BTP-1

Reinforcement Learning

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Motivation

- Improving the efficiency of algorithms for fundamental computations can have a widespread impact, as it can affect the overall speed of a large amount of computations.
- Algorithm Optimisation can be a hard problem mostly in case of critical problems like discovery of faster matrix multiplication algorithm. Where we need to decrease the number of scalar multiplications as they are more complex over other operations.

Motivation

- Matrix Multiplication are used in every basic things like processing and displaying image.
- However, automating the algorithm discovery procedure is intricate, as the space of possible algorithms is enormous.
- Monte Carlo Tree Search (**MCTS**): is a key component of AlphaZero; the Efficiency, Adaptability, Robustness makes it perfect to use as search algorithms in the Critical problems.

Goals and Deliverables

Short Term Goals

- Getting a Good Understanding of matrix multiplication using AlphaTensor and low rank decomposition of tensor.
- Understand Monte Carlo Algorithm to the point where we can replicate it.

Long Term Goals

- Exploring Various critical problems which use Monte Carlo Tree Search Algorithms for example Matrix Multiplications.
- Build atleast a minimalistic version of matrix multiplication (AlphaTensor) Based on the Paper where the code is not open-sourced.

Tentative Timeline

End of February:

- Understand Low rank decomposition of Tensor, Application of Reinforcement Learning over it.
- Understand Monte Carlo Tree Search.

End of March:

- Understand AlphaZero Algorithm in matrix multiplication and its application on tensors. Good Understanding of AlphaTensor other Details Mentioned in paper.
- Explore Other critical problems that uses Monte Carlo Tree Search Algorithms.

End of April:

- Build a Basic version of Matrix multiplication using AlphaTensor mentioned in the paper (or) other MCTS algorithms used in Critical problems.

AlphaTensor

- AlphaTensor is built on AlphaZero, where a neural network is trained to guide a planning procedure searching for efficient matrix multiplication algorithms by applying the Deep RL on this 3D tensors.
- AlphaTensor is a general-purpose reinforcement learning algorithm that can be applied on a wide range of problems including matrix multiplication where it is formulated a single player game. Where the problem is transformed into a tensor, for example matrix multiplication tensor.
- Even finding low-rank decompositions of 3D tensors (and beyond) is NP-hard.
- Monte Carlo Tree Search: It is a method used to search every possible move that may exist after each decomposition and find the best path for final optimal solution.

AlphaTensor

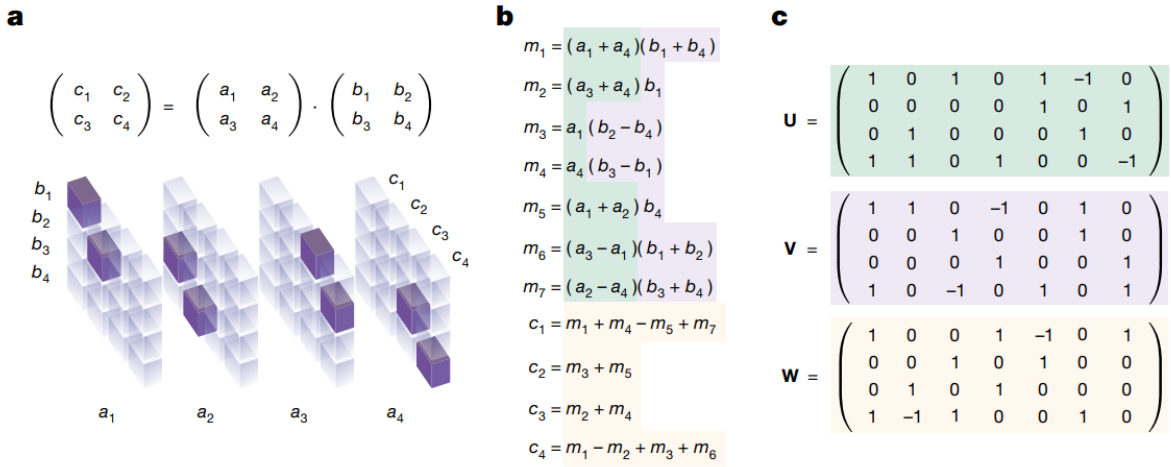

Fig. 1 | Matrix multiplication tensor and algorithms. a, Tensor $\mathcal{T}_2$ representing the multiplication of two 2×2 matrices. Tensor entries equal to 1 are depicted in purple, and 0 entries are semi-transparent. The tensor specifies which entries from the input matrices to read, and where to write the result. For example, as $c_1 = a_1 b_1 + a_2 b_3$, tensor entries located at (a_1, b_1, c_1) and (a_2, b_3, c_1) are set to 1. **b**, Strassen's algorithm[2] for multiplying 2×2 matrices using 7 multiplications. **c**, Strassen's algorithm in tensor factor representation. The stacked factors **U**, **V** and **W** (green, purple and yellow, respectively) provide a rank-7 decomposition of $\mathcal{T}_2$ (equation (1)). The correspondence between arithmetic operations (**b**) and factors (**c**) is shown by using the aforementioned colours.

Resources

- Discovering faster matrix multiplication algorithms with reinforcement learning (Alhussein Fawzi) [Paper]
- Discovering novel algorithms with AlphaTensor — deepmind [Blog]
- Discovering faster matrix multiplication algorithms with reinforcement learning (Alhussein Fawzi) [Video]