ECE/CS/ME 539 Activity 1
Getting Started

September 3, 2025

0. PyTorch Basics

PyTorch is an open-source machine learning library developed by Facebook's AI Research lab. It is widely used for applications such as natural language processing and computer vision. At its core, neural networks heavily rely on linear algebra operations, which PyTorch implements efficiently.

(a) Create a new Jupyter notebook, and ensure PyTorch is installed. You can install PyTorch using the command `!pip install torch` within your notebook.

(b) *Dive into Deep Learning* Section 2.1: Data manipulation and Section 2.3: Linear Algebra provide references on using PyTorch to create and handle matrices, as well as perform basic matrix operations.

1. Matrix-matrix multiplication for movie recommendation

In this exercise, you will explore how matrix-matrix multiplication can be used in a movie recommendation system. Each user has certain preferences based on movie attributes, and each movie has its own set of attributes. By computing the inner product (i.e., alignment) between a user's preferences and a movie's attributes, we can predict how much the user will like a particular movie.

Imagine you have three users, each with their own set of preferences for various movie attributes such as "romantic", "adventuruous", and "mysterious". Additionally, there are four movies, each described by these same attributes. The users' preferences (i.e., query vectors) and the movies' attributes (i.e., key vectors) are given as follows:

$$\text{User 1's preference.:} \quad \mathbf{q_1} = \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix}, \quad \text{U2:} \quad \mathbf{q_2} = \begin{bmatrix} 1 \\ 2 \\ 0 \end{bmatrix}, \quad \text{U3:} \quad \mathbf{q_3} = \begin{bmatrix} 0 \\ 1 \\ 3 \end{bmatrix}$$

$$\text{Movie 1's attributes:} \quad \mathbf{k_1} = \begin{bmatrix} 1 \\ 0 \\ 2 \end{bmatrix}, \quad \text{M2:} \quad \mathbf{k_2} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}, \quad \text{M3:} \quad \mathbf{k_3} = \begin{bmatrix} 2 \\ 1 \\ 0 \end{bmatrix}, \quad \text{M4:} \quad \mathbf{k_4} = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix}$$

(a) **Stacking the Vectors:** Construct the matrix $\mathbf{Q}$ by converting the three user preference vectors $\mathbf{q_1}$, $\mathbf{q_2}$, and $\mathbf{q_3}$ into row vectors and then stacking them vertically. Do the same movie attributes to construct a matrix $\mathbf{K}$.

(b) **Matrix-Matrix Multiplication:** Compute the score matrix $\mathbf{S}$ by multiplying the query matrix $\mathbf{Q}$ with the transpose of the key matrix $\mathbf{K}$. That is, compute:

$$\mathbf{S} = \mathbf{Q} \cdot \mathbf{K}^\top$$

(c) **Interpretation:** The matrix $\mathbf{S}$ contains the predicted preference scores. Describe the meaning of each entry S_{ij} in this matrix. Which movie would user 3 prefer the most?

(d) **PyTorch:** Compute the score matrix $\mathbf{S}$ in PyTorch.