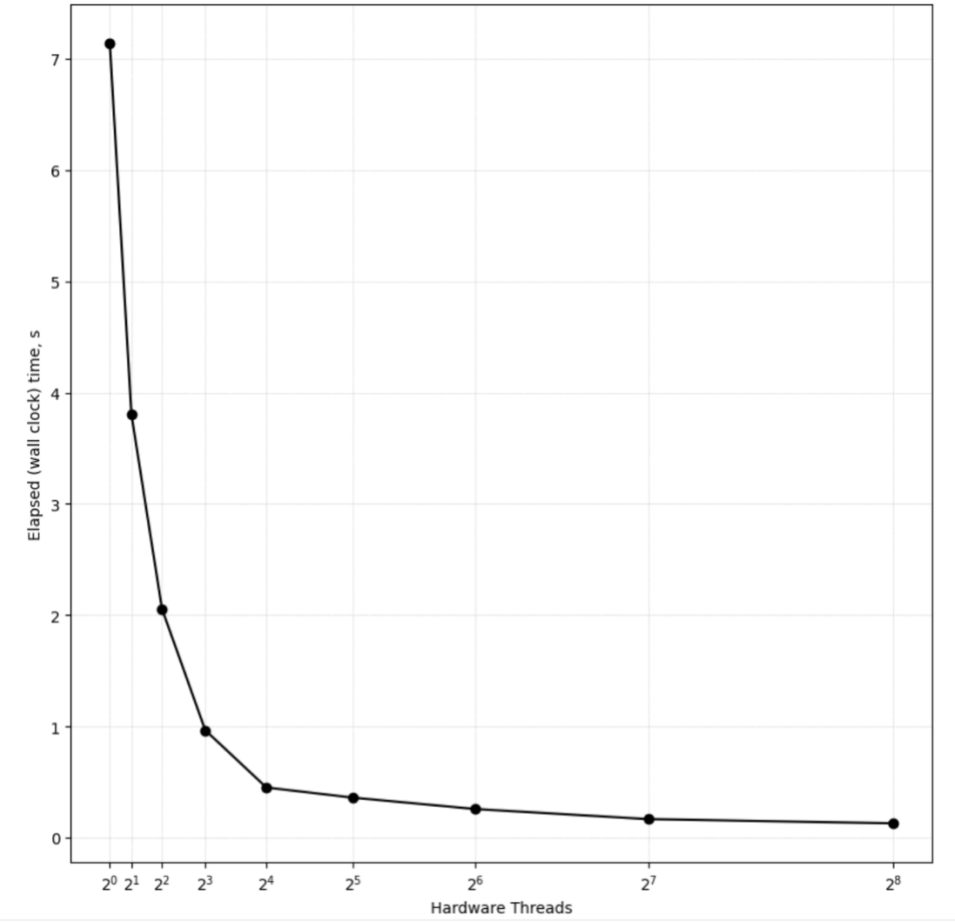
1. Runtime Plot



2. Code Listing

Code written in C++

```
#include <bits/stdc++.h>
#include <omp.h>
using namespace std;

#define ORDER 1000
#define AVAL 5.0
#define BVAL 7.0
```

```
int main(int argc, char* argv[]){
  int Pdim, Ndim, Mdim;
  int i,j,k;
  double tmpVal;
  Ndim = Mdim = Pdim = ORDER;
  vector<double> A(Ndim*Pdim, AVAL);
  vector<double> B(Pdim*Mdim, BVAL);
  vector<double> C(Mdim*Ndim, 0);

  int thread_nums = atoi(argv[1]);
  omp_set_num_threads(thread_nums);

  double start = omp_get_wtime();

  #pragma omp parallel for private(tmpVal, i, j, k)
  for(int i = 0; i<Ndim; i++){
    for(int j = 0; j<Mdim; j++){
      tmpVal = 0.0;
      for (k = 0; k < Pdim; k++) {
              tmpVal += A[i * Ndim + k] * B[k * Pdim + j];
          }
          C[i * Ndim + j] = tmpVal;
    }
  }

  double end = omp_get_wtime();
  double run_time = end - start;
  printf("%.6f,", run_time);
  return 0;
```

}

3. Program Output

i. Makefile output –

```
Running matrix_mult with 1 threads...
Running matrix_mult with 2 threads...
Running matrix_mult with 4 threads...
Running matrix_mult with 8 threads...
Running matrix_mult with 16 threads...
Running matrix_mult with 32 threads...
Running matrix_mult with 64 threads...
Running matrix_mult with 128 threads...
Running matrix_mult with 256 threads...
```

ii. Results File Output –

```
# Threads Elapsed_Time (s)
7.139942,3.803579,2.055581,0.965708,0.450673,0.359758,0.257488,0.166898,0.129000
```

4. MATLAB plot script

```
import numpy as np

import matplotlib.pyplot as plt



hardware_threads = np.array([2**i for i in range(0, 9)])  # 2^1 to 2^7

elapsed_time =
[7.139942,3.803579,2.055581,0.965708,0.450673,0.359758,0.257488,0.166898,0.129000]

transformed_x = np.sqrt(hardware_threads)



plt.figure(figsize=(10, 10))
```

```
plt.plot(transformed_x, elapsed_time, marker='o', linestyle='-', color='black')

plt.xticks(transformed_x, [f"$2^{i}$" for i in range(0, 9)])



plt.xlabel("Hardware Threads")

plt.ylabel("Elapsed (wall clock) time, s")

plt.grid(True, which="both", linestyle=":", linewidth=0.5)
```

5. Results Analysis

The time taken drastically reduces as number of threads increases from 1->2->4->8->16, reducing the time taken by almost an order of 2 for each iteration. However, as we go to higher number of hardware threads from 64->128->256 the decrease in time taken becomes more marginal as evidenced by the runtime plot plateauing out around 2^5 threads.