NeRF or Nothing

Creating Virtual Reality Videos through Neural Radiance Fields

Through learning about neural networks, current computer graphics techniques, PyTorch, and the strains of needing a RTX 4090/3090, you will develop Neural Radiance Fields (NeRFs). From there, you will take a look at the many different approaches to developing NeRFs under various contexts. You will synthesize your own process of creating a dynamic NeRF through your own understanding in ideally a room-scale environment, which can be accessible through a virtual reality interface.

Faculty Advisor
Dr. Xiaohu Guo (https://cs.utdallas.edu/people/faculty/guo-xiaohu/)

Research Plan Summary
For Week 1-2, you will get familiar with the core concepts of research, computer graphics' volume rendering and view synthesis, the basics of neural networks, the feedforward artificial neural network (ANN), the relevant class of Multi-Layer Perceptrons (MLPs), backpropagation, setting up development environments, and then a brief understanding of the concepts that make up Neural Radiance Fields. We will accomplish this through practice using PyTorch's Neural Network implementation through Google Colab, Miniconda and Ubuntu Virtual Machines, and observing the composition of current 3D Voxel rendering, raytracting, and by creating stationary NeRFs using end-user applications (Instant-NGP, LumaAI). Here we will also establish rules, getting every team member on the same level of knowledge, and re-evaluating the path of the research project moving forward in a realistic scope.

From Week 3-5, you will be constantly building up and demonstrating your knowledge base of the many different relevant implementations of Neural Radiance Fields. This includes creating a NeRF neural network from scratch using PyTorch, adapting them as a function over time for dynamic NeRFs (D-NeRFs), and then replicating relevant research papers in VR and large/room-scale applications. You will work in-depth with your faculty advisor and his research group at this stage to gain a greater understanding of the technology. You may also leverage tools such as NVIDIA's Kaolin Wisp and COLMAP.

For Week 6-10, you will demonstrate your understanding of Neural Networks, Computer Graphics, Neural Radiance Fields, the Research Process, Development Environments into creating a dynamic neural radiance field over a room-scale view. You will plan days to meet and gather the dataset needed for public presentation. You will encounter the current problems and limitations of current NeRF implementations such as computing large-scale view-synthesis and positioning, datasets, optimizing for time, and then collaborating on how to solve them. You will also start compiling the knowledge base and citations into a comprehensive public paper, poster, slides, and presentation for the Symposium using LaTEX and Zotero.

Week 1

Objectives

- Get to know and collaborate with your fellow team members
    - Get on the Discord Server. Say hello to someone else in your group chat/channel!
- Learn the concepts of Neural Networks, Computer Rendering, and Neural Radiance Fields
- Best way to learn is to follow these 3 steps:
    - Absorb
        - Learn the concepts
    - Review
        - Review your own notes and understanding
    - Practice
        - Put your understanding into practice
- Setup your development environment
    - Google Colab
    - Ubuntu Bare-metal/Virtual Machine with CUDA
    - WSL 2 with CUDA
- Stay curious, stay hungry, stay foolish

Homework

Learn all the basic concepts

- https://www.youtube.com/playlist?list=PL4dMUs5Qb0ULGU-EMq9BYABtJDCTsAEm0
- NOTE: The Coding Train's tutorial is in JavaScript. Try to translate to Python and PyTorch for an extra challenge. But mostly, I want you to understand the practical application. You can deviate to a more relevant tutorial if possible.

Fill out the Homework Sheet to the best of your ability independently

- https://docs.google.com/document/d/1vqWjkOPp4oKELInz-E-24u7GjrWwlBPEWzsUgE-a2MI/edit?usp=sharing
- You may collaborate with your fellow team members to reach a better understanding. However, all of these words and especially your demonstration must be of your own creation.

Fill out this schedule for meeting with your faculty advisor, Dr. Xiaohu Guo, next week

- https://www.when2meet.com/?18738855-rhneE

Create a Neural Radiance Field

- Use LumaAI on iOS: https://apps.apple.com/us/app/luma-ai/id1615849914
- Render on your own PC using Instant-NGP: https://github.com/NVlabs/instant-ngp
- If none of the above works, create your own using pictures and videos on Luma AI Fields. https://captures.lumalabs.ai/me

Week 2

Objectives

Build Night:

- Show off your homework and neural radiance fields you've taken.
- Discuss and teach with your teammates what you've learned to each other
- Planning the future steps of the research project, the resources needed, and finally re-establishing what is possible, and adjusting our research question for that.
- Upload your current work to the internal github repository (https://github.com/ACM-Research/nerf-or-nothing-internal)

Key Concepts:

