INDIAN INSTITUTE OF TECHNOLOGY GANDHINAGAR

ES 215 COMPUTER ORGANISATION AND ARCHITECTURE

A REPORT ON THE

ASSIGNMENT 1

Submitted By:

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All codes are available at the GitHub repository link for your kind perusal: https://github.com/JohnTwiprahamDebbarma/ES215_Computer_Organisation_And_Architecture

Solution to Question No. 1

The implementation of program(s) to list the first 50 fibonacci numbers in C and C++ is done and the outputs are:

a. **Using Recursion:** The time taken using Recursion for the above task in C is 93.570617 seconds and that in C++ comes out to be 94.4461 seconds.
b. **Using Loop:** Using this method, the speedup of listing the first 50 fibonacci numbers in C by keeping the recursion as the baseline comes out to be 3226573.000000 and the speedup of listing the first 50 fibonacci numbers in C++ by keeping the recursion as the baseline comes out to be 2.0988e+06.
c. **Using Recursion and Memoization:** Using this method, the speedup of listing the first 50 fibonacci numbers in C by keeping the recursion as the baseline comes out to be 93570617.000000 and the speedup of listing the first 50 fibonacci numbers in C++ by keeping the recursion as the baseline comes out to be 1.34923e+07.
d. **Using Loop and Memoization:** Using this method, the speedup of listing the first 50 fibonacci numbers in C by keeping the recursion as the baseline comes out to be 31190205.666667 and the speedup of listing the first 50 fibonacci numbers in C++ by keeping the recursion as the baseline comes out to be 1.18058e+07.

Solution to Question No. 2(a)

The output of the problem comes as follows:

In C++:

Compiling 64x64 integer matrix multiplication program and time taken is:

real 0m0.581s
user 0m0.298s
sys 0m0.201s
Running the compiled program and time taken is:
Generated matrices (int) for N=64 and saved to files.
Multiplication result for integer matrices of size 64 saved to matrix_int_result_64.txt

real 0m0.422s
user 0m0.005s
sys 0m0.001s
Compiling 128x128 integer matrix multiplication program and time taken is:

real 0m0.322s
user 0m0.298s
sys 0m0.039s
Running the compiled program and time taken is:
Generated matrices (int) for N=128 and saved to files.
Multiplication result for integer matrices of size 128 saved to matrix_int_result_128.txt

real 0m0.279s
user 0m0.017s
sys 0m0.001s
Compiling 256x256 integer matrix multiplication program and time taken is:

real 0m0.334s
user 0m0.318s
sys 0m0.037s
Running the compiled program and time taken is:
Generated matrices (int) for N=256 and saved to files.
Multiplication result for integer matrices of size 256 saved to matrix_int_result_256.txt

real 0m0.350s
user 0m0.112s
sys 0m0.003s
Compiling 512x512 integer matrix multiplication program and time taken is:

real 0m0.314s
user 0m0.300s
sys 0m0.035s
Running the compiled program and time taken is:
Generated matrices (int) for N=512 and saved to files.
Multiplication result for integer matrices of size 512 saved to matrix_int_result_512.txt

real 0m0.974s
user 0m0.721s
sys 0m0.007s
Compiling 1024x1024 integer matrix multiplication program and time taken is:

real 0m0.337s
user 0m0.310s
sys 0m0.039s
Running the compiled program and time taken is:
Generated matrices (int) for N=1024 and saved to files.
Multiplication result for integer matrices of size 1024 saved to matrix_int_result_1024.txt

real 0m5.844s
user 0m5.459s
sys 0m0.033s
Compiling 64x64 double matrix multiplication program and time taken is:

real 0m0.345s

user 0m0.317s
sys 0m0.047s
Running the compiled program and time taken is:
Generated matrices (double) for N=64 and saved to files.
Multiplication result for double matrices of size 64 saved to matrix_double_result_64.txt

real 0m0.423s
user 0m0.015s
sys 0m0.004s
Compiling 128x128 double matrix multiplication program and time taken is:

real 0m0.373s
user 0m0.335s
sys 0m0.043s
Running the compiled program and time taken is:
Generated matrices (double) for N=128 and saved to files.
Multiplication result for double matrices of size 128 saved to matrix_double_result_128.txt

real 0m0.336s
user 0m0.030s
sys 0m0.002s
Compiling 256x256 double matrix multiplication program and time taken is:

