CPU performance (GFLOPS)	MEMORY BANDWIDTH (MB/s)	LINPACK benchmark (MFLOPS)
66	41800	4,861.17

3. Obtain the information about the theoretical CPU performance (MFLOPS) and the processor-memory interface speed (MB/s) (eg, file /proc/cpuinfo, /proc/meminfo and based on the Internet)

MFLOPS as a performance metric consists of million floating point operations per second. Theoretically, its formula is:

$$MFLOPS = (number\ floating\ point\ operations\ in\ program) / (execution\ time\ * 10^6)$$

Each MFLOPS performance metric depends on the number of floating point operations that each program needs to perform, because of this, it is said that MFLOPS is more fair that MIPS because between two different PCs executing same program may have same number of instructions but not necessarily have same float point operations number.

However, as the others performance metrics, MFLOPS should not be used as the only metric because there are different types of MFLOPS as MFLOPS peak and MFLOPS normalized and each one provides different information and clock speed is not everything when comparing different CPUs from different families and even if they do not have the same number of cores.

3.1 Let's check /**prop/cpuinfo** that displays the following information:

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ cat /proc/cpuinfo
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 158
model name      : Intel(R) Core(TM) i7-8750H CPU @ 2.20GHz
stepping        : 10
microcode       : 0xde
cpu MHz         : 2207.999
cache size      : 9216 KB
physical id     : 0
siblings        : 1
core id         : 0
cpu cores       : 1
apicid          : 0
initial apicid  : 0
fpu             : yes
fpu_exception   : yes
cpuid level     : 22
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush mmx
fxsr sse sse2 ss syscall nx pdpe1gb rdtscp lm constant_tsc arch_perfmon nopl xtopology tsc_reliable no
nstop_tsc cpuid pni pclmulqdq ssse3 fma cx16 pcid sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer
 aes xsave avx f16c rdrand hypervisor lahf_lm abm 3dnowprefetch cpuid_fault invpcid_single pti ssbd ib
rs ibpb stibp fsgsbase tsc_adjust bmi1 avx2 smep bmi2 invpcid rdseed adx smap clflushopt xsaveopt xsav
ec xgetbv1 xsaves arat md_clear flush_l1d arch_capabilities
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf mds swapgs itlb_multihit s
rbds
bogomips        : 4415.99
clflush size    : 64
cache_alignment : 64
address sizes   : 45 bits physical, 48 bits virtual
power management:
```

Also, it shows the same information about the other processors.

Some of the fields are:

- ❏ **Processor:** id of the processor starting in 0
- ❏ **CPU family:** type of processor, in this case because it is an intel one, we only have to place the number that is contained by this field in front of 86 to get the value.
- ❏ **Model name:** name of the processor
- ❏ **CPU MHz:** speed of the processor (to the thousandth decimal point)
- ❏ **Cache size:** memory cache available to this processor
- ❏ **Flags:** attributes for the processor

Now, we can calculate GFLOPS:
> ➔ **5 ipc* 2.20 ghz* 6 cores = 66 GFLOPS.**

If we compare it with other cpuinfo files as this one I found in
https://www.thegeekdiary.com/proccpuinfo-file-explained/ :

```
# cat /proc/cpuinfo
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 45
model name      : Intel(R) Xeon(R) CPU E5-2660 0 @ 2.20GHz
stepping        : 6
microcode       : 1561
cpu MHz         : 600.000
cache size      : 20480 KB
physical id     : 0
siblings        : 16
core id         : 0
cpu cores       : 8
apicid          : 0
initial apicid  : 0
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov p
bogomips        : 4399.93
clflush size    : 64
cache_alignment : 64
address sizes   : 46 bits physical, 48 bits virtual
power management:
```

3.2 Let's check **/prop/meminfo** file in our pc and also another example from the web
https://www.thegeekdiary.com/understanding-proc-meminfo-file-analyzing-memory-utilization-in-linux/

