

Mechanistic Interpretability and Simple Games

Since their inception [Vaswani et al., 2017], transformer models have come to dominate first the field of natural language processing, and then the field of computer vision [Dosovitskiy et al., 2021]. Later on, they were finetuned to be helpful virtual assistants [Ouyang et al., 2022], and by now they can perform assignments as diverse as emotional support, ideas brainstorming, mathematical problem solving, and pair programming.

As virtual assistants are being deployed in areas of increasing importance, such as healthcare, education, and law, it is crucial to understand how they work. Mechanistic Interpretability (MI) Elhage et al. [2021] takes a bottom-up approach to understanding the inner workings of neural networks, focusing on the individual components and their interactions.

In this project, we aim to understand transformer models trained and being trained on simple games. This way, we can study the internals of these models in a controlled environment. The benefits include:

1. Training models on tasks that are simple enough to be analyzed by hand, we can compare the model's behavior to our own understanding of the task.
2. The games can be easily modified to test specific hypotheses about the model's behavior.
3. I don't assume any prior knowledge of transformers. This project can be a fun way to learn about the leading machine learning architecture of our time!
4. We can avoid the resource need of using large models. You will be able to contribute to the project even if you don't have access to a powerful GPU.

We will build upon work undertaken during the BSM RES Summer 2025 project of the same name. I will tell you about what we did in person, as the paper that describes our results is in preparation.

Prerequisites

Strong command of the `Python` numerical library `numpy`.

Qualifying problems

See the contents of the attached `zip` file: `qualifying_problems.py` contains functions to be written, and after the `if __name__ == "__main__":` line, there are some tests to be passed. The tests require the `npz` files to be uncompressed into the same directory.

I very much welcome partial solutions! Ordered by test cases, the problems are intended to range in difficulty from easy to hard for someone who has never seen a transformer before. Please try to avoid explicit `Python` loops, as they are slow and not necessary for the problems at hand. Instead, use `numpy` functions that operate on the entire arrays at once.

You can hand in multiple versions. I will evaluate the latest submission. A valid submission must arrive to my email address by the deadline written in the general RES course description on the BSM webpage. You can expect me to answer a question before this time if it arrived to my email address at least 24 hours before this deadline.

In your email, please also write me the following:

1. Your Mathematics and Computer Science background.
2. Your Mathematics and Computer Science interests.
3. What do you find especially interesting in this project?

Have fun with the problems and hope to see you in the group!

Contact

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