CECS 574 HW1 Report

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1 Report deliverables

- The file is named `report.pdf`.

- Links to exact locations where the original program is referenced in Section 3.

- An explanation of the code, the program's functionality, flow, and SIMD acceleration in Section 4.

- Compilation steps and flags in Section 5.

- Proof of achieved speedup with expectations in Section 6.

2 Introduction

The *Z-score normalization* is a normalization method used in machine learning to improve the training of models. While the *Z-score normalization* improves the run time of machine learning models, it is costly to compute. First, one needs to get the mean, then the standard deviation, and then update every input from the matrix.

In this homework, I have made a program that uses SIMD instructions to accelerate the calculation of *Z-score normalization* by 5.1x without any drawbacks; the only necessary thing is to execute an x86 processor that supports AVX2 instructions.

3 Links to Exact Locations

I was not able to find exact code for Z normalization, but refer to the following articles to understand the implementation.

Explanation and example usage of data normalization:

- https://www.turing.com/kb/data-normalization-with-python-scikit-learn-tips-tricks-for-data-science

The code implementation of the Z-score normalization (Scikit-learn repository):

- https://github.com/scikit-learn/scikit-learn/blob/main/sklearn/preprocessing/_data.py

4 Code Explanation

Here, I will explain the original code implementation in Section 4.1 and the SIMD code implementation in Section 4.2.

4.1 Original Algorithm

The original algorithm (not optimized) uses the basic functions of mean and standard deviation to update each value individually. Since this needs to be run for a single data at a time, it takes n times to finish executing the algorithm, where n is the number of data. To *Z-score normalize* data, I make every row a different feature. This means that every row would have to be normalized by itself (Need to calculate the mean and standard deviation for every row). I have made functions to find the mean and standard deviation. And used in the main normalization function. Each function finds its functions as follows:

- The following formula is used to calculate the *Z-score normalization*: $Z = \frac{\vec{X} - \mu}{\sigma}$. where: $\vec{X}$ is the original input, μ is the mean of $\vec{X}$, σ is the standard deviation of $\vec{X}$.

- The mean is calculated by $\mu = \frac{\sum_{i=1}^{n} x_i}{n}$; where: x_i is the ith data point, and n is the total points.

- The standard deviation is calculated by: $\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \mu)^2}{n}}$.

4.2 SIMD

The Single Instruction Multiple Data algorithm handles multiple inputs at a time (Multiple Data). In my case, since I'm using floating point values and 256 SIMD registers, it handles 8 values at a time.

4.2.1 Matrix Normalization

The following formula is used to calculate the *Z-score normalization*: $Z = \frac{\vec{X} - \mu}{\sigma}$. where: $\vec{X}$ is the original input; μ is the mean of $\vec{X}$; σ is the standard deviation of $\vec{X}$; In my case of normalizing data with *Z-score normalization*, I need to calculate the mean (Section 4.2.2) and Standard Deviation (Section 4.2.3), which I also optimized using SIMD.

For *Z-score normalization*, I make every row a different feature. This means that every row would have to be normalized by itself (Need to calculate the mean and standard deviation for every row). The explanation of mean is in Section 4.2.2, and for standard deviation is in Section 4.2.3. Once I have the mean and standard deviation, we must update every value based on the formula. To speed up the process of updating every value, I use SIMD instructions, handling 8 data points at a time (256-bit registers, floats).

First, I broadcast the mean and standard deviation values to 8 different locations using the function `_mm256_set1_ps`, which will allow us to normalize 8 values at a time. Then, I load 8 float values from the matrix into a SIMD register using `_mm256_loadu_ps`. Using those values, I normalize based on our formula, taking the difference between the mean using formula `_mm256_sub_ps` and dividing by the standard deviation using the function `_mm256_div_ps`. Once the values normalize, I stored them in a standard matrix using the function `_mm256_storeu_ps`. In my case, I avoid going over the last elements to avoid reading memory from the wrong location(Remainder of 8). I handle these values at the end using the basic C++ syntax $((matrix[row][col] - mean)/stnddev;)$.

4.2.2 Mean

The mean is calculated by $\mu = \frac{\sum_{i=1}^{n} x_i}{n}$; where: x_i is the ith data point, and n is the total number of data points.

The idea to optimize the mean function is by adding multiple data at one time, in our case, 8 floats. It is possible to handle 8 operations parallel using a float zero vector `_mm256_setzero_ps`. In this point, I have a loop iterating over the data, loading using `_mm256_loadu_ps`, then adding the values from the zero_vector with the new values using the function `_mm256_add_ps`. After summing the data with SIMD operations, I convert them back to regular x86 using the function `_mm256_storeu_ps`.

In my case, I avoid going over the last elements to avoid reading memory from the wrong location(Remainder of 8). I add these values at the end using the regular C++ syntax.

4.2.3   Standard Deviation

The standard deviation is calculated by: $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \mu)^2}{n}}$; where: x_i is the ith data point, μ is the mean, n is the total points.

   Same idea here as Sections 4.2.1, 4.2.2(handle 8 datapoints at a time). First, I have a zero vector of 8 points where I store the sum of 8 floats ($difference^2$), created this zero vector using **_mm256_setzero_ps**, Load 8 float values from the original data using **_mm256_loadu_ps**, subtracting the mean value(8 at one time) using **_mm256_sub_ps**, taking the square of the difference(8 at one time) using **_mm256_mul_ps**, and summing them to the zero vector(8 at one time) using **_mm256_add_ps**.

   As mentioned earlier, I don't go over the last elements to avoid reading memory from a wrong memory location. I go over the remainder of the values and sum them using the standard C++ syntax. In the end, I take the squared square of the differences and the total values.

5   Compilation Steps and Flags

I used the following commands to compile the code and run it.

- **Original version:**

    – $ g++ ./z_score_norm__Original__.cpp -o z_norm_og.exe && ./z_norm_og.exe

- **AVX-optimized version:**

    – $ g++ -mavx2 ./z_score_norm__Optimized__.cpp -o z_opt.exe && ./z_opt.exe

Where the flags mean the following:

- **g++**: Compiler used to compile the C++ code.

- **-mavx2**: This flag enables AVX2 instructions.

- **./z_score_norm__Original__.cpp**: The source file.

- **-o z_norm_og.exe**: The **-o**: name of the output executable file.

- **&& ./z_norm_og.exe**: Execute the program after compiling.

   The mean should be 0, and the standard deviation should be 1 when a matrix has been normalized. I performed this operation to validate that the normalization had been done correctly. This is shown in the output log files 7, 8

6   Proof of Achieved Speedup

Proof of the actual run is shown in Figure 6. Also, I posted the logs (run the programs 15 times) for the original version in section 7 and the SIMD version in section 8.

   The programs were executed 15 times, and the average values are shown below:

Version	Average Time (seconds)
Original	23.10
AVX-Optimized	4.47

$$\text{Speed-up} = \frac{\text{Time for Original Version}}{\text{Time for AVX Version}} = \frac{23.10}{4.47} \approx 5.16$$