```
ifranl00@ubuntu:~$ cat /proc/meminfo
MemTotal:         4000696 kB
MemFree:           545660 kB
MemAvailable:     1570304 kB
Buffers:            40252 kB
Cached:           1244616 kB
SwapCached:             0 kB
Active:           1963792 kB
Inactive:          926648 kB
Active(anon):     1607676 kB
Inactive(anon):    102920 kB
Active(file):      356116 kB
Inactive(file):    823728 kB
Unevictable:            0 kB
Mlocked:                0 kB
SwapTotal:        2097148 kB
SwapFree:         2097148 kB
Dirty:                648 kB
Writeback:              0 kB
AnonPages:        1605592 kB
Mapped:            526608 kB
Shmem:             105028 kB
KReclaimable:       99324 kB
Slab:              222008 kB
SReclaimable:       99324 kB
SUnreclaim:        122684 kB
KernelStack:        14720 kB
PageTables:         21844 kB
NFS_Unstable:           0 kB
Bounce:                 0 kB
WritebackTmp:           0 kB
CommitLimit:      4097496 kB
Committed_AS:     5284964 kB
VmallocTotal:   34359738367 kB
VmallocUsed:        28428 kB
VmallocChunk:           0 kB
Percpu:             91648 kB
HardwareCorrupted:      0 kB
AnonHugePages:          0 kB
ShmemHugePages:         0 kB
ShmemPmdMapped:         0 kB
FileHugePages:          0 kB
FilePmdMapped:          0 kB
HugePages_Total:        0
HugePages_Free:         0
HugePages_Rsvd:         0
HugePages_Surp:         0
Hugepagesize:        2048 kB
Hugetlb:                0 kB
DirectMap4k:       241472 kB
DirectMap2M:      3952640 kB
DirectMap1G:      2097152 kB
```

```
# cat /proc/meminfo
MemTotal:        1882064 kB
MemFree:         1376380 kB
MemAvailable:    1535676 kB
Buffers:            2088 kB
Cached:           292324 kB
SwapCached:            0 kB
Active:           152944 kB
Inactive:         252628 kB
Active(anon):     111328 kB
Inactive(anon):    16508 kB
Active(file):      41616 kB
Inactive(file):   236120 kB
Unevictable:           0 kB
Mlocked:               0 kB
SwapTotal:       2097148 kB
SwapFree:        2097148 kB
Dirty:                40 kB
Writeback:             0 kB
AnonPages:        111180 kB
Mapped:            56396 kB
Shmem:             16676 kB
Slab:              54508 kB
SReclaimable:      25456 kB
SUnreclaim:        29052 kB
KernelStack:        2608 kB
PageTables:         5056 kB
NFS_Unstable:          0 kB
Bounce:                0 kB
WritebackTmp:          0 kB
CommitLimit:     3038180 kB
Committed_AS:     577664 kB
VmallocTotal:   34359738367 kB
VmallocUsed:       14664 kB
VmallocChunk:   34359717628 kB
HardwareCorrupted:     0 kB
AnonHugePages:     24576 kB
HugePages_Total:       0
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       2048 kB
DirectMap4k:       69632 kB
DirectMap2M:     2027520 kB
```

Some interesting fields are:

- **MemTotal:** RAM usable.
- **MemFree:** free memory in low memory region + free memory in high memory region.
- **Buffers:** buffer cache memory.
- **Cached:** disk cache memory - swap cache memory.
- **SwapCache:** memory that is swapped back after being swapped out but present in swapfile.

So with this information, we can see the difference between my computer and the one I obtained on the internet.

Also, with these data and knowing some related fields as the memory type, memory bandwidth can be calculated but Intel official website provide us this required information directly at
https://ark.intel.com/content/www/us/en/ark/products/134906/intel-core-i7-8750h-processor-9m-cache-up-to-4-10-ghz.html

➔ **The maximum speed to read or write by the processor Intel Core i7-8750H in memory is 41.800 MB/s**

4. **Start STREAM test and measure the performance.**
◦ **measurements for different sizes in the range 10.000 - 10.000.000, the results should be presented in the form of a chart (X-axis - size (scale may be logarithmic), Y-axis – time)**