real 0m0.330s
user 0m0.314s
sys 0m0.038s
Running the compiled program and time taken is:
Generated matrices (double) for N=256 and saved to files.
Multiplication result for double matrices of size 256 saved to matrix_double_result_256.txt

real 0m0.614s
user 0m0.141s
sys 0m0.006s
Compiling 512x512 double matrix multiplication program and time taken is:

real 0m0.323s
user 0m0.310s
sys 0m0.035s
Running the compiled program and time taken is:
Generated matrices (double) for N=512 and saved to files.
Multiplication result for double matrices of size 512 saved to matrix_double_result_512.txt

real 0m1.280s
user 0m0.872s
sys 0m0.012s
Compiling 1024x1024 double matrix multiplication program and time taken is:

real 0m0.323s
user 0m0.307s
sys 0m0.034s
Running the compiled program and time taken is:
Generated matrices (double) for N=1024 and saved to files.
Multiplication result for double matrices of size 1024 saved to matrix_double_result_1024.txt

real 0m6.536s
user 0m6.188s
sys 0m0.039s

In Python:

64_int
Generated matrices (int) for N=64 and saved to files.
Multiplication result for integer matrices of size 64 saved to matrix_int_result_64.txt

real 0m0.325s
user 0m1.634s
sys 0m0.287s
128_int
Generated matrices (int) for N=128 and saved to files.
Multiplication result for integer matrices of size 128 saved to
matrix_int_result_128.txt

real 0m0.789s
user 0m2.124s
sys 0m0.529s
256_int
Generated matrices (int) for N=256 and saved to files.
Multiplication result for integer matrices of size 256 saved to
matrix_int_result_256.txt

real 0m5.418s
user 0m6.153s
sys 0m1.113s
512_int
Generated matrices (int) for N=512 and saved to files.
Multiplication result for integer matrices of size 512 saved to
matrix_int_result_512.txt

real 0m42.794s
user 0m43.788s
sys 0m0.608s
1024_int

Generated matrices (int) for N=1024 and saved to files.
Multiplication result for integer matrices of size 1024 saved to matrix_int_result_1024.txt

real 5m41.171s
user 5m40.164s
sys 0m0.951s
64_double
Generated matrices (double) for N=64 and saved to files.
Multiplication result for double matrices of size 64 saved to matrix_double_result_64.txt

real 0m0.268s
user 0m1.477s
sys 0m0.207s
128_double
Generated matrices (double) for N=128 and saved to files.
Multiplication result for double matrices of size 128 saved to matrix_double_result_128.txt

real 0m0.879s
user 0m2.052s
sys 0m0.540s
256_double
Generated matrices (double) for N=256 and saved to files.
Multiplication result for double matrices of size 256 saved to matrix_double_result_256.txt

real 0m5.637s
user 0m7.189s
sys 0m0.100s
512_double
Generated matrices (double) for N=512 and saved to files.
Multiplication result for double matrices of size 512 saved to matrix_double_result_512.txt

real 0m43.736s
user 0m44.787s
sys 0m0.424s
1024_double
Generated matrices (double) for N=1024 and saved to files.
Multiplication result for double matrices of size 1024 saved to matrix_double_result_1024.txt

real 5m47.687s
user 5m46.371s
sys 0m1.753s

Solution to Question No. 2(b)

The output for the problem comes out to be:

In C++:

Generated matrices (int) for N=64 and saved to files.
Time for int matrix multiplication for N=64 and iteration=1:
Meat portion time: 3.47275e+06 nanoseconds
Total time: 5793250 nanoseconds
Meat portion proportion: 59.9448%
Time for int matrix multiplication for N=64 and iteration=2:
Meat portion time: 2.83312e+06 nanoseconds
Total time: 4832542 nanoseconds
Meat portion proportion: 58.626%
Time for int matrix multiplication for N=64 and iteration=3:
Meat portion time: 2.76242e+06 nanoseconds
Total time: 4548750 nanoseconds
Meat portion proportion: 60.7291%
Median Meat Time for int matrix multiplication for N=64: 2.83312e+06 nanoseconds
Median Total Time for int matrix multiplication for N=64: 4.83254e+06 nanoseconds