   Getting a speedup of 5.1 is good, but it is expected to get a speed close to 8(without taking into consideration the additional latency of AVX instructions and data movement) since we're handling eight data points at one time. SIMD instructions have a longer latency than regular x86 instructions and require additional instructions to move memory from regular x86 registers to AVX registers, so a 5.1x speed-up is expected.

```
$ g++ -mavx2 z_score_norm__Original__.cpp -o z_norm_og.exe

# Run the executable 15 times
for i in {1..15}
do
  echo -e "----------\n\n\n\nRun #$i"
  ./z_norm_og.exe
done
----------


Run #1
Matrix before normalization
1.00 8.00 9.00 0.00 1.00 7.00 5.00 5.00 4.00 8.00
11.00 0.00 3.00 2.00 10.00 1.00 9.00 1.00 1.00 2.00
2.00 0.00 4.00 6.00 11.00 11.00 2.00 3.00 1.00 1.00
7.00 1.00 13.00 5.00 8.00 0.00 11.00 10.00 7.00 8.00
3.00 1.00 6.00 8.00 0.00 13.00 8.00 12.00 2.00 8.00
5.00 11.00 14.00 8.00 7.00 8.00 8.00 11.00 10.00 5.00
17.00 4.00 8.00 6.00 18.00 2.00 11.00 16.00 14.00 10.00
5.00 6.00 8.00 7.00 16.00 11.00 7.00 11.00 17.00 4.00
11.00 20.00 3.00 2.00 2.00 21.00 22.00 10.00 2.00 15.00
9.00 22.00 4.00 19.00 11.00 0.00 3.00 21.00 4.00 13.00
Mean of the first row: 5.00
Standard Deviation of the first row: 3.17
Mean of the last row: 16398.37
Standard Deviation of the last row: 9453.82

Matrix after normalization
-1.26 0.95 1.26 -1.58 -1.26 0.63 0.00 0.00 -0.31 0.95
1.60 -1.59 -0.72 -1.01 1.31 -1.30 1.02 -1.30 -1.30 -1.01
-1.06 -1.60 -0.53 0.00 1.34 1.34 -1.06 -0.80 -1.33 -1.33
0.12 -1.37 1.62 -0.37 0.37 -1.62 1.12 0.87 0.12 0.37
-0.93 -1.39 -0.24 0.23 -1.63 1.39 0.23 1.16 -1.16 0.23
-0.61 0.62 1.23 0.01 -0.20 0.01 0.01 0.62 0.42 -0.61
1.47 -0.91 -0.18 -0.54 1.65 -1.27 0.37 1.28 0.92 0.19
-0.83 -0.66 -0.33 -0.50 0.99 0.16 -0.50 0.16 1.15 -0.99
0.01 1.36 -1.20 -1.35 -1.35 1.51 1.66 -0.15 -1.35 0.61
-0.41 1.40 -1.11 0.98 -0.14 -1.67 -1.25 1.26 -1.11 0.14
Mean of the first row: -0.00
Standard Deviation of the first row: 1.00
Mean of the last row: 0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 29.86 seconds.
----------


Run #2
Matrix before normalization
10.00 6.00 2.00 1.00 0.00 0.00 4.00 2.00 4.00 1.00
6.00 3.00 11.00 5.00 5.00 2.00 1.00 9.00 9.00 9.00
7.00 1.00 1.00 7.00 0.00 7.00 1.00 2.00 5.00 8.00
2.00 4.00 1.00 0.00 4.00 7.00 5.00 3.00 3.00 13.00
5.00 2.00 10.00 7.00 2.00 10.00 1.00 1.00 14.00 12.00
16.00 1.00 12.00 14.00 15.00 7.00 7.00 8.00 8.00 4.00
4.00 6.00 10.00 18.00 7.00 3.00 2.00 9.00 18.00 6.00
5.00 11.00 20.00 4.00 4.00 6.00 2.00 3.00 12.00 7.00
20.00 19.00 18.00 4.00 16.00 1.00 6.00 0.00 19.00 10.00
18.00 7.00 20.00 19.00 14.00 12.00 8.00 24.00 22.00 10.00
Mean of the first row: 5.03
Standard Deviation of the first row: 3.16
Mean of the last row: 16395.50
Standard Deviation of the last row: 9469.18

Matrix after normalization
1.58 0.31 -0.96 -1.28 -1.59 -1.59 -0.33 -0.96 -0.33 -1.28
0.15 -0.72 1.60 -0.14 -0.14 -1.01 -1.30 1.02 1.02 1.02
0.26 -1.35 -1.35 0.26 -1.62 0.26 -1.35 -1.08 -0.28 0.53
-1.10 -0.61 -1.35 -1.60 -0.61 0.14 -0.36 -0.85 -0.85 1.62
-0.46 -1.15 0.70 0.01 -1.15 0.70 -1.38 0.93 1.63 1.16
1.63 -1.44 0.82 1.22 1.43 -0.21 -0.21 -0.00 0.20 -0.82
-0.92 -0.56 0.17 1.63 -0.37 -1.10 -1.28 -0.01 1.63 -0.56
-0.83 0.17 1.65 -0.99 -0.99 -0.66 -1.32 -1.16 0.33 -0.49
1.35 1.20 1.05 -1.06 0.75 -1.51 -0.76 -1.66 1.20 -0.16
0.83 -0.70 1.10 0.96 0.27 -0.00 -0.56 1.66 1.18 -0.28
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 25.70 seconds.
----------


Run #3
Matrix before normalization
7.00 9.00 2.00 6.00 0.00 4.00 5.00 5.00 10.00 3.00
2.00 5.00 9.00 2.00 7.00 5.00 7.00 9.00 8.00 9.00
0.00 2.00 9.00 0.00 10.00 3.00 1.00 5.00 12.00 8.00
```

```
$ g++ -mavx2 z_score_norm__Optimized__.cpp -o z_opt.exe

# Run the executable 15 times
for i in {1..15}
do
  echo -e "----------\n\n\n\nRun #$i"
  ./z_opt.exe
done
----------


Run #1
Matrix before normalization
6.00 6.00 2.00 1.00 0.00 7.00 0.00 10.00 6.00 8.00
10.00 1.00 11.00 8.00 1.00 2.00 10.00 5.00 11.00 2.00
11.00 12.00 5.00 6.00 2.00 4.00 0.00 6.00 5.00 5.00
6.00 0.00 2.00 10.00 3.00 12.00 3.00 4.00 9.00 13.00
11.00 4.00 5.00 10.00 3.00 11.00 1.00 5.00 2.00 13.00
15.00 1.00 0.00 14.00 6.00 11.00 12.00 9.00 12.00 9.00
7.00 13.00 12.00 18.00 3.00 15.00 4.00 16.00 9.00 9.00
4.00 4.00 19.00 10.00 8.00 7.00 0.00 20.00 20.00 2.00
19.00 12.00 18.00 17.00 7.00 10.00 12.00 22.00 14.00 12.00
11.00 24.00 4.00 3.00 24.00 9.00 4.00 16.00 11.00 16.00
Mean of the first row: 5.00
Standard Deviation of the first row: 3.16
Mean of the last row: 16359.28
Standard Deviation of the last row: 9462.05

Matrix after normalization
0.32 0.32 -0.95 -1.27 -1.58 0.63 -1.58 1.58 0.32 0.95
1.31 -1.30 1.60 0.73 -1.30 -1.01 1.31 -0.14 1.60 -1.01
1.35 1.61 -0.26 0.01 -1.06 -0.52 -1.59 0.01 -0.26 -0.26
-0.13 -1.61 -1.12 0.86 -0.87 1.36 -0.87 -0.62 0.62 1.61
0.93 -0.69 -0.46 0.70 -0.92 0.93 -1.38 -0.46 -1.15 1.39
1.40 -1.42 -1.62 1.23 -0.40 0.62 0.82 0.21 0.82 0.21
-0.36 0.73 0.55 1.65 -1.10 1.10 -0.91 1.28 0.00 0.00
-1.00 -1.00 1.48 -0.01 -0.34 -0.50 -1.66 1.65 1.65 -1.33
1.21 0.15 1.05 0.90 -0.61 -0.15 0.15 1.66 0.45 0.15
-0.14 1.66 -1.11 -1.25 1.66 -0.42 -1.11 0.55 -0.14 0.55
Mean of the first row: -0.00
Standard Deviation of the first row: 1.00
Mean of the last row: 0.00
Standard Deviation of the last row: 1.00
Time taken for SIMD vectorized code: 4.16 seconds.
----------


Run #2
Matrix before normalization
1.00 0.00 7.00 3.00 9.00 4.00 1.00 2.00 8.00 3.00
11.00 3.00 5.00 3.00 8.00 9.00 4.00 9.00 7.00 1.00
4.00 10.00 12.00 2.00 5.00 2.00 2.00 4.00 2.00 11.00
13.00 10.00 0.00 3.00 12.00 2.00 5.00 4.00 5.00 0.00
14.00 8.00 8.00 14.00 11.00 2.00 4.00 13.00 10.00 1.00
11.00 0.00 10.00 3.00 4.00 15.00 12.00 1.00 12.00 14.00
2.00 17.00 1.00 8.00 16.00 15.00 16.00 2.00 12.00 9.00
2.00 6.00 17.00 6.00 10.00 17.00 16.00 3.00 17.00 6.00
1.00 16.00 14.00 16.00 7.00 0.00 14.00 22.00 13.00 8.00
21.00 6.00 22.00 20.00 12.00 7.00 18.00 4.00 23.00 9.00
Mean of the first row: 4.98
Standard Deviation of the first row: 3.16
Mean of the last row: 16422.21
Standard Deviation of the last row: 9441.46

Matrix after normalization
-1.26 -1.58 0.64 -0.63 1.27 -0.31 -1.26 -0.94 0.95 -0.63
1.61 -0.72 -0.14 -0.72 0.74 1.03 -0.43 1.03 0.45 -1.30
-0.53 1.07 1.61 -1.06 -0.26 -1.06 -1.06 -0.53 -1.06 1.34
1.60 0.86 -1.12 0.61 1.60 -1.12 -0.38 -0.63 -0.38 -1.62
1.61 0.23 0.23 1.61 0.92 -1.16 -0.70 1.38 0.69 -1.39
0.60 -1.63 0.40 -1.02 -0.82 1.41 0.80 -1.43 0.80 1.21
-1.28 1.47 -1.46 -0.18 1.29 1.10 1.29 0.55 0.00 1.29
-1.32 -0.66 1.16 -0.66 0.00 1.16 0.99 -1.15 1.16 -0.66
-1.49 0.76 0.46 -0.14 0.01 -0.59 -1.64 0.46 1.66 0.31
1.52 -0.84 -0.00 1.11 -0.00 -0.70 0.83 -1.11 1.52 -0.42
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for SIMD vectorized code: 4.08 seconds.
----------


Run #3
Matrix before normalization
3.00 4.00 0.00 7.00 10.00 0.00 2.00 6.00 8.00 7.00
9.00 11.00 9.00 6.00 11.00 9.00 9.00 1.00 10.00 1.00
11.00 4.00 0.00 2.00 2.00 7.00 3.00 8.00 11.00 5.00
```