```
ifranl00@ubuntu:~/Documents/LAB4/stream$ ./stream_d
-------------------------------------------------------------
This system uses 8 bytes per DOUBLE PRECISION word.
-------------------------------------------------------------
Array size = 10000000, Offset = 0
Total memory required = 228.9 MB.
Each test is run 10 times, but only
the *best* time for each is used.
-------------------------------------------------------------
Your clock granularity/precision appears to be 1 microseconds.
Each test below will take on the order of 23960 microseconds.
   (= 23960 clock ticks)
Increase the size of the arrays if this shows that
you are not getting at least 20 clock ticks per test.
-------------------------------------------------------------
WARNING -- The above is only a rough guideline.
For best results, please be sure you know the
precision of your system timer.
-------------------------------------------------------------
Function      Rate (MB/s)   RMS time     Min time     Max time
Copy:        13828.8955     0.0167       0.0116       0.0268
Scale:       10046.9891     0.0244       0.0159       0.0387
Add:         10162.2613     0.0303       0.0236       0.0382
Triad:        8918.5955     0.0342       0.0269       0.0561
```
N=10.000.000

```
ifranl00@ubuntu:~/Documents/LAB4/stream$ ./stream_d
-----------------------------------------------------------
This system uses 8 bytes per DOUBLE PRECISION word.
-----------------------------------------------------------
Array size = 1000000, Offset = 0
Total memory required = 22.9 MB.
Each test is run 10 times, but only
the *best* time for each is used.
-----------------------------------------------------------
Your clock granularity/precision appears to be 1 microseconds.
Each test below will take on the order of 2269 microseconds.
   (= 2269 clock ticks)
Increase the size of the arrays if this shows that
you are not getting at least 20 clock ticks per test.
-----------------------------------------------------------
WARNING -- The above is only a rough guideline.
For best results, please be sure you know the
precision of your system timer.
-----------------------------------------------------------
Function      Rate (MB/s)   RMS time     Min time     Max time
Copy:        14506.8880      0.0019       0.0011       0.0030
Scale:       11568.4992      0.0019       0.0014       0.0030
Add:         12403.0675      0.0030       0.0019       0.0043
Triad:       11582.4757      0.0037       0.0021       0.0072
```

N=1.000.000

```
ifranl00@ubuntu:~/Documents/LAB4/stream$ ./stream_d
-----------------------------------------------------------
This system uses 8 bytes per DOUBLE PRECISION word.
-----------------------------------------------------------
Array size = 100000, Offset = 0
Total memory required = 2.3 MB.
Each test is run 10 times, but only
the *best* time for each is used.
-----------------------------------------------------------
Your clock granularity/precision appears to be 1 microseconds.
Each test below will take on the order of 189 microseconds.
   (= 189 clock ticks)
Increase the size of the arrays if this shows that
you are not getting at least 20 clock ticks per test.
-----------------------------------------------------------
WARNING -- The above is only a rough guideline.
For best results, please be sure you know the
precision of your system timer.
-----------------------------------------------------------
Function      Rate (MB/s)   RMS time     Min time     Max time
Copy:        23546.9698      0.0001       0.0001       0.0002
Scale:       28079.0226      0.0001       0.0001       0.0003
Add:         60277.4228      0.0001       0.0000       0.0002
Triad:       58525.1721      0.0001       0.0000       0.0001
```

N=100.000