Generated matrices (double) for N=64 and saved to files.
Time for double matrix multiplication for N=64 and iteration=1:
  Meat portion time: 1.90567e+06 nanoseconds
  Total time: 2879750 nanoseconds
  Meat portion proportion: 66.1747%
Time for double matrix multiplication for N=64 and iteration=2:
  Meat portion time: 1.68183e+06 nanoseconds
  Total time: 3049125 nanoseconds
  Meat portion proportion: 55.1579%
Time for double matrix multiplication for N=64 and iteration=3:
  Meat portion time: 1.83875e+06 nanoseconds
  Total time: 3245834 nanoseconds
  Meat portion proportion: 56.6495%
Median Meat Time for double matrix multiplication for N=64: 1.83875e+06 nanoseconds
Median Total Time for double matrix multiplication for N=64: 3.04912e+06 nanoseconds
Generated matrices (int) for N=128 and saved to files.
Time for int matrix multiplication for N=128 and iteration=1:
  Meat portion time: 1.24443e+07 nanoseconds
  Total time: 16511833 nanoseconds
  Meat portion proportion: 75.3662%
Time for int matrix multiplication for N=128 and iteration=2:
  Meat portion time: 1.10703e+07 nanoseconds
  Total time: 15107000 nanoseconds
  Meat portion proportion: 73.2795%
Time for int matrix multiplication for N=128 and iteration=3:
  Meat portion time: 1.01934e+07 nanoseconds
  Total time: 14053667 nanoseconds
  Meat portion proportion: 72.5321%
Median Meat Time for int matrix multiplication for N=128: 1.10703e+07 nanoseconds
Median Total Time for int matrix multiplication for N=128: 1.5107e+07 nanoseconds
Generated matrices (double) for N=128 and saved to files.
Time for double matrix multiplication for N=128 and iteration=1:
  Meat portion time: 1.02903e+07 nanoseconds
  Total time: 14341875 nanoseconds
  Meat portion proportion: 71.7503%
Time for double matrix multiplication for N=128 and iteration=2:

  Meat portion time: 9.68538e+06 nanoseconds
  Total time: 13397208 nanoseconds
  Meat portion proportion: 72.294%
Time for double matrix multiplication for N=128 and iteration=3:
  Meat portion time: 9.60275e+06 nanoseconds
  Total time: 13398750 nanoseconds
  Meat portion proportion: 71.669%
Median Meat Time for double matrix multiplication for N=128: 9.68538e+06 nanoseconds
Median Total Time for double matrix multiplication for N=128: 1.33988e+07 nanoseconds
Generated matrices (int) for N=256 and saved to files.
Time for int matrix multiplication for N=256 and iteration=1:
  Meat portion time: 7.83754e+07 nanoseconds
  Total time: 92081541 nanoseconds
  Meat portion proportion: 85.1152%
Time for int matrix multiplication for N=256 and iteration=2:
  Meat portion time: 7.90944e+07 nanoseconds
  Total time: 92532375 nanoseconds
  Meat portion proportion: 85.4775%
Time for int matrix multiplication for N=256 and iteration=3:
  Meat portion time: 7.84353e+07 nanoseconds
  Total time: 92837375 nanoseconds
  Meat portion proportion: 84.4868%
Median Meat Time for int matrix multiplication for N=256: 7.84353e+07 nanoseconds
Median Total Time for int matrix multiplication for N=256: 9.25324e+07 nanoseconds
Generated matrices (double) for N=256 and saved to files.
Time for double matrix multiplication for N=256 and iteration=1:
  Meat portion time: 7.83542e+07 nanoseconds
  Total time: 92906458 nanoseconds
  Meat portion proportion: 84.3367%
Time for double matrix multiplication for N=256 and iteration=2:
  Meat portion time: 8.11802e+07 nanoseconds
  Total time: 95261500 nanoseconds
  Meat portion proportion: 85.2183%
Time for double matrix multiplication for N=256 and iteration=3:
  Meat portion time: 7.98817e+07 nanoseconds
  Total time: 94385083 nanoseconds