7   Logs for Original File Execution

```
1
2   kevin@Kevin-X16 MINGW64
      ↪  /c/Repositories/School/Semester4/CECS_574/HW1/lopez_kevin_013378831 (main)
3   $ g++ -mavx2 z_score_norm__Original__.cpp -o z_norm_og.exe
4
5   # Run the executable 15 times
6   for i in {1..15}
7   do
8     echo -e "-----\n\n\n\nRun #$i"
9     ./z_norm_og.exe
10  done
11  -----
12
13
14
15  Run #1
16  Matrix before normalization
17  1.00 8.00 9.00 0.00 1.00 7.00 5.00 5.00 4.00 8.00
18  11.00 0.00 3.00 2.00 10.00 1.00 9.00 1.00 1.00 2.00
19  2.00 0.00 4.00 6.00 11.00 11.00 2.00 3.00 1.00 1.00
20  7.00 1.00 13.00 5.00 8.00 0.00 11.00 10.00 7.00 8.00
21  3.00 1.00 6.00 8.00 0.00 13.00 8.00 12.00 2.00 8.00
22  5.00 11.00 14.00 8.00 7.00 8.00 8.00 11.00 10.00 5.00
23  17.00 4.00 8.00 6.00 18.00 2.00 11.00 16.00 14.00 10.00
24  5.00 6.00 8.00 7.00 16.00 11.00 7.00 11.00 17.00 4.00
25  11.00 20.00 3.00 2.00 2.00 21.00 22.00 10.00 2.00 15.00
26  9.00 22.00 4.00 19.00 11.00 0.00 3.00 21.00 4.00 13.00
27  Mean of the first row: 5.00
28  Standard Deviation of the first row: 3.17
29  Mean of the last row: 16398.37
30  Standard Deviation of the last row: 9453.82
31
32  Matrix after normalization
33  -1.26 0.95 1.26 -1.58 -1.26 0.63 0.00 0.00 -0.31 0.95
34  1.60 -1.59 -0.72 -1.01 1.31 -1.30 1.02 -1.30 -1.30 -1.01
35  -1.06 -1.60 -0.53 0.00 1.34 1.34 -1.06 -0.80 -1.33 -1.33
36  0.12 -1.37 1.62 -0.37 0.37 -1.62 1.12 0.87 0.12 0.37
37  -0.93 -1.39 -0.24 0.23 -1.63 1.39 0.23 1.16 -1.16 0.23
38  -0.61 0.62 1.23 0.01 -0.20 0.01 0.01 0.62 0.42 -0.61
39  1.47 -0.91 -0.18 -0.54 1.65 -1.27 0.37 1.28 0.92 0.19
40  -0.83 -0.66 -0.33 -0.50 0.99 0.16 -0.50 0.16 1.15 -0.99
41  0.01 1.36 -1.20 -1.35 -1.35 1.51 1.66 -0.15 -1.35 0.61
42  -0.41 1.40 -1.11 0.98 -0.14 -1.67 -1.25 1.26 -1.11 0.14
43  Mean of the first row: 0.00
44  Standard Deviation of the first row: 1.00
45  Mean of the last row: 0.00
46  Standard Deviation of the last row: 1.00
47  Time taken for NON-SIMD code: 29.86 seconds.
48  -----
49
50
```

```
Run #2
Matrix before normalization
10.00 6.00 2.00 1.00 0.00 0.00 4.00 2.00 4.00 1.00
6.00 3.00 11.00 5.00 5.00 2.00 1.00 9.00 9.00 9.00
7.00 1.00 1.00 7.00 0.00 7.00 1.00 2.00 5.00 8.00
2.00 4.00 1.00 0.00 4.00 7.00 5.00 3.00 3.00 13.00
5.00 2.00 10.00 7.00 2.00 10.00 1.00 11.00 14.00 12.00
16.00 1.00 12.00 14.00 15.00 7.00 7.00 8.00 9.00 4.00
4.00 6.00 10.00 18.00 7.00 3.00 2.00 9.00 18.00 6.00
5.00 11.00 20.00 4.00 4.00 6.00 2.00 3.00 12.00 7.00
20.00 19.00 18.00 4.00 16.00 1.00 6.00 0.00 19.00 10.00
18.00 7.00 20.00 19.00 14.00 12.00 8.00 24.00 22.00 10.00
Mean of the first row: 5.03
Standard Deviation of the first row: 3.16
Mean of the last row: 16395.50
Standard Deviation of the last row: 9469.18

Matrix after normalization
1.58 0.31 -0.96 -1.28 -1.59 -1.59 -0.33 -0.96 -0.33 -1.28
0.15 -0.72 1.60 -0.14 -0.14 -1.01 -1.30 1.02 1.02 1.02
0.26 -1.35 -1.35 0.26 -1.62 0.26 -1.35 -1.08 -0.28 0.53
-1.10 -0.61 -1.35 -1.60 -0.61 0.14 -0.36 -0.85 -0.85 1.62
-0.46 -1.15 0.70 0.01 -1.15 0.70 -1.38 0.93 1.63 1.16
1.63 -1.44 0.82 1.22 1.43 -0.21 -0.21 -0.00 0.20 -0.82
-0.92 -0.56 0.17 1.63 -0.37 -1.10 -1.28 -0.01 1.63 -0.56
-0.83 0.17 1.65 -0.99 -0.99 -0.66 -1.32 -1.16 0.33 -0.49
1.35 1.20 1.05 -1.06 0.75 -1.51 -0.76 -1.66 1.20 -0.16
0.83 -0.70 1.10 0.96 0.27 -0.00 -0.56 1.66 1.38 -0.28
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 25.70 seconds.
-----


Run #3
Matrix before normalization
7.00 9.00 2.00 6.00 0.00 4.00 5.00 5.00 10.00 3.00
2.00 5.00 9.00 2.00 7.00 5.00 7.00 9.00 8.00 9.00
0.00 2.00 9.00 0.00 10.00 3.00 1.00 5.00 12.00 8.00
1.00 10.00 3.00 13.00 9.00 8.00 0.00 3.00 1.00 6.00
3.00 1.00 4.00 6.00 6.00 4.00 13.00 12.00 9.00 13.00
10.00 16.00 5.00 2.00 15.00 16.00 6.00 2.00 11.00 6.00
6.00 0.00 12.00 12.00 3.00 9.00 14.00 8.00 13.00 14.00
13.00 14.00 15.00 20.00 8.00 5.00 9.00 14.00 15.00 8.00
0.00 12.00 5.00 7.00 11.00 8.00 0.00 13.00 2.00 8.00
4.00 4.00 22.00 6.00 19.00 17.00 4.00 1.00 23.00 9.00
Mean of the first row: 4.99
Standard Deviation of the first row: 3.16
Mean of the last row: 16376.04
Standard Deviation of the last row: 9450.01
```

```
105
106  Matrix after normalization
107  0.64 1.27 -0.95 0.32 -1.58 -0.31 0.00 0.00 1.59 -0.63
108  -1.03 -0.15 1.01 -1.03 0.43 -0.15 0.43 1.01 0.72 1.01
109  -1.61 -1.07 0.81 -1.61 1.08 -0.80 -1.34 -0.26 1.61 0.54
110  -1.37 0.87 -0.87 1.62 0.62 0.37 -1.62 -0.87 -1.37 -0.12
111  -0.93 -1.39 -0.70 -0.23 -0.23 -0.70 1.39 1.16 0.46 1.39
112  0.41 1.64 -0.61 -1.22 1.43 1.64 -0.40 -1.22 0.62 -0.40
113  -0.55 -1.64 0.55 0.55 -1.10 -0.00 0.91 -0.18 0.73 0.91
114  0.49 0.65 0.82 1.64 -0.34 -0.84 -0.18 0.65 0.82 -0.34
115  -1.66 0.15 -0.90 -0.60 0.00 -0.45 -1.66 0.30 -1.36 -0.45
116  -1.11 -1.11 1.38 -0.83 0.97 0.69 -1.11 -1.52 1.52 -0.42
117  Mean of the first row: -0.00
118  Standard Deviation of the first row: 1.00
119  Mean of the last row: 0.00
120  Standard Deviation of the last row: 1.00
121  Time taken for NON-SIMD code: 22.17 seconds.
122  -----
123
124
125
126  Run #4
127  Matrix before normalization
128  2.00 0.00 7.00 6.00 10.00 10.00 10.00 7.00 9.00 9.00
129  1.00 1.00 10.00 8.00 0.00 1.00 4.00 7.00 9.00 5.00
130  11.00 6.00 9.00 3.00 7.00 1.00 12.00 10.00 4.00 2.00
131  12.00 8.00 13.00 4.00 10.00 9.00 9.00 0.00 7.00 1.00
132  0.00 3.00 14.00 14.00 8.00 6.00 4.00 2.00 6.00 0.00
133  14.00 2.00 1.00 10.00 11.00 14.00 5.00 8.00 11.00 15.00
134  15.00 2.00 7.00 7.00 10.00 10.00 9.00 7.00 18.00 1.00
135  14.00 6.00 11.00 6.00 12.00 12.00 7.00 14.00 7.00 3.00
136  18.00 9.00 10.00 8.00 16.00 12.00 9.00 18.00 7.00 9.00
137  7.00 22.00 12.00 14.00 12.00 8.00 22.00 14.00 13.00 21.00
138  Mean of the first row: 4.99
139  Standard Deviation of the first row: 3.17
140  Mean of the last row: 16363.19
141  Standard Deviation of the last row: 9469.18
142
143  Matrix after normalization
144  -0.94 -1.58 0.63 0.32 1.58 1.58 1.58 0.63 1.26 1.26
145  -1.31 -1.31 1.30 0.72 -1.60 -1.31 -0.44 0.43 1.01 -0.15
146  1.34 -0.00 0.80 -0.80 0.27 -1.34 1.60 1.07 -0.54 -1.07
147  1.37 0.37 1.62 -0.62 0.87 0.62 0.62 -1.61 0.13 -1.36
148  -1.63 -0.93 1.62 1.62 0.23 -0.23 -0.70 -1.16 -0.23 -1.63
149  1.23 -1.22 -1.43 0.41 0.61 1.23 -0.61 0.00 0.61 1.43
150  1.10 -1.28 -0.37 -0.37 0.18 0.18 -0.00 -0.37 1.64 -1.46
151  0.66 -0.66 0.16 -0.66 0.33 0.33 -0.49 0.66 -0.49 -1.15
152  1.06 -0.29 -0.14 -0.44 0.76 0.16 -0.29 1.06 -0.59 -0.29
153  -0.68 1.38 0.00 0.28 0.00 -0.55 1.38 0.28 0.14 1.24
154  Mean of the first row: -0.00
155  Standard Deviation of the first row: 1.00
156  Mean of the last row: 0.00
157  Standard Deviation of the last row: 1.00
158  Time taken for NON-SIMD code: 23.97 seconds.
```

```
-----




Run #5
Matrix before normalization
7.00 7.00 4.00 5.00 1.00 3.00 2.00 5.00 10.00 7.00
5.00 1.00 7.00 6.00 5.00 5.00 10.00 10.00 3.00 1.00
11.00 12.00 5.00 8.00 1.00 12.00 8.00 6.00 5.00 3.00
1.00 3.00 5.00 0.00 3.00 4.00 4.00 13.00 6.00 8.00
11.00 0.00 11.00 5.00 6.00 12.00 7.00 13.00 7.00 5.00
7.00 9.00 6.00 5.00 12.00 12.00 4.00 15.00 8.00 10.00
18.00 16.00 17.00 9.00 11.00 3.00 12.00 0.00 3.00 10.00
0.00 5.00 10.00 10.00 18.00 0.00 5.00 0.00 20.00 4.00
15.00 2.00 15.00 6.00 6.00 9.00 6.00 18.00 18.00 10.00
4.00 16.00 24.00 11.00 12.00 5.00 20.00 23.00 22.00 23.00
Mean of the first row: 5.00
Standard Deviation of the first row: 3.16
Mean of the last row: 16319.82
Standard Deviation of the last row: 9485.34

Matrix after normalization
0.63 0.63 -0.32 0.00 -1.26 -0.63 -0.95 0.00 1.58 0.63
-0.14 -1.31 0.44 0.15 -0.14 -0.14 1.32 1.32 -0.72 -1.31
1.33 1.60 -0.27 0.53 -1.35 1.60 0.53 -0.01 -0.27 -0.81
-1.37 -0.87 -0.37 -1.62 -0.87 -0.62 -0.62 1.61 -0.13 0.37
0.92 -1.62 0.92 -0.46 -0.23 1.15 -0.00 1.38 -0.00 -0.46
-0.21 0.20 -0.41 -0.61 0.81 0.81 -0.82 1.42 -0.00 0.40
1.64 1.27 1.46 -0.00 0.36 -1.09 0.55 -1.64 -1.09 0.18
-1.65 -0.83 -0.00 -0.00 1.32 -1.65 -0.83 -1.65 1.65 -0.99
0.59 -1.37 0.59 -0.77 -0.77 -0.31 -0.77 1.05 1.05 -0.16
-1.10 0.56 1.67 -0.13 0.00 -0.97 1.11 1.53 1.39 1.53
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 21.83 seconds.
-----




Run #6
Matrix before normalization
10.00 6.00 10.00 9.00 3.00 8.00 6.00 7.00 8.00 3.00
1.00 0.00 7.00 0.00 5.00 2.00 7.00 8.00 8.00 11.00
10.00 5.00 12.00 7.00 5.00 10.00 5.00 1.00 4.00 9.00
10.00 1.00 11.00 6.00 5.00 12.00 6.00 11.00 9.00 10.00
10.00 11.00 5.00 10.00 7.00 7.00 6.00 4.00 7.00 7.00
15.00 0.00 0.00 8.00 6.00 10.00 12.00 3.00 6.00 16.00
9.00 15.00 3.00 6.00 0.00 6.00 18.00 17.00 4.00 9.00
7.00 10.00 14.00 2.00 6.00 12.00 15.00 17.00 13.00 11.00
6.00 19.00 0.00 13.00 6.00 17.00 13.00 4.00 13.00 14.00
18.00 23.00 22.00 6.00 14.00 5.00 4.00 6.00 14.00 20.00
Mean of the first row: 4.96
```

```
213  Standard Deviation of the first row: 3.15
214  Mean of the last row: 16484.77
215  Standard Deviation of the last row: 9456.29
216
217  Matrix after normalization
218  1.60 0.33 1.60 1.28 -0.62 0.97 0.33 0.65 0.97 -0.62
219  -1.30 -1.59 0.43 -1.59 -0.15 -1.01 0.43 0.72 0.72 1.59
220  1.06 -0.27 1.60 0.26 -0.27 1.06 -0.27 -1.34 -0.54 0.80
221  0.86 -1.37 1.11 -0.13 -0.38 1.36 -0.13 1.11 0.61 0.86
222  0.70 0.93 -0.46 0.70 0.00 0.00 -0.23 -0.69 0.00 0.00
223  1.43 -1.64 -1.64 0.00 -0.41 0.41 0.82 -1.02 -0.41 1.64
224  -0.00 1.09 -1.10 -0.55 -1.65 -0.55 1.64 1.46 -0.92 -0.00
225  -0.49 0.00 0.67 -1.32 -0.66 0.33 0.83 1.16 0.50 0.17
226  -0.75 1.22 -1.66 0.31 -0.75 0.92 0.31 -1.05 0.31 0.46
227  0.82 1.51 1.38 -0.84 0.27 -0.98 -1.12 -0.84 0.27 1.10
228  Mean of the first row: 0.00
229  Standard Deviation of the first row: 1.00
230  Mean of the last row: 0.00
231  Standard Deviation of the last row: 1.00
232  Time taken for NON-SIMD code: 22.96 seconds.
233  -----
234
235
236
237  Run #7
238  Matrix before normalization
239  9.00 9.00 5.00 4.00 0.00 2.00 10.00 8.00 8.00 0.00
240  0.00 6.00 9.00 6.00 11.00 9.00 0.00 6.00 7.00 9.00
241  2.00 12.00 11.00 7.00 0.00 12.00 10.00 12.00 6.00 3.00
242  3.00 12.00 11.00 3.00 6.00 6.00 11.00 6.00 3.00 4.00
243  12.00 5.00 1.00 8.00 10.00 0.00 3.00 1.00 7.00 10.00
244  8.00 6.00 16.00 11.00 12.00 9.00 3.00 0.00 16.00 12.00
245  5.00 8.00 6.00 5.00 14.00 12.00 13.00 9.00 13.00 3.00
246  10.00 2.00 15.00 5.00 5.00 2.00 8.00 2.00 3.00 5.00
247  12.00 20.00 3.00 1.00 16.00 17.00 8.00 5.00 4.00 20.00
248  2.00 2.00 23.00 2.00 11.00 13.00 23.00 24.00 21.00 23.00
249  Mean of the first row: 5.02
250  Standard Deviation of the first row: 3.17
251  Mean of the last row: 16424.88
252  Standard Deviation of the last row: 9434.16
253
254  Matrix after normalization
255  1.26 1.26 -0.01 -0.32 -1.58 -0.95 1.57 0.94 0.94 -1.58
256  -1.59 0.15 1.01 0.15 1.59 1.01 -1.59 0.15 0.44 1.01
257  -1.07 1.61 1.34 0.27 -1.60 1.61 1.07 1.61 0.00 -0.80
258  -0.87 1.36 1.11 -0.87 -0.13 -0.13 1.11 -0.13 -0.87 -0.62
259  1.15 -0.47 -1.40 0.23 0.69 -1.63 -0.93 -1.40 -0.01 0.69
260  -0.00 -0.41 1.64 0.61 0.82 0.20 -1.03 -1.64 1.64 0.82
261  -0.73 -0.18 -0.54 -0.73 0.91 0.55 0.73 0.00 0.73 -1.09
262  0.00 -1.32 0.83 -0.83 -0.83 -1.32 -0.33 -1.32 -1.16 -0.83
263  0.15 1.35 -1.20 -1.50 0.75 0.90 -0.45 -0.90 -1.05 1.35
264  -1.39 -1.39 1.53 -1.39 -0.14 0.14 1.53 1.67 1.25 1.53
265  Mean of the first row: 0.00
266  Standard Deviation of the first row: 1.00
```

```
267  Mean of the last row: -0.00
268  Standard Deviation of the last row: 1.00
269  Time taken for NON-SIMD code: 21.54 seconds.
270  -----
271
272
273
274  Run #8
275  Matrix before normalization
276  1.00 10.00 10.00 8.00 3.00 8.00 4.00 0.00 5.00 6.00
277  8.00 5.00 9.00 1.00 11.00 6.00 9.00 5.00 3.00 6.00
278  1.00 5.00 0.00 11.00 4.00 5.00 6.00 7.00 6.00 9.00
279  12.00 10.00 3.00 3.00 1.00 9.00 5.00 4.00 12.00 6.00
280  11.00 1.00 10.00 13.00 10.00 11.00 3.00 7.00 7.00 4.00
281  7.00 5.00 9.00 14.00 6.00 7.00 10.00 5.00 6.00 0.00
282  15.00 7.00 11.00 2.00 2.00 15.00 0.00 7.00 14.00 13.00
283  9.00 7.00 18.00 18.00 14.00 6.00 18.00 19.00 4.00 13.00
284  3.00 13.00 3.00 1.00 9.00 2.00 15.00 13.00 22.00 2.00
285  17.00 16.00 21.00 21.00 6.00 14.00 6.00 7.00 12.00 20.00
286  Mean of the first row: 4.98
287  Standard Deviation of the first row: 3.16
288  Mean of the last row: 16444.46
289  Standard Deviation of the last row: 9450.49
290
291  Matrix after normalization
292  -1.26 1.59 1.59 0.96 -0.62 0.96 -0.31 -1.57 0.01 0.32
293  0.73 -0.14 1.02 -1.30 1.60 0.15 1.02 -0.14 -0.72 0.15
294  -1.34 -0.27 -1.60 1.34 -0.54 -0.27 -0.00 0.27 -0.00 0.80
295  1.38 0.88 -0.86 -0.86 -1.36 0.63 -0.36 -0.61 1.38 -0.12
296  0.91 -1.40 0.68 1.38 0.68 0.91 -0.94 -0.01 -0.01 -0.71
297  -0.20 -0.61 0.21 1.23 -0.41 -0.20 0.41 -0.61 -0.41 -1.63
298  1.09 -0.37 0.36 -1.28 -1.28 1.09 -1.64 -0.37 0.91 0.73
299  -0.16 -0.49 1.32 1.32 0.66 -0.65 1.32 1.49 -0.98 0.50
300  -1.21 0.30 -1.21 -1.51 -0.31 -1.36 0.60 0.30 1.65 -1.36
301  0.69 0.56 1.25 1.25 -0.83 0.28 -0.83 -0.69 0.00 1.11
302  Mean of the first row: -0.00
303  Standard Deviation of the first row: 1.00
304  Mean of the last row: 0.00
305  Standard Deviation of the last row: 1.00
306  Time taken for NON-SIMD code: 22.04 seconds.
307  -----
308
309
310
311  Run #9
312  Matrix before normalization
313  7.00 1.00 5.00 8.00 2.00 1.00 9.00 2.00 4.00 2.00
314  3.00 2.00 6.00 3.00 5.00 2.00 5.00 3.00 5.00 2.00
315  7.00 1.00 5.00 1.00 1.00 3.00 4.00 12.00 6.00 3.00
316  8.00 8.00 12.00 1.00 9.00 10.00 9.00 0.00 10.00 7.00
317  1.00 3.00 5.00 7.00 5.00 12.00 9.00 13.00 4.00 14.00
318  4.00 0.00 5.00 13.00 10.00 5.00 10.00 1.00 6.00 9.00
319  12.00 17.00 5.00 4.00 17.00 4.00 13.00 6.00 0.00 12.00
320  18.00 12.00 6.00 17.00 18.00 1.00 16.00 7.00 17.00 20.00
```

