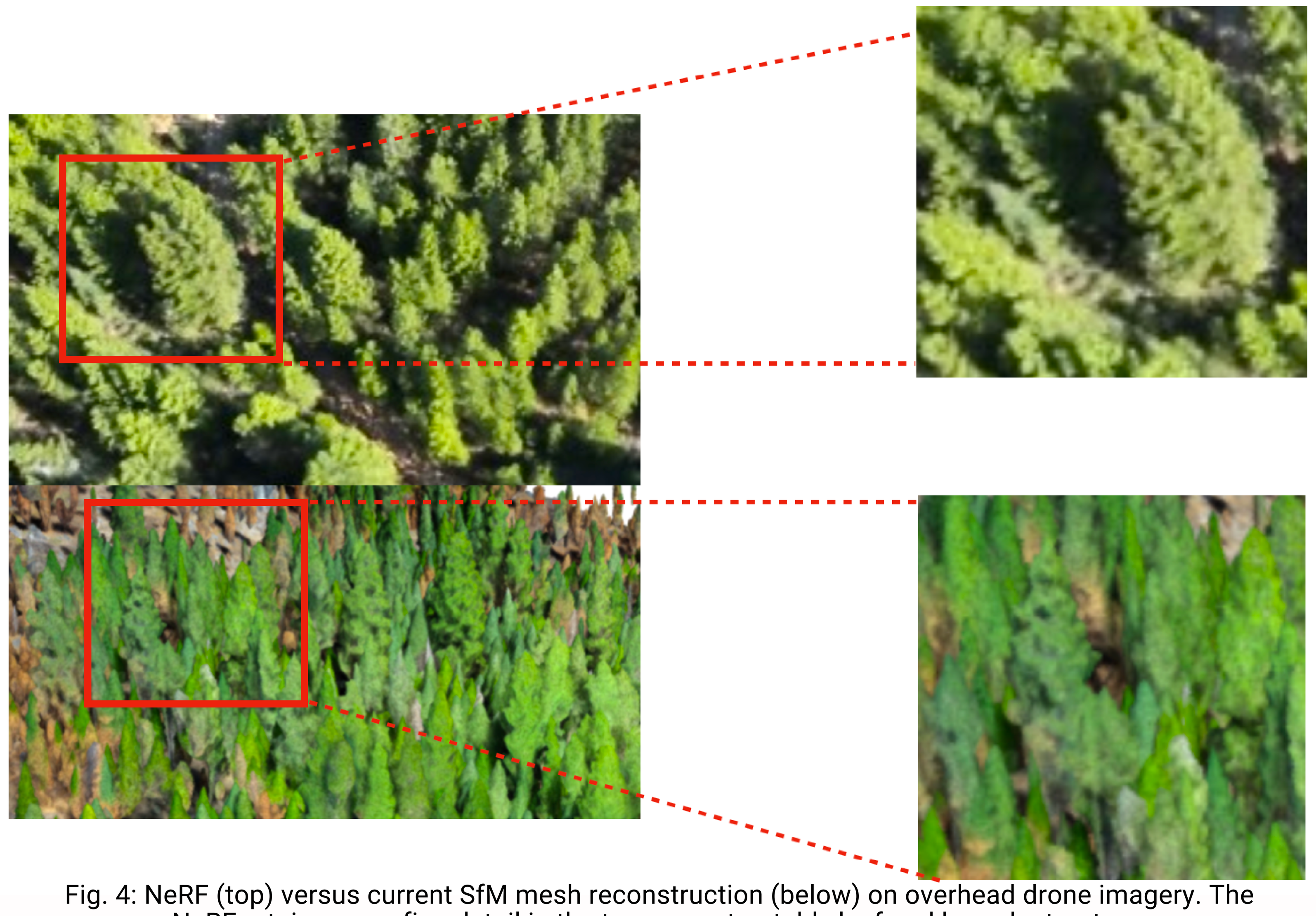

Fig. 4: NeRF (top) versus current SfM mesh reconstruction (below) on overhead drone imagery. The NeRF retains more fine detail in the trees, most notably leaf and branch structure.

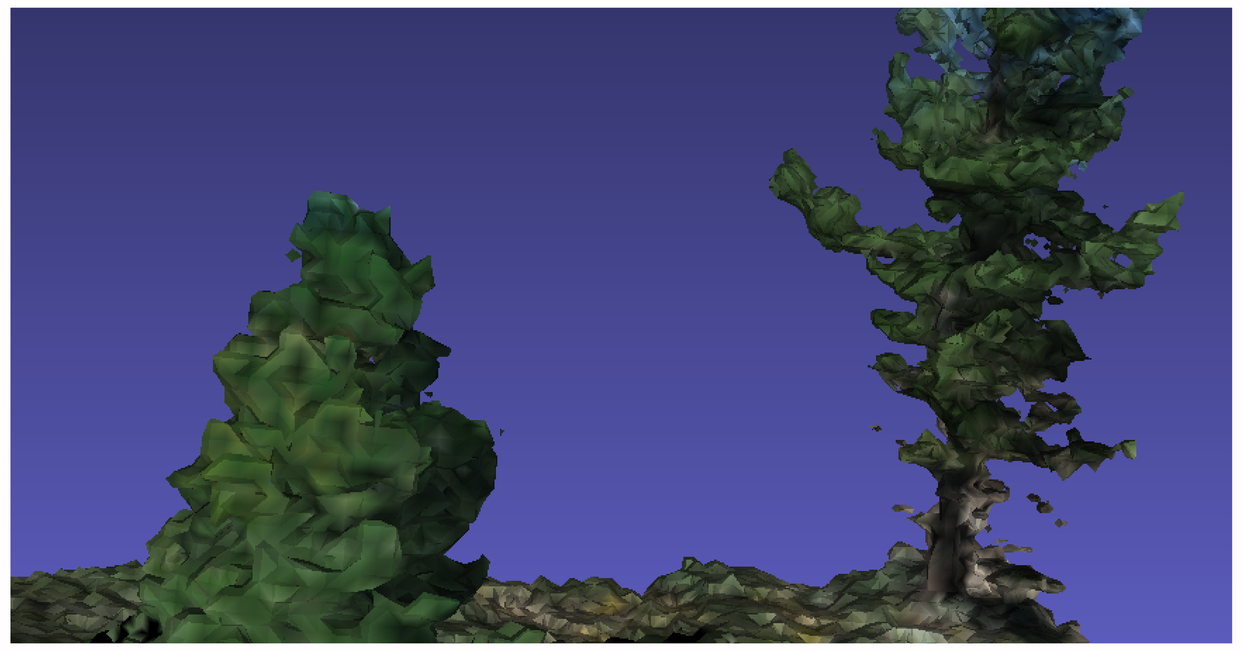

Fig. 5: Mesh extracted from NeRF

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