  Meat portion proportion: 84.6338%
Median Meat Time for double matrix multiplication for N=256: 7.98817e+07 nanoseconds
Median Total Time for double matrix multiplication for N=256: 9.43851e+07 nanoseconds
Generated matrices (int) for N=512 and saved to files.
Time for int matrix multiplication for N=512 and iteration=1:
  Meat portion time: 6.80874e+08 nanoseconds
  Total time: 735161375 nanoseconds
  Meat portion proportion: 92.6156%
Time for int matrix multiplication for N=512 and iteration=2:
  Meat portion time: 6.62221e+08 nanoseconds
  Total time: 717693250 nanoseconds
  Meat portion proportion: 92.2708%
Time for int matrix multiplication for N=512 and iteration=3:
  Meat portion time: 6.51901e+08 nanoseconds
  Total time: 706005167 nanoseconds
  Meat portion proportion: 92.3366%
Median Meat Time for int matrix multiplication for N=512: 6.62221e+08 nanoseconds
Median Total Time for int matrix multiplication for N=512: 7.17693e+08 nanoseconds
Generated matrices (double) for N=512 and saved to files.
Time for double matrix multiplication for N=512 and iteration=1:
  Meat portion time: 6.81915e+08 nanoseconds
  Total time: 736554792 nanoseconds
  Meat portion proportion: 92.5817%
Time for double matrix multiplication for N=512 and iteration=2:
  Meat portion time: 6.70435e+08 nanoseconds
  Total time: 726298458 nanoseconds
  Meat portion proportion: 92.3084%
Time for double matrix multiplication for N=512 and iteration=3:
  Meat portion time: 6.77501e+08 nanoseconds
  Total time: 730924250 nanoseconds
  Meat portion proportion: 92.691%
Median Meat Time for double matrix multiplication for N=512: 6.77501e+08 nanoseconds
Median Total Time for double matrix multiplication for N=512: 7.30924e+08 nanoseconds
Generated matrices (int) for N=1024 and saved to files.

Time for int matrix multiplication for N=1024 and iteration=1:
  Meat portion time: 5.49234e+09 nanoseconds
  Total time: 5710353083 nanoseconds
  Meat portion proportion: 96.1821%
Time for int matrix multiplication for N=1024 and iteration=2:
  Meat portion time: 5.3423e+09 nanoseconds
  Total time: 5550614583 nanoseconds
  Meat portion proportion: 96.247%
Time for int matrix multiplication for N=1024 and iteration=3:
  Meat portion time: 5.39028e+09 nanoseconds
  Total time: 5608155458 nanoseconds
  Meat portion proportion: 96.115%
Median Meat Time for int matrix multiplication for N=1024: 5.39028e+09 nanoseconds
Median Total Time for int matrix multiplication for N=1024: 5.60816e+09 nanoseconds
Generated matrices (double) for N=1024 and saved to files.
Time for double matrix multiplication for N=1024 and iteration=1:
  Meat portion time: 5.34001e+09 nanoseconds
  Total time: 5572241833 nanoseconds
  Meat portion proportion: 95.8323%
Time for double matrix multiplication for N=1024 and iteration=2:
  Meat portion time: 5.45735e+09 nanoseconds
  Total time: 5670228459 nanoseconds
  Meat portion proportion: 96.2458%
Time for double matrix multiplication for N=1024 and iteration=3:
  Meat portion time: 5.39203e+09 nanoseconds
  Total time: 5605106708 nanoseconds
  Meat portion proportion: 96.1986%
Median Meat Time for double matrix multiplication for N=1024: 5.39203e+09 nanoseconds
Median Total Time for double matrix multiplication for N=1024: 5.60511e+09 nanoseconds

In Python:

Generated matrices (int) for N=64 and saved to files.
Time for integer matrix multiplication for N=64 and iteration=1:

Meat portion time: 0.089035 seconds
Total time: 0.089766 seconds
Meat portion proportion: 99.19%
Time for integer matrix multiplication for N=64 and iteration=2:
Meat portion time: 0.090449 seconds
Total time: 0.091148 seconds
Meat portion proportion: 99.23%
Time for integer matrix multiplication for N=64 and iteration=3:
Meat portion time: 0.088627 seconds
Total time: 0.089314 seconds
Meat portion proportion: 99.23%
Generated matrices (double) for N=64 and saved to files.
Time for double matrix multiplication for N=64 and iteration=1:
Meat portion time: 0.085125 seconds
Total time: 0.086564 seconds
Meat portion proportion: 98.34%
Time for double matrix multiplication for N=64 and iteration=2:
Meat portion time: 0.085484 seconds
Total time: 0.086861 seconds
Meat portion proportion: 98.41%
Time for double matrix multiplication for N=64 and iteration=3:
Meat portion time: 0.086545 seconds
Total time: 0.087934 seconds
Meat portion proportion: 98.42%
Generated matrices (int) for N=128 and saved to files.
Time for integer matrix multiplication for N=128 and iteration=1:
Meat portion time: 0.713654 seconds
Total time: 0.716563 seconds
Meat portion proportion: 99.59%
Time for integer matrix multiplication for N=128 and iteration=2:
Meat portion time: 0.712264 seconds
Total time: 0.715077 seconds
Meat portion proportion: 99.61%
Time for integer matrix multiplication for N=128 and iteration=3:
Meat portion time: 0.706546 seconds
Total time: 0.708728 seconds
Meat portion proportion: 99.69%
Generated matrices (double) for N=128 and saved to files.
Time for double matrix multiplication for N=128 and iteration=1:
Meat portion time: 0.688139 seconds