```
ifranl00@ubuntu:~/Documents/LAB4/stream$ ./stream_d
----------------------------------------------------------
This system uses 8 bytes per DOUBLE PRECISION word.
----------------------------------------------------------
Array size = 10000, Offset = 0
Total memory required = 0.2 MB.
Each test is run 10 times, but only
the *best* time for each is used.
----------------------------------------------------------
Your clock granularity/precision appears to be 1 microseconds.
Each test below will take on the order of 2 microseconds.
   (= 2 clock ticks)
Increase the size of the arrays if this shows that
you are not getting at least 20 clock ticks per test.
----------------------------------------------------------
WARNING -- The above is only a rough guideline.
For best results, please be sure you know the
precision of your system timer.
----------------------------------------------------------
Function      Rate (MB/s)   RMS time    Min time    Max time
Copy:        23140.9876      0.0000      0.0000      0.0000
Scale:       26843.5456      0.0000      0.0000      0.0000
Add:         83886.0800      0.0000      0.0000      0.0000
Triad:       77433.3046      0.0000      0.0000      0.0000
```
N=10.000

SIZE	FUNCTIONS RMS TIME			
	COPY	SCALE	ADD	TRIAD
10000000	0.0167	0.0244	0.0303	0.0342
1000000	0.0019	0.0019	0.003	0.0037
100000	0.001	0.001	0.001	0.001
10000	0	0	0	0

RMS FUNCTIONS
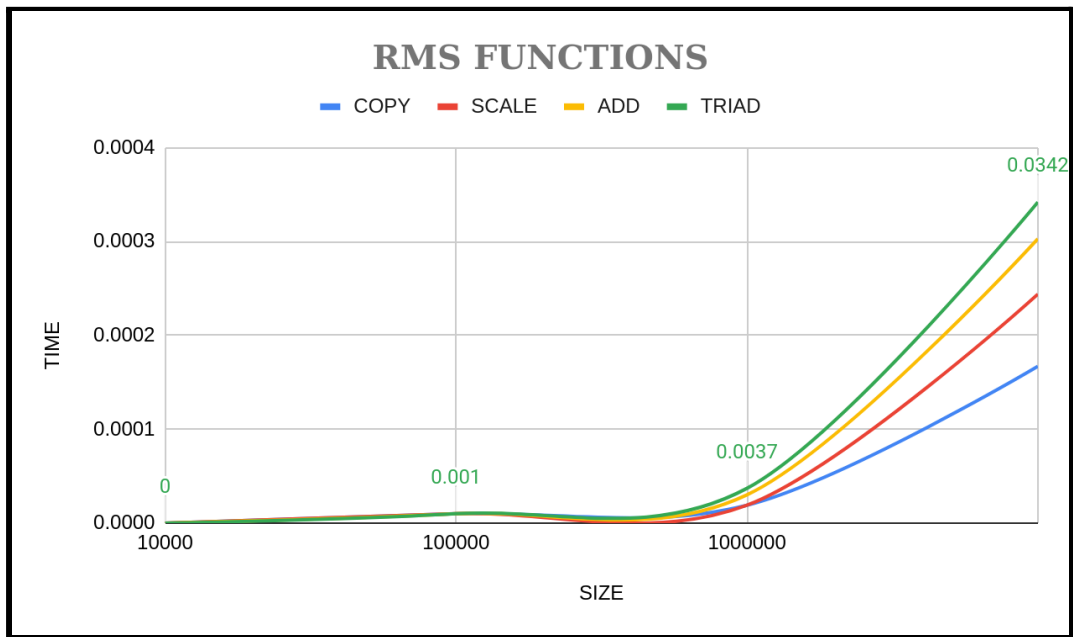
5. **Comparison of the results obtained from theoretical estimates of the memory access time recalculated to the throughput and capacity of the memory-processor bus.**

As we can see from the official page to search about our processor specifications, our memory is of the type DDR4-2666, which means that it could make 2666.67 mega-transfers per second.

Also, teoricately, the maximum speed to read or write by the processor Intel Core i7-8750H in memory is 41.800 MB/s.

The throughput depends on the capacity of the memory bus and we can see that 41800 MB/s is not the maximum rate in some executions. However, we can see that most of the times the throughput does not reach even 40% of its capacity.

Usually, these theoretical calculations do not match with reality because we usually do not even know the real frequency of our memory: (MHz x 8) / 64/4 = actual memory frequency.

6. **Start LINPACK test - note the complete printout from LINPACK: measurement methodology (repetition of calculations, the use of two sizes of the array - array padding, the accuracy of the system of equations solved), calculate the result in MFLOPS.**

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 500
Rolled Double Precision Linpack

Rolled Double Precision Linpack

     norm. resid        resid             machep          x[0]-1          x[n-1]-1
        5.8          1.27986510e-12  2.22044605e-16  5.59552404e-14  3.39728246e-14
     times are reported for matrices of order    500
      dgefa       dgesl       total        kflops       unit       ratio
  times for array with leading dimension of 1001
     0.01586     0.00061     0.01648     5087592      0.00039     0.29425
     0.01845     0.00064     0.01908     4393090      0.00046     0.34077
     0.02134     0.00020     0.02154     3892707      0.00051     0.38457
     0.01711     0.00014     0.01725     4861172      0.00041     0.30796
  times for array with leading dimension of1000
     0.01784     0.00137     0.01921     4363365      0.00046     0.34309
     0.01991     0.00100     0.02091     4008479      0.00050     0.37346
     0.02547     0.00022     0.02569     3263013      0.00061     0.45879
     0.01668     0.00025     0.01694     4949774      0.00040     0.30244
Rolled Double  Precision 4861172 Kflops ; 10 Reps
ifranl00@ubuntu:~/Documents/LAB4/linpack$
```