10

```
321  21.00 11.00 8.00 1.00 13.00 6.00 1.00 18.00 3.00 19.00
322  19.00 9.00 11.00 4.00 6.00 5.00 24.00 20.00 3.00 7.00
323  Mean of the first row: 5.02
324  Standard Deviation of the first row: 3.17
325  Mean of the last row: 16393.21
326  Standard Deviation of the last row: 9436.13
327
328  Matrix after normalization
329  0.63 -1.27 -0.01 0.94 -0.95 -1.27 1.26 -0.95 -0.32 -0.95
330  -0.74 -1.03 0.14 -0.74 -0.15 -1.03 -0.15 -0.74 -0.15 -1.03
331  0.27 -1.33 -0.27 -1.33 -1.33 -0.80 -0.53 1.60 0.00 -0.80
332  0.36 0.36 1.35 -1.37 0.61 0.86 0.61 -1.62 0.86 0.11
333  -1.39 -0.93 -0.46 -0.00 -0.46 1.16 0.46 1.39 -0.70 1.62
334  -0.81 -1.63 -0.61 1.03 0.41 -0.61 0.41 -1.43 -0.40 0.21
335  0.55 1.46 -0.73 -0.91 1.46 -0.91 0.73 -0.55 -1.64 0.55
336  1.33 0.33 -0.66 1.16 1.33 -1.49 0.99 -0.50 1.16 1.66
337  1.51 0.00 -0.45 -1.51 0.30 -0.75 -1.51 1.06 -1.21 1.21
338  0.97 -0.42 -0.15 -1.12 -0.84 -0.98 1.66 1.11 -1.26 -0.70
339  Mean of the first row: 0.00
340  Standard Deviation of the first row: 1.00
341  Mean of the last row: -0.00
342  Standard Deviation of the last row: 1.00
343  Time taken for NON-SIMD code: 22.12 seconds.
344  -----
345
346
347
348  Run #10
349  Matrix before normalization
350  3.00 2.00 1.00 8.00 2.00 7.00 1.00 5.00 2.00 9.00
351  10.00 10.00 7.00 10.00 6.00 10.00 10.00 1.00 11.00 2.00
352  0.00 5.00 5.00 10.00 3.00 6.00 7.00 0.00 7.00 4.00
353  13.00 5.00 8.00 13.00 10.00 11.00 13.00 11.00 1.00 2.00
354  13.00 5.00 0.00 8.00 6.00 7.00 0.00 10.00 0.00 1.00
355  8.00 2.00 2.00 11.00 6.00 3.00 1.00 7.00 6.00 10.00
356  3.00 7.00 0.00 17.00 12.00 5.00 8.00 5.00 17.00 17.00
357  19.00 3.00 2.00 4.00 1.00 8.00 1.00 7.00 9.00 7.00
358  0.00 8.00 14.00 18.00 18.00 10.00 17.00 0.00 8.00 20.00
359  15.00 2.00 20.00 12.00 6.00 22.00 16.00 8.00 11.00 20.00
360  Mean of the first row: 5.02
361  Standard Deviation of the first row: 3.16
362  Mean of the last row: 16416.02
363  Standard Deviation of the last row: 9445.98
364
365  Matrix after normalization
366  -0.64 -0.96 -1.27 0.94 -0.96 0.63 -1.27 -0.01 -0.96 1.26
367  1.30 1.30 0.43 1.30 0.14 1.30 1.30 -1.30 1.59 -1.01
368  -1.60 -0.27 -0.27 1.07 -0.80 0.00 0.27 -1.60 0.27 -0.53
369  1.61 -0.37 0.37 1.61 0.87 1.12 1.61 1.12 -1.36 -1.11
370  1.39 -0.47 -1.62 0.23 -0.23 -0.00 -1.62 0.69 -1.62 -1.39
371  -0.00 -1.22 -1.22 0.61 -0.41 -1.02 -1.43 -0.20 -0.41 0.41
372  -1.10 -0.36 -1.65 1.47 0.56 -0.73 -0.18 -0.73 1.47 1.47
373  1.49 -1.15 -1.32 -0.99 -1.49 -0.33 -1.49 -0.49 -0.16 -0.49
374  -1.66 -0.45 0.45 1.05 1.05 -0.15 0.90 -1.66 -0.45 1.35
```

```
0.41 -1.40 1.10 -0.01 -0.84 1.38 0.54 -0.57 -0.15 1.10
Mean of the first row: -0.00
Standard Deviation of the first row: 1.00
Mean of the last row: 0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 21.92 seconds.
-----



Run #11
Matrix before normalization
9.00 3.00 6.00 8.00 2.00 1.00 6.00 6.00 1.00 6.00
9.00 7.00 8.00 4.00 11.00 6.00 7.00 0.00 1.00 2.00
11.00 1.00 6.00 5.00 0.00 3.00 6.00 5.00 0.00 11.00
10.00 3.00 3.00 4.00 5.00 6.00 2.00 7.00 6.00 3.00
2.00 7.00 10.00 10.00 8.00 9.00 5.00 1.00 11.00 11.00
13.00 14.00 15.00 2.00 10.00 2.00 0.00 4.00 14.00 3.00
0.00 16.00 13.00 0.00 0.00 13.00 2.00 3.00 3.00 16.00
20.00 8.00 11.00 12.00 5.00 15.00 20.00 8.00 1.00 1.00
17.00 5.00 19.00 12.00 16.00 14.00 3.00 5.00 19.00 13.00
18.00 19.00 10.00 20.00 23.00 20.00 2.00 20.00 1.00 7.00
Mean of the first row: 5.00
Standard Deviation of the first row: 3.16
Mean of the last row: 16284.32
Standard Deviation of the last row: 9482.18

Matrix after normalization
1.27 -0.63 0.32 0.95 -0.95 -1.26 0.32 0.32 -1.26 0.32
1.01 0.43 0.72 -0.44 1.59 0.14 0.43 -1.60 -1.31 -1.02
1.35 -1.33 0.01 -0.26 -1.60 -0.80 0.01 -0.26 -1.60 1.35
0.87 -0.88 -0.88 -0.63 -0.38 -0.13 -1.12 0.12 -0.13 -0.88
-1.16 0.00 0.70 0.70 0.23 0.47 -0.46 -1.39 0.93 0.93
1.02 1.22 1.43 -1.23 0.40 -1.23 -1.64 -0.82 1.22 -1.03
-1.64 1.27 0.72 -1.64 -1.64 0.72 -1.28 -1.10 -1.10 1.27
1.65 -0.33 0.17 0.33 -0.82 0.83 1.65 -0.33 -1.48 -1.48
0.90 -0.91 1.20 0.15 0.75 0.45 -1.21 -0.91 1.20 0.30
0.83 0.97 -0.28 1.10 1.52 1.10 -1.39 1.10 -1.53 -0.70
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 21.80 seconds.
-----



Run #12
Matrix before normalization
1.00 4.00 1.00 1.00 5.00 6.00 0.00 9.00 9.00 0.00
2.00 6.00 8.00 10.00 11.00 4.00 3.00 10.00 9.00 7.00
4.00 6.00 8.00 4.00 4.00 9.00 2.00 0.00 7.00 4.00
4.00 1.00 9.00 4.00 7.00 1.00 11.00 12.00 1.00 6.00
2.00 11.00 12.00 0.00 8.00 4.00 5.00 7.00 11.00 13.00
```

```
429   4.00 13.00 8.00 13.00 13.00 0.00 8.00 8.00 4.00 8.00
430   3.00 15.00 6.00 16.00 8.00 16.00 8.00 2.00 4.00 14.00
431   6.00 13.00 15.00 4.00 6.00 7.00 9.00 4.00 2.00 9.00
432   8.00 22.00 3.00 19.00 16.00 16.00 10.00 6.00 14.00 18.00
433   7.00 1.00 8.00 21.00 0.00 20.00 10.00 22.00 18.00 4.00
434   Mean of the first row: 5.00
435   Standard Deviation of the first row: 3.15
436   Mean of the last row: 16383.45
437   Standard Deviation of the last row: 9504.30
438
439   Matrix after normalization
440   -1.27 -0.32 -1.27 -1.27 -0.00 0.32 -1.59 1.27 1.27 -1.59
441   -1.02 0.14 0.72 1.30 1.59 -0.44 -0.73 1.30 1.01 0.43
442   -0.54 -0.01 0.53 -0.54 -0.54 0.79 -1.08 -1.61 0.26 -0.54
443   -0.63 -1.38 0.61 -0.63 0.11 -1.38 1.11 1.36 -1.38 -0.13
444   -1.15 0.93 1.16 -1.61 0.24 -0.69 -0.46 0.01 0.93 1.40
445   -0.80 1.02 0.01 1.02 1.02 -1.61 0.01 0.01 -0.80 0.01
446   -1.10 1.09 -0.55 1.28 -0.19 1.28 -0.19 -1.29 -0.92 0.91
447   -0.66 0.50 0.83 -0.99 -0.66 -0.49 -0.16 -0.99 -1.32 -0.16
448   -0.45 1.66 -1.21 1.21 0.75 0.75 -0.15 -0.75 0.45 1.06
449   -0.69 -1.52 -0.55 1.25 -1.66 1.11 -0.27 1.39 0.83 -1.11
450   Mean of the first row: 0.00
451   Standard Deviation of the first row: 1.00
452   Mean of the last row: -0.00
453   Standard Deviation of the last row: 1.00
454   Time taken for NON-SIMD code: 22.33 seconds.
455   -----
456
457
458
459   Run #13
460   Matrix before normalization
461   0.00 7.00 7.00 7.00 1.00 0.00 3.00 9.00 9.00 8.00
462   4.00 7.00 6.00 5.00 5.00 10.00 9.00 8.00 9.00 10.00
463   10.00 1.00 11.00 4.00 12.00 3.00 2.00 11.00 1.00 11.00
464   12.00 12.00 9.00 1.00 1.00 2.00 9.00 8.00 9.00 13.00
465   3.00 11.00 0.00 13.00 11.00 12.00 2.00 12.00 12.00 1.00
466   13.00 11.00 7.00 8.00 10.00 6.00 15.00 6.00 14.00 4.00
467   18.00 9.00 10.00 15.00 3.00 14.00 3.00 13.00 13.00 2.00
468   9.00 5.00 16.00 6.00 13.00 17.00 2.00 9.00 5.00 2.00
469   14.00 0.00 6.00 6.00 3.00 15.00 12.00 7.00 5.00 1.00
470   16.00 5.00 9.00 10.00 23.00 3.00 4.00 14.00 0.00 7.00
471   Mean of the first row: 5.03
472   Standard Deviation of the first row: 3.16
473   Mean of the last row: 16351.89
474   Standard Deviation of the last row: 9459.09
475
476   Matrix after normalization
477   -1.59 0.63 0.63 0.63 -1.27 -1.59 -0.64 1.26 1.26 0.94
478   -0.44 0.43 0.14 -0.15 -0.15 1.30 1.01 0.72 1.01 1.30
479   1.06 -1.33 1.33 -0.53 1.60 -0.80 -1.06 1.33 -1.33 1.33
480   1.36 1.36 0.62 -1.36 -1.36 -1.12 0.62 0.37 0.62 1.61
481   -0.92 0.93 -1.62 1.39 0.93 1.16 -1.16 1.16 1.16 -1.39
482   1.02 0.62 -0.20 0.00 0.41 -0.41 1.43 -0.41 1.23 -0.81
```