Total time: 0.693169 seconds
Meat portion proportion: 99.27%
Time for double matrix multiplication for N=128 and iteration=2:
Meat portion time: 0.677625 seconds
Total time: 0.683768 seconds
Meat portion proportion: 99.10%
Time for double matrix multiplication for N=128 and iteration=3:
Meat portion time: 0.674846 seconds
Total time: 0.679815 seconds
Meat portion proportion: 99.27%
Generated matrices (int) for N=256 and saved to files.
Time for integer matrix multiplication for N=256 and iteration=1:
Meat portion time: 5.677347 seconds
Total time: 5.685104 seconds
Meat portion proportion: 99.86%
Time for integer matrix multiplication for N=256 and iteration=2:
Meat portion time: 5.567229 seconds
Total time: 5.574920 seconds
Meat portion proportion: 99.86%
Time for integer matrix multiplication for N=256 and iteration=3:
Meat portion time: 5.624307 seconds
Total time: 5.632131 seconds
Meat portion proportion: 99.86%
Generated matrices (double) for N=256 and saved to files.
Time for double matrix multiplication for N=256 and iteration=1:
Meat portion time: 5.552380 seconds
Total time: 5.570984 seconds
Meat portion proportion: 99.67%
Time for double matrix multiplication for N=256 and iteration=2:
Meat portion time: 5.458349 seconds
Total time: 5.477552 seconds
Meat portion proportion: 99.65%
Time for double matrix multiplication for N=256 and iteration=3:
Meat portion time: 5.527812 seconds
Total time: 5.545929 seconds
Meat portion proportion: 99.67%
Generated matrices (int) for N=512 and saved to files.
Time for integer matrix multiplication for N=512 and iteration=1:
Meat portion time: 45.161192 seconds
Total time: 45.191466 seconds

