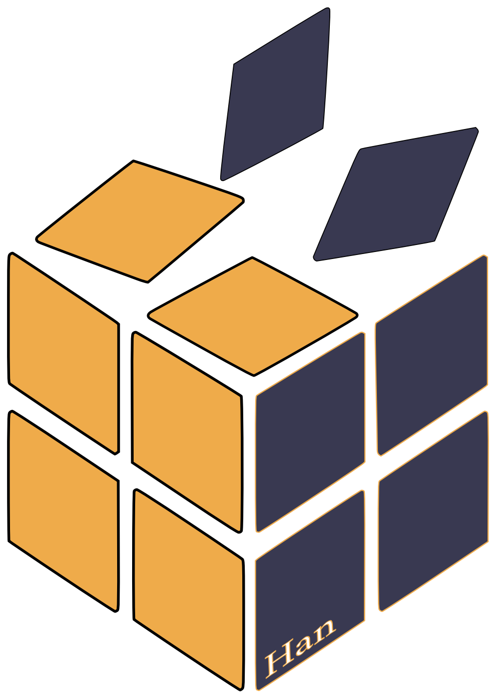
Deep Learning System Design



Engineering and Service Architectures

Han Cheol Moon
School of Computer Science and Engineering
Nanyang Technological University

Singapore
hancheol001@edu.ntu.edu.sg
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Chapter 1

Introduction

1.1 Complexity of Matrix Multiplication

Matrix multiplication is a fundamental operation in many computational tasks, including neural networks. The complexity of multiplying two matrices depends on their dimensions. Let's dive into the specifics.

- Let A be a matrix of size $m \times k$.
- Let B be a matrix of size $k \times n$.
- The result C will be a matrix of size $m \times n$.

Standard Matrix Multiplication: For each element c_{ij} in the resulting matrix C:

$$c_{ij} = \sum_{l=1}^{k} a_{il} \cdot b_{lj}$$

This involves:

- Multiplications: k multiplications for each element c_{ij}.
- Additions: $k - 1$ additions for each element c_{ij}.

Complexity

- The total number of elements in C is $m \times n$.
- Therefore, the total number of multiplications is $m \times n \times k$.
- The total number of additions is $m \times n \times (k - 1)$.

Thus, the total complexity is $O(m \times n \times k)$.

Even though there are several advanced methods, the standard $O(m \times n \times k)$ complexity is often used in practice, due to the simplicity and efficiency of implementation on modern hardware. Optimized libraries (like BLAS, cuBLAS for GPUs) leverage hardware-specific optimizations to improve practical performance.

1.1.1 Complexity in Neural Networks

In the context of neural networks:

- Input Matrices: Weight matrices and input feature vectors.
- Typical Sizes:
  - Weight matrix: $d \times d_{in}$ for RNNs, $d \times d$ for Transformers.
  - Input/Output vectors: Usually batch-processed, leading to sizes like $batch\_size \times sequence\_length \times feature\_size$.

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