13

```
1.64 -0.00 0.18 1.09 -1.10 0.91 -1.10 0.73 0.73 -1.28
-0.17 -0.83 0.99 -0.66 0.49 1.15 -1.32 -0.17 -0.83 -1.32
0.46 -1.64 -0.74 -0.74 -1.19 0.61 0.16 -0.59 -0.89 -1.49
0.56 -0.97 -0.41 -0.28 1.53 -1.25 -1.11 0.28 -1.66 -0.69
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 22.49 seconds.
-----



Run #14
Matrix before normalization
7.00 10.00 8.00 2.00 1.00 4.00 5.00 2.00 5.00 9.00
0.00 1.00 5.00 5.00 7.00 1.00 2.00 8.00 7.00 6.00
8.00 2.00 2.00 9.00 4.00 7.00 2.00 1.00 12.00 11.00
11.00 4.00 2.00 0.00 6.00 9.00 4.00 8.00 7.00 0.00
2.00 3.00 8.00 12.00 8.00 6.00 7.00 13.00 7.00 2.00
7.00 10.00 0.00 13.00 2.00 14.00 6.00 0.00 16.00 5.00
1.00 3.00 12.00 9.00 17.00 2.00 16.00 0.00 15.00 17.00
9.00 7.00 11.00 13.00 17.00 16.00 9.00 20.00 9.00 4.00
17.00 0.00 16.00 10.00 20.00 7.00 22.00 21.00 5.00 22.00
3.00 3.00 11.00 22.00 21.00 8.00 1.00 24.00 1.00 6.00
Mean of the first row: 5.02
Standard Deviation of the first row: 3.17
Mean of the last row: 16363.52
Standard Deviation of the last row: 9501.37

Matrix after normalization
0.62 1.57 0.94 -0.95 -1.27 -0.32 -0.01 -0.95 -0.01 1.25
-1.59 -1.30 -0.14 -0.14 0.44 -1.30 -1.01 0.72 0.44 0.15
0.54 -1.06 -1.06 0.80 -0.53 0.27 -1.06 -1.33 1.60 1.34
1.12 -0.61 -1.11 -1.60 -0.12 0.62 -0.61 0.38 0.13 -1.60
-1.16 -0.93 0.22 1.14 0.22 -0.24 -0.01 1.37 -0.01 -1.16
-0.21 0.41 -1.64 1.02 -1.23 1.22 -0.41 -1.64 1.63 -0.61
-1.46 -1.09 0.54 -0.00 1.45 -1.28 1.27 -1.64 1.09 1.45
-0.17 -0.50 0.15 0.48 1.14 0.98 -0.17 1.64 -0.17 -1.00
0.91 -1.66 0.76 -0.15 1.36 -0.60 1.67 1.52 -0.91 1.67
-1.25 -1.25 -0.14 1.38 1.25 -0.56 -1.53 1.66 -1.53 -0.84
Mean of the first row: -0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 23.62 seconds.
-----



Run #15
Matrix before normalization
1.00 6.00 4.00 1.00 2.00 9.00 8.00 10.00 7.00 7.00
4.00 2.00 2.00 11.00 0.00 5.00 9.00 3.00 9.00 3.00
```

```
0.00 7.00 2.00 9.00 11.00 6.00 3.00 10.00 0.00 12.00
0.00 13.00 3.00 2.00 13.00 4.00 12.00 13.00 1.00 7.00
5.00 1.00 6.00 2.00 14.00 4.00 2.00 9.00 9.00 14.00
16.00 0.00 15.00 0.00 3.00 13.00 13.00 7.00 13.00 0.00
4.00 9.00 16.00 5.00 18.00 6.00 0.00 4.00 0.00 15.00
16.00 15.00 10.00 17.00 2.00 4.00 7.00 6.00 0.00 5.00
14.00 16.00 5.00 15.00 11.00 3.00 19.00 5.00 16.00 0.00
7.00 21.00 23.00 13.00 21.00 23.00 0.00 0.00 9.00 0.00
Mean of the first row: 5.02
Standard Deviation of the first row: 3.15
Mean of the last row: 16358.55
Standard Deviation of the last row: 9477.26

Matrix after normalization
-1.27 0.31 -0.32 -1.27 -0.96 1.26 0.95 1.58 0.63 0.63
-0.44 -1.02 -1.02 1.59 -1.60 -0.15 1.01 -0.73 1.01 -0.73
-1.60 0.27 -1.07 0.80 1.34 0.00 -0.80 1.07 -1.60 1.61
-1.61 1.62 -0.87 -1.12 1.62 -0.62 1.37 1.62 -1.37 0.13
-0.46 -1.39 -0.23 -1.15 1.62 -0.69 -1.15 0.47 0.47 1.62
1.63 -1.66 1.43 -1.66 -1.04 1.02 1.02 -0.22 1.02 -1.66
-0.91 0.00 1.28 -0.73 1.65 -0.55 -1.64 -0.91 -1.64 1.10
0.99 0.83 -0.00 1.16 -1.33 -0.99 -0.50 -0.66 -1.66 -0.83
0.45 0.75 -0.91 0.60 -0.01 -1.21 1.20 -0.91 0.75 -1.67
-0.70 1.24 1.52 0.13 1.24 1.52 -1.67 -1.67 -0.42 -1.67
Mean of the first row: -0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for NON-SIMD code: 22.22 se
```

8 Logs for SIMD File Execution

```
1
2   kevin@Kevin-X16 MINGW64
    ↪ /c/Repositories/School/Semester4/CECS_574/HW1/lopez_kevin_013378831 (main)
3   $ g++ -mavx2 z_score_norm__Optimized__.cpp -o z_opt.exe
4
5   # Run the executable 15 times
6   for i in {1..15}
7   do
8     echo -e "-----------\n\n\n\nRun #$i"
9     ./z_opt.exe
10  done
11  -----------
12
13
14
15  Run #1
16  Matrix before normalization
17  6.00 6.00 2.00 1.00 0.00 7.00 0.00 10.00 6.00 8.00
18  10.00 1.00 11.00 8.00 1.00 2.00 10.00 5.00 11.00 2.00
19  11.00 12.00 5.00 6.00 2.00 4.00 0.00 6.00 5.00 5.00
20  6.00 0.00 2.00 10.00 3.00 12.00 3.00 4.00 9.00 13.00
21  11.00 4.00 5.00 10.00 3.00 11.00 1.00 5.00 2.00 13.00
22  15.00 1.00 0.00 14.00 6.00 11.00 12.00 9.00 12.00 9.00
23  7.00 13.00 12.00 18.00 3.00 15.00 4.00 16.00 9.00 9.00
24  4.00 4.00 19.00 10.00 8.00 7.00 0.00 20.00 20.00 2.00
25  19.00 12.00 18.00 17.00 7.00 10.00 12.00 22.00 14.00 12.00
26  11.00 24.00 4.00 3.00 24.00 9.00 4.00 16.00 11.00 16.00
27  Mean of the first row: 5.00
28  Standard Deviation of the first row: 3.16
29  Mean of the last row: 16359.28
30  Standard Deviation of the last row: 9462.05
31
32  Matrix after normalization
33  0.32 0.32 -0.95 -1.27 -1.58 0.63 -1.58 1.58 0.32 0.95
34  1.31 -1.30 1.60 0.73 -1.30 -1.01 1.31 -0.14 1.60 -1.01
35  1.35 1.61 -0.26 0.01 -1.06 -0.52 -1.59 0.01 -0.26 -0.26
36  -0.13 -1.61 -1.12 0.86 -0.87 1.36 -0.87 -0.62 0.62 1.61
37  0.93 -0.69 -0.46 0.70 -0.92 0.93 -1.38 -0.46 -1.15 1.39
38  1.44 -1.42 -1.62 1.23 -0.40 0.62 0.82 0.21 0.82 0.21
39  -0.36 0.73 0.55 1.65 -1.10 1.10 -0.91 1.28 0.00 0.00
40  -1.00 -1.00 1.48 -0.01 -0.34 -0.50 -1.66 1.65 1.65 -1.33
41  1.21 0.15 1.05 0.90 -0.61 -0.15 0.15 1.66 0.45 0.15
42  -0.14 1.66 -1.11 -1.25 1.66 -0.42 -1.11 0.55 -0.14 0.55
43  Mean of the first row: -0.00
44  Standard Deviation of the first row: 1.00
45  Mean of the last row: 0.00
46  Standard Deviation of the last row: 1.00
47  Time taken for SIMD vectorized code: 4.16 seconds.
48  -----------
49
50
```

```
51
52   Run #2
53   Matrix before normalization
54   1.00 0.00 7.00 3.00 9.00 4.00 1.00 2.00 8.00 3.00
55   11.00 3.00 5.00 3.00 8.00 9.00 4.00 9.00 7.00 1.00
56   4.00 10.00 12.00 2.00 5.00 2.00 2.00 4.00 2.00 11.00
57   13.00 10.00 2.00 9.00 13.00 2.00 5.00 4.00 5.00 0.00
58   14.00 8.00 8.00 14.00 11.00 2.00 4.00 13.00 10.00 1.00
59   11.00 0.00 10.00 3.00 4.00 15.00 12.00 1.00 12.00 14.00
60   2.00 17.00 1.00 8.00 16.00 15.00 16.00 12.00 9.00 16.00
61   2.00 6.00 17.00 6.00 10.00 17.00 16.00 3.00 17.00 6.00
62   1.00 16.00 14.00 10.00 11.00 7.00 0.00 14.00 22.00 13.00
63   23.00 6.00 12.00 20.00 12.00 7.00 18.00 4.00 23.00 9.00
64   Mean of the first row: 4.98
65   Standard Deviation of the first row: 3.16
66   Mean of the last row: 16422.21
67   Standard Deviation of the last row: 9441.46
68
69   Matrix after normalization
70   -1.26 -1.58 0.64 -0.63 1.27 -0.31 -1.26 -0.94 0.95 -0.63
71   1.61 -0.72 -0.14 -0.72 0.74 1.03 -0.43 1.03 0.45 -1.30
72   -0.53 1.07 1.61 -1.06 -0.26 -1.06 -1.06 -0.53 -1.06 1.34
73   1.60 0.86 -1.12 0.61 1.60 -1.12 -0.38 -0.63 -0.38 -1.62
74   1.61 0.23 0.23 1.61 0.92 -1.16 -0.70 1.38 0.69 -1.39
75   0.60 -1.63 0.40 -1.02 -0.82 1.41 0.80 -1.43 0.80 1.21
76   -1.28 1.47 -1.46 -0.18 1.29 1.10 1.29 0.55 0.00 1.29
77   -1.32 -0.66 1.16 -0.66 0.00 1.16 0.99 -1.15 1.16 -0.66
78   -1.49 0.76 0.46 -0.14 0.01 -0.59 -1.64 0.46 1.66 0.31
79   1.52 -0.84 -0.00 1.11 -0.00 -0.70 0.83 -1.11 1.52 -0.42
80   Mean of the first row: -0.00
81   Standard Deviation of the first row: 1.00
82   Mean of the last row: -0.00
83   Standard Deviation of the last row: 1.00
84   Time taken for SIMD vectorized code: 4.08 seconds.
85   -----------
86
87
88
89   Run #3
90   Matrix before normalization
91   3.00 4.00 0.00 7.00 10.00 0.00 2.00 6.00 8.00 7.00
92   9.00 11.00 9.00 6.00 11.00 9.00 1.00 0.00 10.00 1.00
93   11.00 4.00 0.00 2.00 2.00 7.00 3.00 8.00 11.00 5.00
94   12.00 8.00 12.00 11.00 3.00 0.00 6.00 8.00 5.00 7.00
95   4.00 7.00 11.00 5.00 3.00 1.00 1.00 0.00 8.00 11.00
96   3.00 12.00 0.00 13.00 1.00 10.00 3.00 9.00 1.00 7.00
97   16.00 10.00 6.00 12.00 11.00 17.00 8.00 9.00 5.00 14.00
98   5.00 20.00 2.00 8.00 18.00 12.00 15.00 3.00 3.00 10.00
99   4.00 9.00 5.00 16.00 9.00 2.00 2.00 3.00 13.00 2.00
100  22.00 3.00 9.00 7.00 3.00 15.00 5.00 5.00 11.00 1.00
101  Mean of the first row: 4.97
102  Standard Deviation of the first row: 3.17
103  Mean of the last row: 16486.46
104  Standard Deviation of the last row: 9441.56
```