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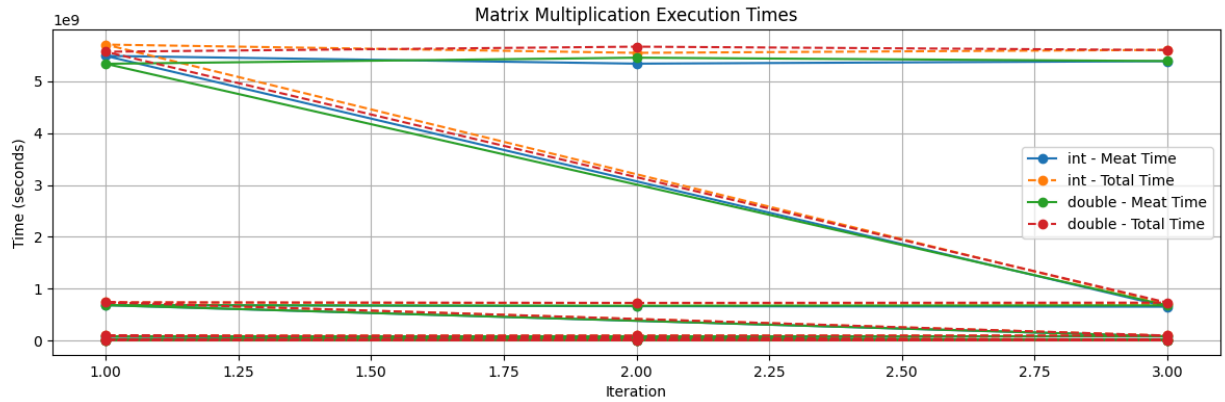
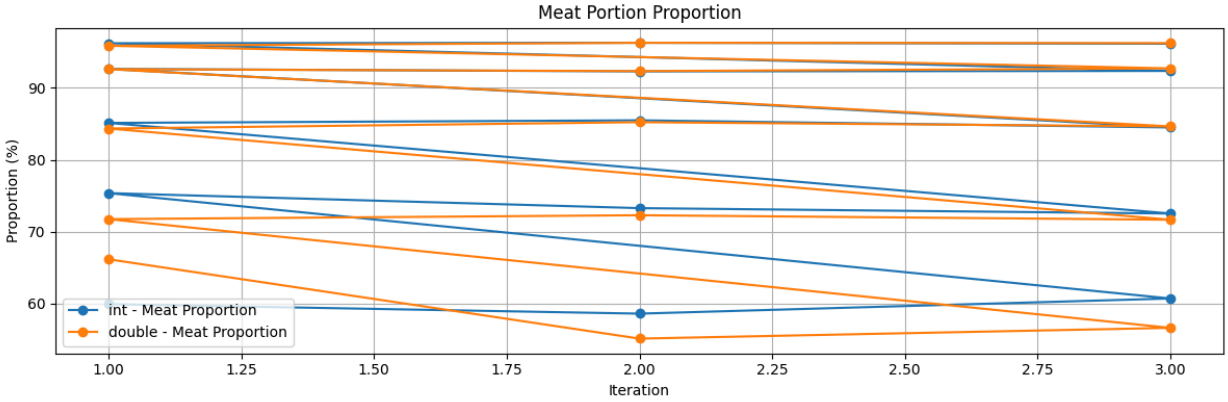
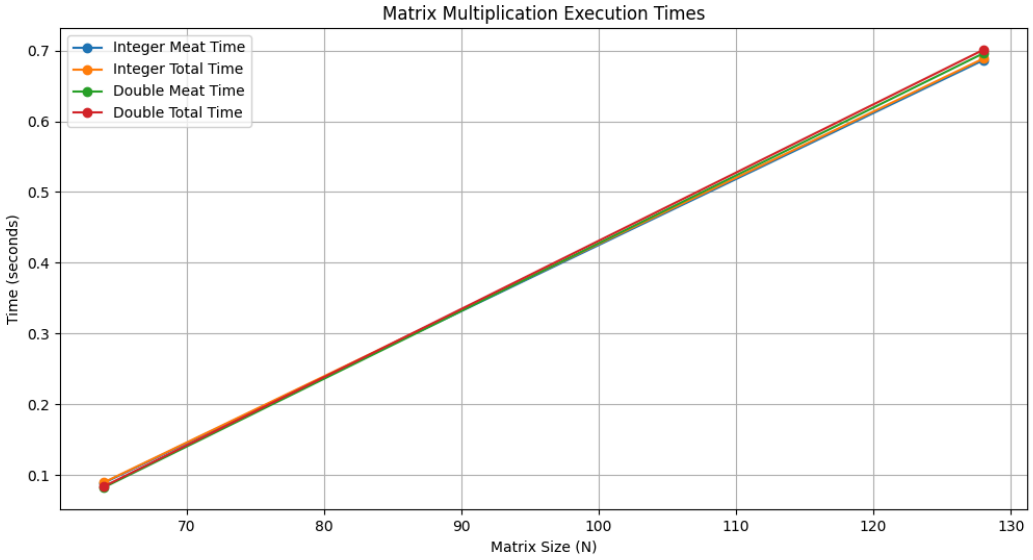
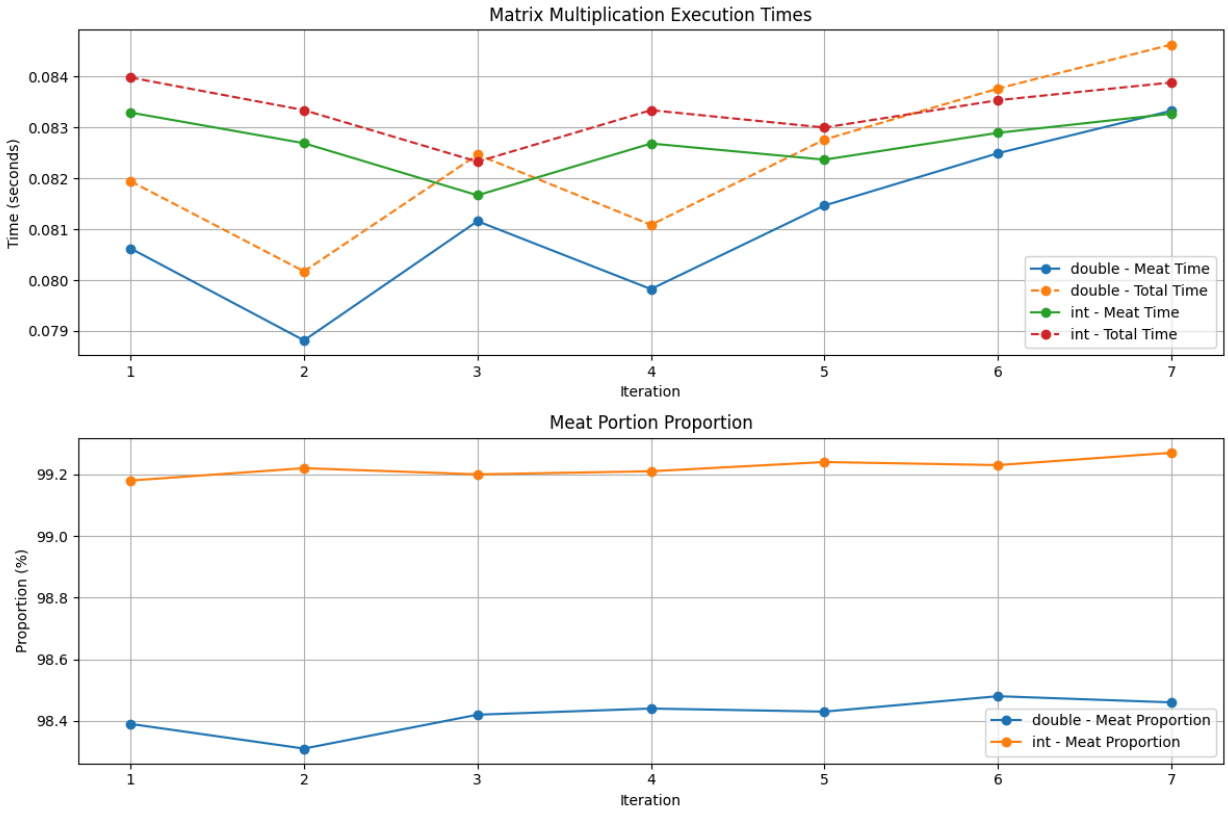
  Meat portion proportion: 99.93%
Time for integer matrix multiplication for N=512 and iteration=2:
  Meat portion time: 45.760794 seconds
  Total time: 45.791416 seconds
  Meat portion proportion: 99.93%
Time for integer matrix multiplication for N=512 and iteration=3:
  Meat portion time: 44.721293 seconds
  Total time: 44.750961 seconds
  Meat portion proportion: 99.93%
Generated matrices (double) for N=512 and saved to files.
Time for double matrix multiplication for N=512 and iteration=1:
  Meat portion time: 43.081019 seconds
  Total time: 43.153235 seconds
  Meat portion proportion: 99.83%
Time for double matrix multiplication for N=512 and iteration=2:
  Meat portion time: 43.795557 seconds
  Total time: 43.868667 seconds
  Meat portion proportion: 99.83%
Time for double matrix multiplication for N=512 and iteration=3:
  Meat portion time: 43.726042 seconds
  Total time: 43.804641 seconds
  Meat portion proportion: 99.82%
Generated matrices (int) for N=1024 and saved to files.
Time for integer matrix multiplication for N=1024 and iteration=1:
  Meat portion time: 370.452917 seconds
  Total time: 370.574347 seconds
  Meat portion proportion: 99.97%
```

Solution to Question No. 2(c)


Matrix Multiplication Execution Times
1e9
Time (seconds)
Iteration
int - Meat Time
int - Total Time
double - Meat Time
double - Total Time


Meat Portion Proportion
Proportion (%)
Iteration
int - Meat Proportion
double - Meat Proportion


Matrix Multiplication Execution Times
Time (seconds)
Matrix Size (N)
Integer Meat Time
Integer Total Time
Double Meat Time
Double Total Time



Observations: It is observed that, for a higher value of N, both the system and Program execution times tend to increase as there is more memory usage for which the calculations required for each step for the matrix multiplications increase and thus, the complicacies increase for a higher sized matrix multiplications. Also, they are somewhat grouped for each of int and double, which is also obvious keeping the assumption that the systems on which the programs are run are constant.