

Strassen Algorithm: Revolutionizing Matrix Multiplication

Federico Rinzo*

Department of Applied Mathematics, University of Urbino, Urbino, Italy

DESCRIPTION

Matrix multiplication is a fundamental operation in various fields of computer science and mathematics, including machine learning, image processing, and scientific computing. Traditional matrix multiplication algorithms, such as the naive approach or the widely used strassen algorithm, play a vital role in optimizing this computationally intensive task. Among these algorithms, the strassen algorithm stands out for its groundbreaking divide-and-conquer technique, which revolutionized the field.

The strassen algorithm, developed by Volker Strassen in 1969, employs a divide-and-conquer strategy to reduce the number of basic multiplications required for matrix multiplication. The key idea behind this algorithm is to divide the given matrices into smaller sub matrices and recursively compute the intermediate products. By exploiting this approach, the strassen algorithm achieves a lower time complexity compared to the traditional matrix multiplication algorithm, known as the naive algorithm. To understand how the strassen algorithm works, let's consider multiplying two matrices, a and b .

The algorithm follows the following steps

Divide: Divide the given matrices a and b into four equal-sized sub matrices, each of size $n/2 \times n/2$. this step requires $O(n^2)$ time complexity.

Conquer: Recursively compute the following seven products using the sub matrices obtained in the previous step: $p_1 = (a_{11} + a_{22}) \times (b_{11} + b_{22})$, $p_2 = (a_{21} + a_{22}) \times b_{11}$, $p_3 = a_{11} \times (b_{12} - b_{22})$, $p_4 = a_{22} \times (b_{21} - b_{11})$, $p_5 = (a_{11} + a_{12}) \times b_{22}$, $p_6 = (a_{21} - a_{11}) \times (b_{11} + b_{12})$, $p_7 = (a_{12} - a_{22}) \times (b_{21} + b_{22})$. This step requires seven recursive calls to the strassen algorithm.

Combine: Combine the computed products from the conquer step

to obtain the final result matrix c . this step involves four additions and five subtractions, each requiring $O(n^2)$ time complexity.

The strassen algorithm exhibits a time complexity of $O(n^{\log_2(7)})$, which is approximately $O(n^{2.81})$. This represents a significant improvement over the naive algorithm's time complexity of $O(n^3)$. Consequently, for large matrices, the strassen algorithm can offer substantial computational savings.

However, it is important to note that despite its faster time complexity, the strassen algorithm may not always outperform the naive algorithm in practice. This is due to the strassen algorithm's additional overhead introduced by the recursive calls and the need for sub matrix partitioning. As a result, the strassen algorithm is typically advantageous when used with very large matrices, where the computational savings outweigh the overhead.

Moreover, the strassen algorithm has opened up avenues for further advancements in matrix multiplication algorithms. researchers have built upon the principles of the strassen algorithm and developed improved algorithms that achieve even lower time complexities, such as the coppersmith-winograd algorithm and recent breakthrough by Joshua Alman and Virginia Vassilevska Williams. These developments continue to drive progress in matrix multiplication and optimize its efficiency.

The strassen algorithm has made a significant impact on matrix multiplication by introducing a novel divide-and-conquer technique. With its lower time complexity compared to the naive algorithm, the strassen algorithm offers computational savings, particularly for large matrices. While its practicality depends on various factors, it has laid the foundation for further advancements in matrix multiplication algorithms. As the demand for faster matrix operations continues to grow, the strassen algorithm remains a vital part of the computational toolbox for numerous fields and applications.

Correspondence to: Federico Rinzo, Department of Applied Mathematics, University of Urbino, Urbino, Italy, E-mail: federicorzo.quadrio@polimi.it

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