17

```
105
106  Matrix after normalization
107  -0.62 -0.31 -1.57 0.64 1.59 -1.57 -0.94 0.33 0.96 0.64
108  1.02 1.59 1.02 0.15 1.59 1.02 -1.29 -1.58 1.31 -1.29
109  1.34 -0.53 -1.60 -1.07 -1.07 0.27 -0.80 0.54 1.34 -0.27
110  1.37 0.38 1.37 1.12 -0.86 -1.61 -0.12 0.38 -0.37 0.13
111  -0.69 0.01 0.93 -0.46 -0.92 -1.38 -1.38 -1.61 0.24 0.93
112  -1.02 0.81 -1.63 1.02 -1.43 0.41 -1.02 0.20 -1.43 -0.21
113  1.28 0.19 -0.54 0.55 0.37 1.46 -0.18 0.00 -0.73 0.92
114  -0.82 1.65 -1.31 -0.32 1.32 0.33 0.83 -1.15 -1.15 0.00
115  -1.04 -0.29 -0.89 0.76 -0.29 -1.34 -1.34 -1.19 0.31 -1.34
116  1.39 -1.25 -0.42 -0.69 -1.25 0.42 -0.97 -0.97 -0.14 -1.53
117  Mean of the first row: -0.00
118  Standard Deviation of the first row: 1.00
119  Mean of the last row: 0.00
120  Standard Deviation of the last row: 1.00
121  Time taken for SIMD vectorized code: 4.23 seconds.
122  -----------
123
124
125
126  Run #4
127  Matrix before normalization
128  9.00 8.00 4.00 8.00 8.00 8.00 3.00 9.00 10.00 2.00
129  10.00 1.00 3.00 0.00 7.00 4.00 8.00 4.00 6.00 0.00
130  4.00 1.00 12.00 11.00 5.00 5.00 5.00 10.00 1.00 12.00
131  5.00 5.00 12.00 4.00 13.00 4.00 8.00 9.00 1.00 0.00
132  13.00 12.00 14.00 0.00 11.00 6.00 13.00 9.00 1.00 14.00
133  0.00 11.00 2.00 11.00 16.00 5.00 2.00 2.00 1.00 13.00
134  11.00 7.00 13.00 1.00 5.00 17.00 1.00 17.00 5.00 2.00
135  11.00 13.00 1.00 17.00 20.00 1.00 2.00 7.00 0.00 14.00
136  9.00 13.00 1.00 9.00 13.00 22.00 5.00 18.00 21.00 4.00
137  9.00 3.00 17.00 24.00 17.00 14.00 1.00 17.00 23.00 1.00
138  Mean of the first row: 5.01
139  Standard Deviation of the first row: 3.16
140  Mean of the last row: 16362.86
141  Standard Deviation of the last row: 9466.31
142
143  Matrix after normalization
144  1.26 0.95 -0.32 0.95 0.95 0.95 -0.63 1.26 1.58 -0.95
145  1.31 -1.31 -0.73 -1.60 0.44 -0.43 0.73 -0.43 0.15 -1.60
146  -0.53 -1.33 1.61 1.34 -0.26 -0.26 -0.26 1.07 -1.33 1.61
147  -0.36 -0.36 1.38 -0.61 1.63 -0.61 0.39 0.64 -1.35 -1.60
148  1.38 1.15 1.61 -1.61 0.92 -0.23 1.38 0.46 -1.38 1.61
149  -1.64 0.61 -1.23 0.61 1.64 -0.61 -1.23 -1.23 -1.43 1.02
150  0.36 -0.37 0.73 -1.47 -0.74 1.46 -1.47 1.46 -0.74 -1.29
151  0.16 0.49 -1.50 1.16 1.65 -1.50 -1.33 -0.50 -1.66 0.66
152  -0.30 0.31 -1.51 -0.30 0.31 1.67 -0.90 1.06 1.52 -1.05
153  -0.41 -1.25 0.70 1.67 0.70 0.28 -1.52 0.70 1.53 -1.52
154  Mean of the first row: -0.00
155  Standard Deviation of the first row: 1.00
156  Mean of the last row: 0.00
157  Standard Deviation of the last row: 1.00
158  Time taken for SIMD vectorized code: 4.14 seconds.
```

```
159    -----------
160
161
162
163    Run #5
164    Matrix before normalization
165    4.00 2.00 9.00 9.00 5.00 5.00 4.00 1.00 1.00 6.00
166    11.00 6.00 9.00 3.00 3.00 11.00 6.00 7.00 6.00 4.00
167    10.00 11.00 11.00 7.00 8.00 7.00 7.00 8.00 11.00 6.00
168    6.00 2.00 6.00 12.00 9.00 7.00 11.00 4.00 4.00 0.00
169    1.00 9.00 10.00 11.00 4.00 12.00 9.00 2.00 10.00 10.00
170    13.00 2.00 12.00 9.00 14.00 9.00 2.00 2.00 1.00 2.00
171    5.00 11.00 9.00 10.00 18.00 17.00 0.00 14.00 4.00 8.00
172    9.00 15.00 0.00 14.00 2.00 19.00 18.00 11.00 4.00 5.00
173    15.00 17.00 12.00 2.00 17.00 19.00 16.00 10.00 22.00 5.00
174    21.00 11.00 0.00 17.00 24.00 12.00 15.00 23.00 10.00 1.00
175    Mean of the first row: 4.99
176    Standard Deviation of the first row: 3.16
177    Mean of the last row: 16385.56
178    Standard Deviation of the last row: 9453.65
179
180    Matrix after normalization
181    -0.31 -0.95 1.27 1.27 0.00 0.00 -0.31 -1.26 -1.26 0.32
182    1.59 0.14 1.01 -0.73 -0.73 1.59 0.14 0.43 0.14 -0.44
183    1.07 1.34 1.34 0.27 0.54 0.27 0.27 0.54 1.34 0.00
184    -0.12 -1.12 -0.12 1.37 0.62 0.13 1.12 -0.62 -0.62 -1.61
185    -1.40 0.46 0.69 0.92 -0.71 1.15 0.46 -1.17 0.69 0.69
186    1.03 -1.22 0.82 0.21 1.23 0.21 -1.22 -1.22 -1.43 -1.22
187    -0.74 0.36 -0.00 0.18 1.65 1.46 -1.65 0.91 -0.92 -0.19
188    -0.16 0.83 -1.64 0.66 -1.31 1.49 1.32 0.17 -0.98 -0.82
189    0.61 0.91 0.16 -1.35 0.91 1.21 0.76 -0.14 1.66 -0.89
190    1.24 -0.14 -1.67 0.69 1.66 -0.00 0.41 1.52 -0.28 -1.53
191    Mean of the first row: -0.00
192    Standard Deviation of the first row: 1.00
193    Mean of the last row: 0.00
194    Standard Deviation of the last row: 1.00
195    Time taken for SIMD vectorized code: 4.11 seconds.
196    -----------
197
198
199
200    Run #6
201    Matrix before normalization
202    6.00 6.00 3.00 4.00 5.00 1.00 6.00 6.00 2.00 0.00
203    9.00 10.00 1.00 10.00 5.00 7.00 3.00 11.00 9.00 0.00
204    8.00 10.00 6.00 7.00 5.00 0.00 7.00 12.00 7.00 0.00
205    11.00 13.00 3.00 13.00 12.00 11.00 4.00 0.00 11.00 0.00
206    6.00 1.00 13.00 10.00 3.00 4.00 6.00 4.00 7.00 13.00
207    14.00 14.00 2.00 3.00 2.00 4.00 1.00 10.00 15.00 12.00
208    13.00 4.00 14.00 2.00 6.00 0.00 11.00 10.00 0.00 6.00
209    12.00 0.00 14.00 15.00 1.00 6.00 17.00 11.00 3.00 9.00
210    10.00 10.00 4.00 8.00 15.00 14.00 11.00 5.00 13.00 17.00
211    19.00 8.00 22.00 3.00 15.00 20.00 9.00 6.00 24.00 11.00
212    Mean of the first row: 5.03
```