Get introduced to the basic steps of proper research

1. Question
    a. Develop an idea of what you're looking for. If the scope you're looking for is too broad, try re-approaching and reevaluate your goal. If it is a general interest, you may look on Google for general information.
2. Search
    a. When you have a modest question to answer needing expert information, try searching with the key-terms of interest in Google Scholar, the UTD databases (https://libguides.utdallas.edu/acs), or arXiv Cornell University's database (https://arxiv.org/list/cs/recent).
3. Skim
    a. Open up as many resources that may seem relevant to answering your question. Then start skimming through them by reading only the summary paragraph and then judging its relevance from there. If it is not relevant to your question after all, you may close it. This is where you will narrow down your search.
4. Read
    a. Once you have narrowed down your relevant resources, you must start reading the resource. You may find from here that it may be irrelevant now, so you may narrow down even further. However, you must not skim but absorb the first read through,
5. Correlate
    a. After reading, you must go through the resource again, and correlate your understanding and the resource's new understanding. Do they match what you know? Do they add to what you know? Do they contradict your understanding? At this point, you may add the resource to your citations through programs like Zotero (https://www.zotero.org/). Utilize the information and infuse it into your understanding to answer your research question.
6. Test your new understanding to explore your research question

Homework

Start practicing the learned concepts (Playlist Link here)

- This is the same playlist, and you are expected to be at least done with the conceptual videos ending at NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis (ML Research Paper Explained).
- You may begin at The Coding Train, or if you are running low on time, I'd suggest watching the following:
    1. What are MLPs (Multilayer Perceptrons)?
    2. Learn PyTorch for deep learning in a day. Literally.
        - This reviews the concepts you've already learned and their practical applications. You may skip through the video to relevant parts due to time constraints. However, this is VERY IMPORTANT TO LEARN if you haven't done any ML/AI/Deep Learning before.
        - **You may try other faster alternatives if they are better for you, but the basic idea is that you're learning PyTorch.**

The following NeRF related videos for people who have understood the first two. We will focus on these videos in the next week:

3. NeRF: Neural Radiance Fields
4. Jon Barron - Understanding and Extending Neural Radiance Fields
5. Neural Radiance Fields | NeRF in 100 lines of PyTorch code

Read the following research papers:

1. NeRF: Neural Radiance Fields
2. Baking Neural Radiance Fields for Real-Time View Synthesis
3. Instant Neural Graphics Primitives with a Multiresolution Hash Encoding
4. D-NeRF: Neural Radiance Fields for Dynamic Scenes
5. NeuS2: Fast Learning of Neural Implicit Surfaces for Multi-view Reconstruction
6. Learning to Generate Radiance Fields of Indoor Scenes - Apple Machine Learning Research
7. NeRFusion: Fusing Radiance Fields for Large-Scale Scene Reconstruction
8. HyperReel

After reading the research papers, listen to this music video: Jamiroquai - Virtual Insanity

Homework Sheet 2

This is not a requirement, but something to help you learn.

- https://docs.google.com/document/d/1Tvj6itPgvpnPxwYu3sMTuXIDKee-iqCfp_5E7d6cPMs/edit?usp=sharing

If you cannot finish the homework this week or get through learning all of PyTorch this week, you can continue learning/filling it out next week as well. I know everyone has exams and stuff, so I want you to prioritize your own health and grades first! Just let me know beforehand.

Week 3

Objectives

Build Night:

- Discussion about what we learned in the research papers, and how that has changed our understanding of Neural Radiance Fields, and what we can realistically do now.
- Come up with the final, detailed research plan filled with deadlines and milestones for the next 5-7 weeks of our research project.
- Learning how to properly carry out the final plan and then getting ready for the next faculty meeting with Dr. Xiaohu Guo next week.
- Coming up with a list of needed supplies and devices to allocate our budget to

Key Concepts:

We will now begin the transition from a conceptual focus on Neural Radiance Fields into a more practical and applicable approach. Basically, it's time to apply our knowledge from the past two weeks!

Based on the final research plan from our team, you will now focus on simultaneously learning new relevant concepts and techniques used in other neural radiance field applications, and then applying them to your own new application. If you're still behind learning PyTorch, use neural radiance fields as your tool to learn PyTorch. If you're a pro at PyTorch already, start exploring other tools that might help you in building neural radiance fields. **Learn, Apply, Build, Repeat.**

Use the Research framework taught in Week 2 (Question, Search, Skim, Read, Correlate, Test) to bring efficiency in learning that new information. Always keep up to date and check the CS research paper database for new techniques (https://arxiv.org/list/cs/recent), and most importantly, **if you use it, you must cite it, else it's plagiarism.**

The good thing about research is that you can take and build off another researcher's work, however you must cite them properly. In this case, use Zotero to compile your research citations properly without much trouble. Contact me if you can't figure out how to use it, because this is a very important tool.

And as always, if you are having major time constraints as this research project ramps up its intensity, or any concern that may impact your contribution, please let me know. **Your physical and mental health is important to me more than anything**. You may be able to tell yourself "I'm gonna go super crazy on this," but reality is always different from idealism. Thank you.

Homework

If you have not finished Week 2's homework, please continue that into this week.
Please begin applying the concepts you have now learned into actual practicality.