19

```
213  Standard Deviation of the first row: 3.16
214  Mean of the last row: 16368.46
215  Standard Deviation of the last row: 9442.93
216
217  Matrix after normalization
218  0.31 0.31 -0.64 -0.33 -0.01 -1.28 0.31 0.31 -0.96 -1.59
219  1.01 1.30 -1.30 1.30 -0.14 0.44 -0.72 1.59 1.01 -1.59
220  0.54 1.07 0.00 0.27 -0.27 -1.61 0.27 1.61 0.27 -1.61
221  1.12 1.62 -0.86 1.62 1.37 1.12 -0.61 -1.61 1.12 -1.61
222  -0.23 -1.39 1.39 0.69 -0.93 -0.70 -0.23 -0.70 -0.00 1.39
223  1.23 1.23 -1.24 -1.03 -1.24 -0.83 -1.44 0.40 1.43 0.81
224  0.73 -0.91 0.91 -1.28 -0.55 -1.65 0.36 0.18 -1.65 -0.55
225  0.34 -1.64 0.66 0.83 -1.48 -0.65 1.16 0.17 -1.15 -0.16
226  -0.15 -0.15 -1.05 -0.45 0.60 0.45 -0.00 -0.90 0.30 0.90
227  0.97 -0.56 1.39 -1.25 0.42 1.11 -0.42 -0.83 1.66 -0.14
228  Mean of the first row: -0.00
229  Standard Deviation of the first row: 1.00
230  Mean of the last row: -0.00
231  Standard Deviation of the last row: 1.00
232  Time taken for SIMD vectorized code: 5.62 seconds.
233  -----------
234
235
236
237  Run #7
238  Matrix before normalization
239  0.00 6.00 9.00 4.00 5.00 9.00 6.00 4.00 8.00 8.00
240  7.00 8.00 7.00 3.00 5.00 1.00 11.00 7.00 5.00 0.00
241  8.00 12.00 1.00 8.00 12.00 11.00 7.00 10.00 9.00 6.00
242  5.00 8.00 0.00 3.00 6.00 0.00 5.00 4.00 10.00 6.00
243  14.00 9.00 11.00 10.00 8.00 6.00 6.00 11.00 12.00 11.00
244  6.00 0.00 5.00 14.00 6.00 9.00 1.00 13.00 11.00 11.00
245  0.00 17.00 11.00 4.00 14.00 16.00 13.00 13.00 18.00 4.00
246  16.00 17.00 16.00 8.00 5.00 18.00 4.00 1.00 0.00 7.00
247  18.00 10.00 22.00 13.00 11.00 3.00 3.00 0.00 5.00 3.00
248  7.00 9.00 2.00 3.00 4.00 10.00 11.00 8.00 11.00 0.00
249  Mean of the first row: 5.02
250  Standard Deviation of the first row: 3.16
251  Mean of the last row: 16381.65
252  Standard Deviation of the last row: 9470.56
253
254  Matrix after normalization
255  -1.59 0.31 1.26 -0.32 -0.00 1.26 0.31 -0.32 0.94 0.94
256  0.44 0.73 0.44 -0.71 -0.14 -1.29 1.59 0.44 -0.14 -1.58
257  0.53 1.60 -1.33 0.53 1.60 1.33 0.27 1.07 0.80 0.00
258  -0.37 0.38 -1.61 -0.86 -0.12 -1.61 -0.37 -0.61 0.88 -0.12
259  1.62 0.46 0.92 0.69 0.23 -0.24 -0.24 0.92 1.15 0.92
260  -0.42 -1.64 -0.62 1.21 -0.42 0.19 -1.44 1.01 0.60 0.60
261  -1.64 1.45 0.36 -0.91 0.91 1.27 0.72 0.72 1.63 -0.91
262  0.99 1.15 0.99 -0.33 -0.83 1.32 -0.99 -1.49 -1.65 -0.50
263  1.06 -0.15 1.66 0.30 0.00 -1.21 -1.21 -1.66 -0.90 -1.21
264  -0.70 -0.43 -1.40 -1.26 -1.12 -0.29 -0.15 -0.57 -0.15 -1.68
265  Mean of the first row: 0.00
266  Standard Deviation of the first row: 1.00
```

```
267  Mean of the last row: -0.00
268  Standard Deviation of the last row: 1.00
269  Time taken for SIMD vectorized code: 4.49 seconds.
270  ----------
271
272
273
274  Run #8
275  Matrix before normalization
276  6.00 0.00 3.00 5.00 2.00 6.00 7.00 7.00 10.00 3.00
277  8.00 10.00 1.00 6.00 0.00 0.00 5.00 10.00 1.00 3.00
278  1.00 1.00 0.00 4.00 2.00 8.00 9.00 7.00 6.00 0.00
279  12.00 5.00 0.00 11.00 2.00 4.00 8.00 12.00 12.00 7.00
280  2.00 6.00 14.00 5.00 1.00 5.00 3.00 5.00 14.00 7.00
281  3.00 16.00 15.00 12.00 4.00 4.00 0.00 13.00 10.00 0.00
282  14.00 2.00 7.00 13.00 8.00 16.00 5.00 10.00 18.00 11.00
283  14.00 10.00 15.00 17.00 8.00 7.00 12.00 5.00 18.00 19.00
284  1.00 14.00 18.00 5.00 15.00 1.00 14.00 15.00 6.00 5.00
285  19.00 16.00 10.00 3.00 18.00 9.00 0.00 13.00 16.00 1.00
286  Mean of the first row: 4.99
287  Standard Deviation of the first row: 3.15
288  Mean of the last row: 16392.46
289  Standard Deviation of the last row: 9433.11
290
291  Matrix after normalization
292  0.32 -1.58 -0.63 0.00 -0.95 0.32 0.64 0.64 1.59 -0.63
293  0.72 1.30 -1.31 0.14 -1.60 -1.60 -0.15 1.30 -1.31 -0.73
294  -1.33 -1.33 -1.60 -0.53 -1.06 0.54 0.81 0.27 0.01 -1.60
295  1.36 -0.37 -1.62 1.11 -1.12 -0.62 0.37 1.36 1.36 0.12
296  -1.16 -0.23 1.61 -0.46 -1.39 -0.46 -0.93 -0.46 1.61 -0.00
297  -1.01 1.64 1.43 0.82 -0.81 -0.81 -1.62 1.03 0.42 -1.62
298  0.91 -1.28 -0.37 0.73 -0.18 1.28 -0.73 0.18 1.65 0.37
299  0.65 -0.00 0.82 1.15 -0.33 -0.50 0.33 -0.83 1.31 1.48
300  -1.50 0.45 1.05 -0.90 0.60 -1.50 0.45 0.60 -0.75 -0.90
301  0.97 0.55 -0.28 -1.25 0.83 -0.42 -1.66 0.14 0.55 -1.52
302  Mean of the first row: -0.00
303  Standard Deviation of the first row: 1.00
304  Mean of the last row: -0.00
305  Standard Deviation of the last row: 1.00
306  Time taken for SIMD vectorized code: 4.28 seconds.
307  ----------
308
309
310
311  Run #9
312  Matrix before normalization
313  1.00 5.00 7.00 5.00 0.00 2.00 8.00 10.00 1.00 8.00
314  9.00 3.00 3.00 0.00 8.00 7.00 11.00 2.00 1.00 2.00
315  7.00 11.00 12.00 8.00 5.00 5.00 11.00 10.00 9.00 6.00
316  0.00 1.00 9.00 10.00 12.00 8.00 10.00 13.00 8.00 13.00
317  4.00 3.00 10.00 0.00 9.00 10.00 6.00 13.00 7.00 10.00
318  16.00 16.00 9.00 10.00 2.00 8.00 0.00 5.00 10.00 5.00
319  9.00 18.00 15.00 2.00 2.00 16.00 5.00 18.00 18.00 17.00
320  20.00 12.00 13.00 13.00 10.00 18.00 7.00 1.00 2.00 2.00
```

```
321  7.00 18.00 7.00 5.00 18.00 21.00 18.00 7.00 7.00 6.00
322  6.00 24.00 0.00 20.00 6.00 7.00 21.00 1.00 3.00 1.00
323  Mean of the first row: 5.00
324  Standard Deviation of the first row: 3.16
325  Mean of the last row: 16357.56
326  Standard Deviation of the last row: 9451.87
327
328  Matrix after normalization
329  -1.26 0.00 0.63 0.00 -1.58 -0.95 0.95 1.58 -1.26 0.95
330  1.01 -0.73 -0.73 -1.60 0.72 0.43 1.59 -1.02 -1.31 -1.02
331  0.27 1.34 1.61 0.54 -0.26 -0.26 1.34 1.07 0.81 0.01
332  -1.61 -1.37 0.62 0.86 1.36 0.37 0.86 1.61 0.37 1.61
333  -0.70 -0.93 0.69 -1.62 0.46 0.69 -0.24 1.38 -0.00 0.69
334  1.64 1.64 0.21 0.42 -1.21 0.01 -1.62 -0.60 0.42 -0.60
335  -0.01 1.64 1.09 -1.28 -1.28 1.27 -0.74 1.64 1.64 1.45
336  1.64 0.32 0.49 0.49 -0.01 1.31 -0.50 -1.49 -1.33 -1.33
337  -0.61 1.06 -0.61 -0.91 1.06 1.51 1.06 -0.61 -0.61 -0.76
338  -0.83 1.67 -1.66 1.11 -0.83 -0.69 1.25 -1.52 -1.25 -1.52
339  Mean of the first row: -0.00
340  Standard Deviation of the first row: 1.00
341  Mean of the last row: -0.00
342  Standard Deviation of the last row: 1.00
343  Time taken for SIMD vectorized code: 4.36 seconds.
344  -----------
345
346
347
348  Run #10
349  Matrix before normalization
350  7.00 10.00 1.00 7.00 9.00 10.00 9.00 2.00 3.00 2.00
351  10.00 5.00 9.00 7.00 4.00 1.00 5.00 5.00 9.00 5.00
352  0.00 8.00 6.00 5.00 8.00 3.00 1.00 7.00 6.00 0.00
353  7.00 12.00 9.00 4.00 8.00 12.00 12.00 8.00 5.00 13.00
354  6.00 1.00 13.00 11.00 2.00 1.00 3.00 6.00 1.00 6.00
355  13.00 7.00 2.00 8.00 1.00 3.00 16.00 14.00 10.00 2.00
356  10.00 2.00 10.00 11.00 16.00 16.00 17.00 15.00 6.00 4.00
357  5.00 5.00 20.00 10.00 13.00 7.00 14.00 6.00 19.00 5.00
358  13.00 22.00 3.00 21.00 22.00 18.00 6.00 22.00 15.00 8.00
359  18.00 0.00 7.00 13.00 20.00 6.00 17.00 6.00 8.00 1.00
360  Mean of the first row: 5.02
361  Standard Deviation of the first row: 3.17
362  Mean of the last row: 16418.65
363  Standard Deviation of the last row: 9475.11
364
365  Matrix after normalization
366  0.63 1.57 -1.27 0.63 1.26 1.57 1.26 -0.95 -0.64 -0.95
367  1.31 -0.14 1.02 0.44 -0.43 -1.30 -0.14 -0.14 1.02 -0.14
368  -1.60 0.54 0.00 -0.27 0.54 -0.80 -1.34 0.27 0.00 -1.60
369  0.12 1.36 0.61 -0.62 0.37 1.36 1.36 0.37 -0.37 1.60
370  -0.23 -1.38 1.39 0.93 -1.15 -1.38 -0.92 -0.23 -1.38 -0.23
371  1.01 -0.21 -1.23 -0.00 -1.43 -1.02 1.62 1.22 0.40 -1.23
372  0.18 -1.28 0.18 0.37 1.28 1.28 1.46 1.10 -0.55 -0.91
373  -0.82 -0.82 1.67 0.01 0.51 -0.49 0.67 -0.66 1.50 -0.82
374  0.30 1.66 -1.21 1.51 1.66 1.06 -0.75 1.66 0.60 -0.45
```

```
375   0.83 -1.66 -0.69 0.14 1.11 -0.83 0.70 -0.83 -0.55 -1.52
376   Mean of the first row: -0.00
377   Standard Deviation of the first row: 1.00
378   Mean of the last row: -0.00
379   Standard Deviation of the last row: 1.00
380   Time taken for SIMD vectorized code: 4.25 seconds.
381   -----------
382
383
384
385   Run #11
386   Matrix before normalization
387   9.00 2.00 6.00 1.00 9.00 7.00 10.00 7.00 3.00 6.00
388   8.00 1.00 2.00 10.00 6.00 1.00 3.00 9.00 0.00 1.00
389   12.00 2.00 6.00 5.00 5.00 8.00 1.00 3.00 2.00 7.00
390   6.00 10.00 5.00 5.00 12.00 10.00 13.00 4.00 5.00 13.00
391   4.00 7.00 1.00 2.00 1.00 0.00 0.00 8.00 13.00 8.00
392   13.00 2.00 10.00 2.00 6.00 15.00 7.00 13.00 16.00 4.00
393   17.00 15.00 8.00 15.00 3.00 18.00 9.00 12.00 14.00 3.00
394   0.00 19.00 5.00 12.00 12.00 1.00 13.00 13.00 5.00 10.00
395   15.00 22.00 17.00 20.00 21.00 12.00 1.00 18.00 6.00 20.00
396   17.00 21.00 22.00 24.00 4.00 14.00 4.00 7.00 4.00 11.00
397   Mean of the first row: 5.00
398   Standard Deviation of the first row: 3.16
399   Mean of the last row: 16347.57
400   Standard Deviation of the last row: 9479.29
401
402   Matrix after normalization
403   1.27 -0.95 0.32 -1.26 1.27 0.63 1.58 0.63 -0.63 0.32
404   0.73 -1.30 -1.01 1.30 0.15 -1.30 -0.72 1.02 -1.58 -1.30
405   1.60 -1.07 -0.00 -0.27 -0.27 0.53 -1.34 -0.80 -1.07 0.27
406   -0.13 0.87 -0.38 -0.38 1.37 0.87 1.62 -0.63 -0.38 1.62
407   -0.70 -0.01 -1.40 -1.16 -1.40 -1.63 -1.63 0.23 1.38 0.23
408   1.02 -1.23 0.41 -1.23 -0.41 1.43 -0.21 1.02 1.63 -0.82
409   1.47 1.10 -0.17 1.10 -1.08 1.65 0.01 0.56 0.92 -1.08
410   -1.65 1.49 -0.83 0.33 0.33 -1.49 0.50 0.50 -0.83 -0.00
411   0.59 1.65 0.90 1.35 1.50 0.14 -1.52 1.05 -0.76 1.35
412   0.69 1.25 1.39 1.66 -1.11 0.27 -1.11 -0.70 -1.11 -0.14
413   Mean of the first row: 0.00
414   Standard Deviation of the first row: 1.00
415   Mean of the last row: 0.00
416   Standard Deviation of the last row: 1.00
417   Time taken for SIMD vectorized code: 4.39 seconds.
418   -----------
419
420
421
422   Run #12
423   Matrix before normalization
424   4.00 7.00 0.00 2.00 6.00 3.00 0.00 10.00 6.00 1.00
425   9.00 2.00 7.00 4.00 2.00 8.00 1.00 0.00 8.00 4.00
426   5.00 12.00 5.00 1.00 8.00 11.00 3.00 1.00 12.00 1.00
427   13.00 7.00 5.00 13.00 8.00 0.00 2.00 13.00 1.00 0.00
428   6.00 5.00 4.00 13.00 9.00 5.00 3.00 2.00 6.00 4.00
```

```
10.00 1.00 11.00 0.00 4.00 2.00 7.00 5.00 16.00 1.00
12.00 12.00 4.00 4.00 17.00 18.00 2.00 1.00 13.00 9.00
6.00 0.00 4.00 0.00 15.00 12.00 0.00 17.00 2.00 1.00
21.00 3.00 13.00 20.00 1.00 10.00 12.00 10.00 7.00 21.00
4.00 4.00 12.00 17.00 18.00 12.00 18.00 20.00 9.00 11.00
Mean of the first row: 5.02
Standard Deviation of the first row: 3.17
Mean of the last row: 16462.61
Standard Deviation of the last row: 9427.71

Matrix after normalization
-0.32 0.62 -1.58 -0.95 0.31 -0.64 -1.58 1.57 0.31 -1.27
1.02 -1.01 0.44 -0.43 -1.01 0.73 -1.30 -1.59 0.73 -0.43
-0.27 1.60 -0.27 -1.33 0.53 1.33 -0.80 -1.33 1.60 -1.33
1.61 0.12 -0.37 1.61 0.37 -1.61 -1.12 1.61 -1.36 -1.61
-0.24 -0.47 -0.70 1.38 0.46 -0.47 -0.93 -1.16 -0.24 -0.70
0.42 -1.41 0.62 -1.62 -0.80 -1.21 -0.19 -0.60 1.64 -1.41
0.54 0.54 -0.92 -0.92 1.46 1.64 -1.28 -1.46 0.73 -0.00
-0.67 -1.66 -1.00 -1.66 0.82 0.32 -1.66 1.15 -1.33 -1.49
1.51 -1.20 0.30 1.36 -1.51 -0.15 0.15 -0.15 -0.60 1.51
-1.11 -1.11 -0.00 0.69 0.83 -0.00 0.83 1.11 -0.42 -0.14
Mean of the first row: -0.00
Standard Deviation of the first row: 1.00
Mean of the last row: 0.00
Standard Deviation of the last row: 1.00
Time taken for SIMD vectorized code: 4.22 seconds.
-----------



Run #13
Matrix before normalization
10.00 2.00 4.00 3.00 4.00 0.00 1.00 2.00 8.00 6.00
10.00 8.00 1.00 7.00 10.00 3.00 7.00 4.00 8.00 8.00
11.00 10.00 12.00 10.00 11.00 8.00 5.00 3.00 2.00 0.00
0.00 3.00 13.00 13.00 4.00 3.00 4.00 0.00 3.00 0.00
8.00 9.00 7.00 8.00 2.00 11.00 0.00 3.00 0.00 7.00
6.00 0.00 4.00 15.00 10.00 14.00 7.00 14.00 15.00 6.00
7.00 15.00 11.00 13.00 11.00 11.00 1.00 17.00 13.00 15.00
4.00 14.00 2.00 17.00 17.00 9.00 16.00 1.00 20.00 5.00
4.00 7.00 1.00 13.00 5.00 7.00 16.00 2.00 15.00 16.00
16.00 4.00 20.00 9.00 7.00 11.00 14.00 0.00 21.00 11.00
Mean of the first row: 4.99
Standard Deviation of the first row: 3.18
Mean of the last row: 16409.42
Standard Deviation of the last row: 9439.64

Matrix after normalization
1.58 -0.94 -0.31 -0.63 -0.31 -1.57 -1.26 -0.94 0.95 0.32
1.31 0.73 -1.31 0.44 1.31 -0.72 0.44 -0.43 0.73 0.73
1.34 1.07 1.61 1.07 1.34 0.53 -0.27 -0.81 -1.07 -1.61
-1.61 -0.87 1.61 1.61 -0.62 -0.87 -0.62 -1.61 -0.87 -1.61
0.22 0.45 -0.01 0.22 -1.17 0.92 -1.63 -0.94 -1.63 -0.01
-0.41 -1.64 -0.82 1.42 0.40 1.22 -0.21 1.22 1.42 -0.41
```

```
-0.37 1.10 0.36 0.73 0.36 0.36 -1.46 1.46 0.73 1.10
-0.98 0.67 -1.31 1.16 1.16 -0.16 1.00 -1.48 1.66 -0.82
-1.06 -0.61 -1.51 0.30 -0.91 -0.61 0.75 -1.36 0.60 0.75
0.55 -1.11 1.10 -0.42 -0.70 -0.14 0.27 -1.67 1.24 -0.14
Mean of the first row: -0.00
Standard Deviation of the first row: 1.00
Mean of the last row: 0.00
Standard Deviation of the last row: 1.00
Time taken for SIMD vectorized code: 4.31 seconds.
-----------


Run #14
Matrix before normalization
5.00 7.00 9.00 4.00 2.00 7.00 2.00 5.00 10.00 1.00
7.00 10.00 7.00 1.00 6.00 1.00 1.00 8.00 4.00 7.00
4.00 7.00 11.00 1.00 1.00 5.00 8.00 0.00 12.00 6.00
7.00 0.00 0.00 7.00 0.00 7.00 6.00 8.00 0.00 6.00
11.00 6.00 11.00 3.00 11.00 1.00 11.00 12.00 8.00 3.00
3.00 8.00 15.00 13.00 9.00 9.00 6.00 14.00 6.00 3.00
1.00 12.00 7.00 3.00 6.00 11.00 13.00 7.00 1.00 3.00
9.00 7.00 1.00 13.00 7.00 20.00 3.00 18.00 17.00 8.00
10.00 4.00 20.00 13.00 9.00 4.00 4.00 16.00 16.00 17.00
3.00 12.00 3.00 2.00 21.00 10.00 4.00 13.00 8.00 11.00
Mean of the first row: 5.02
Standard Deviation of the first row: 3.16
Mean of the last row: 16355.32
Standard Deviation of the last row: 9473.34

Matrix after normalization
-0.01 0.63 1.26 -0.32 -0.96 0.63 -0.96 -0.01 1.58 -1.27
0.43 1.30 0.43 -1.31 0.14 -1.31 -1.31 0.72 -0.44 0.43
-0.53 0.27 1.33 -1.33 -1.33 -0.26 0.53 -1.60 1.60 0.00
0.13 -1.61 -1.61 0.13 -1.61 0.13 -0.12 0.37 -1.61 -0.12
0.93 -0.23 0.93 -0.92 0.93 -1.38 0.93 1.16 0.23 -0.92
-1.03 -0.00 1.43 1.02 0.20 0.20 -0.41 1.22 -0.41 -1.03
-1.47 0.55 -0.36 -1.10 -0.55 0.37 0.74 -0.36 -1.47 -1.10
-0.17 -0.50 -1.49 0.50 -0.50 1.66 -1.16 1.33 1.16 -0.33
-0.16 -1.07 1.34 0.29 -0.31 -1.07 -1.07 0.74 0.74 0.89
-1.25 0.01 -1.25 -1.38 1.26 -0.27 -1.11 0.15 -0.55 -0.13
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: -0.00
Standard Deviation of the last row: 1.00
Time taken for SIMD vectorized code: 5.69 seconds.
-----------



Run #15
Matrix before normalization
5.00 10.00 7.00 7.00 6.00 4.00 1.00 1.00 6.00 10.00
3.00 2.00 8.00 11.00 0.00 5.00 2.00 8.00 7.00 0.00
```

```
3.00 7.00 3.00 7.00 12.00 0.00 3.00 9.00 0.00 7.00
12.00 7.00 4.00 2.00 7.00 4.00 4.00 2.00 3.00 12.00
13.00 12.00 10.00 11.00 3.00 9.00 9.00 10.00 8.00 11.00
5.00 2.00 16.00 0.00 8.00 6.00 6.00 2.00 5.00 2.00
14.00 7.00 4.00 8.00 0.00 2.00 4.00 10.00 14.00 4.00
9.00 12.00 9.00 8.00 2.00 1.00 2.00 9.00 15.00 0.00
2.00 18.00 18.00 5.00 15.00 7.00 13.00 11.00 22.00 5.00
11.00 3.00 18.00 4.00 12.00 14.00 17.00 24.00 22.00 24.00
Mean of the first row: 4.99
Standard Deviation of the first row: 3.16
Mean of the last row: 16378.62
Standard Deviation of the last row: 9430.00

Matrix after normalization
0.00 1.58 0.64 0.64 0.32 -0.31 -1.26 -1.26 0.32 1.58
-0.72 -1.02 0.73 1.60 -1.60 -0.14 -1.02 0.73 0.44 -1.60
-0.79 0.28 -0.79 0.28 1.61 -1.60 -0.79 0.81 -1.60 0.28
1.36 0.12 -0.62 -1.12 0.12 -0.62 -0.62 -1.12 -0.87 1.36
1.39 1.16 0.69 0.92 -0.93 0.46 0.46 0.69 0.23 0.92
-0.61 -1.22 1.63 -1.63 0.00 -0.41 -0.41 -1.22 -0.61 -1.22
0.90 -0.37 -0.92 -0.19 -1.65 -1.28 -0.92 0.18 0.90 -0.92
-0.16 0.33 -0.16 -0.33 -1.32 -1.48 -1.32 -0.16 0.82 -1.65
-1.35 1.06 1.06 -0.90 0.61 -0.60 0.31 0.01 1.67 -0.90
-0.14 -1.25 0.83 -1.11 -0.00 0.28 0.69 1.66 1.38 1.66
Mean of the first row: 0.00
Standard Deviation of the first row: 1.00
Mean of the last row: 0.00
Standard Deviation of the last row: 1.00
Time taken for SIMD vectorized code: 4.72 seconds.
```