At this point, it is assumed you have watched all the conceptual videos from the playlist, and in some fashion, understood the concepts you are now going to apply. It is okay if you forget them, as you can always refer back to them.

Required Section

Begin starting your application process by following along with this tutorial:

1. NeRF (Neural Radiance Fields) tutorial using google colab part1【NeRF教學中文字幕】
2. NeRF (Neural Radiance Fields) tutorial using google colab part2【NeRF教學中文字幕】

OR you may follow:

1. Neural Radiance Fields | NeRF in 100 lines of PyTorch code
2. Neural Radiance Fields at High FPS | FastNeRF in 100 lines of PyTorch code

No matter what process you use, or where you build your PyTorch neural radiance field application, you need to **turn in your neural radiance field PyTorch application into the #Homework thread before next build night.**

- For people with a GTX or RTX GPU, you may do this on your own computer.
- For people without one, you may accomplish this using Google Colab for now.

So this week, you're going to prove to me that spending over ~$2,000 is worth it for you guys.
As all research goes, without results, there is no funding.
"*And that's how villains are made.*"

Also we will be meeting with Dr. Xiaohu Guo next week so fill out this When2Meet form:
https://www.when2meet.com/?18988174-TP1hQ

Not-Required Recommended Section

If you've finished the required section already, please look into the following resources.

- Nerfstudio
    - An API to efficiently create NeRFs with different rendering methods available. Has support for dynamic NeRFs.
- Slow Motion "Bullet Time" with NeRFs
    - Learn how one company created a dynamic neural radiance field with 15 iPhones, COLMAP, and a lot of genius
- COLMAP - Structure-from-Motion and Multi-View Stereo
    - Pipeline which can calculate camera angle and synthesize together a neural radiance field
- Code release for HyperReel: High-Fidelity 6-DoF Video with Ray-Conditioned Sampling

Week 4

Objectives

Objectives:

- Start development of the video NeRF system
    - Could be a whole different custom system using Instant-NGP or NeuS2
- Choose a place and time to record data for the NeRF video
    - When2Meet Link: (TBD)
- During development, you will have many questions for the Faculty Advisor, so make sure to write them down for our next meeting.
    - Schedule next meeting with Faculty Advisor
        - When2Meet Link: (TBD)

Homework

[RENDERING…]

Week 5

Objectives

We have met or are going to meet the Faculty Advisor. We should “tentatively” have enough data (video and pictures) to create a NeRF video by now or soon. Continue development and measurement of our planned system.
Objectives:

- Discuss any new requirements, plans, or cool things
- Continue development of our NeRF video system
- Start documentation of NeRF video development

Homework

- Work on NeRF video system
- Collaborate with team members on Discord
- Work with Faculty Advisor if stuck if possible

Week 6

Objectives

- Talk about what we did over Spring Break (Sleep)
- Get a recap episode of where we are in the Research Project currently
- Continue development of our NeRF video system
- Schedule new meetup to record more data/footage for the video if need be
    - When2Meet Link: (TBA)
- Schedule next meeting with Faculty Advisor:
    - When2Meet Link: (TBA)
- Introduction to ACM Poster and LaTEX

Homework

- Work on NeRF video and collaborate on Discord as usual
- Go ahead and schedule those meetings with Faculty Advisor and maybe more record day

Week 7

Objectives

- Measure current effectiveness of our method of making NeRF videos into proper documentation
- Discuss current progress on NeRF video
- We should have met or are going to meet with the Faculty Advisor again. Discuss current progress and evaluate if we need to make any changes.
- Schedule next meeting with Faculty Advisor:
    - When2Meet Link: (TBA)

Homework

- Work on NeRF video
- Get LaTEX environment installed or use OverLeaf
    - https://www.youtube.com/watch?v=4lyHIQl4VM8
- Meet with the Faculty Advisor

Week 8

Objectives

- Discuss current progress on NeRF video
- Assign ACM Poster responsibilities

Homework

- Start initial introduction to Research Project on ACM Poster
- Work on NeRF video

Week 9

Objectives

- Discuss current progress on NeRF video
- Work on the ACM poster
- Begin work on ACM presentation (Slides and Script) on poster
- Schedule last meeting with Faculty Advisor
    - When2Meet Link: (TBA)

Homework

- Work on NeRF video
- Work on ACM poster
- Work on ACM presentation
- Meet with the Faculty Advisor

Week 10

Objectives

- We may have or have not made a NeRF video at this point
- Finalize documentation and research over NeRF video on ACM poster
- Work on ACM presentation

Homework

- Work on ACM poster
- Work on ACM presentation

Symposium

Objectives

- Finalize ACM Poster and presentation
- Rehearse. Rehearse. Rehearse. That Presentation.

Homework

- Rehearse the presentation
- Give promotional documents to ACM directors for Symposium Night
    - ACM Poster, Description, etc