➔ **Result: 4,861.172 MFLOPS**

7.Carry out performance measurement for the series of 10 measures for sizes from 100 to 1000 (steps of 100) - with options DP and SP, and UNROLL and ROLL)

➔ DP and ROLL (-DDP -DROLL)

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 100
Rolled Double Precision Linpack

Rolled Double Precision Linpack

    norm. resid      resid          machep         x[0]-1         x[n-1]-1
     1.7        7.41628980e-14  2.22044605e-16 -1.49880108e-14 -1.89848137e-14
   times are reported for matrices of order   100
     dgefa       dgesl       total       kflops      unit        ratio
   times for array with leading dimension of 1001
    0.00014     0.00001     0.00015     4735632     0.00042     0.00259
    0.00012     0.00001     0.00013     5322997     0.00038     0.00230
    0.00012     0.00001     0.00013     5364583     0.00037     0.00229
    0.00012     0.00000     0.00013     5347871     0.00037     0.00229
   times for array with leading dimension of1000
    0.00012     0.00000     0.00013     5449735     0.00037     0.00225
    0.00012     0.00001     0.00013     5406824     0.00037     0.00227
    0.00012     0.00000     0.00013     5493333     0.00036     0.00223
    0.00012     0.00000     0.00013     5423907     0.00037     0.00226
Rolled Double  Precision 5347871 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 200
Rolled Double Precision Linpack

Rolled Double Precision Linpack

    norm. resid      resid          machep         x[0]-1         x[n-1]-1
     3.4        2.99982261e-13  2.22044605e-16  6.90558721e-14 -5.50670620e-14
   times are reported for matrices of order   200
     dgefa       dgesl       total       kflops      unit        ratio
   times for array with leading dimension of 1001
    0.00106     0.00002     0.00108     4993850     0.00040     0.01936
    0.00097     0.00002     0.00099     5451494     0.00037     0.01773
    0.00104     0.00006     0.00109     4948202     0.00040     0.01954
    0.00101     0.00002     0.00103     5234826     0.00038     0.01847
   times for array with leading dimension of1000
    0.00110     0.00003     0.00114     4765258     0.00042     0.02029
    0.00112     0.00004     0.00116     4666667     0.00043     0.02071
    0.00109     0.00004     0.00113     4777876     0.00042     0.02023
    0.00110     0.00003     0.00113     4806725     0.00042     0.02011
Rolled Double  Precision 4806725 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 300
Rolled Double Precision Linpack

Rolled Double Precision Linpack


     norm. resid        resid           machep          x[0]-1          x[n-1]-1
       5.4          7.13873405e-13  2.22044605e-16  2.99760217e-14 -1.40998324e-13
     times are reported for matrices of order    300
       dgefa      dgesl       total        kflops      unit         ratio
  times for array with leading dimension of 1001
     0.00351    0.00005     0.00355     5113924     0.00039      0.06348
     0.00339    0.00004     0.00344     5292576     0.00038      0.06134
     0.00346    0.00005     0.00351     5180963     0.00039      0.06266
     0.00375    0.00004     0.00379     4793545     0.00042      0.06773
  times for array with leading dimension of1000
     0.00699    0.00023     0.00722     2516611     0.00079      0.12900
     0.00550    0.00024     0.00573     3170009     0.00063      0.10241
     0.00369    0.00005     0.00373     4868773     0.00041      0.06668
     0.00345    0.00004     0.00349     5205589     0.00038      0.06236
Rolled Double   Precision 4793545 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 400
Rolled Double Precision Linpack

Rolled Double Precision Linpack


     norm. resid        resid           machep          x[0]-1          x[n-1]-1
       6.9          1.22923893e-12  2.22044605e-16 -4.85167462e-14 -2.32036612e-13
     times are reported for matrices of order    400
       dgefa      dgesl       total        kflops      unit         ratio
  times for array with leading dimension of 1001
     0.00853    0.00009     0.00862     4985696     0.00040      0.15396
     0.00883    0.00041     0.00924     4650727     0.00043      0.16505
     0.01063    0.00024     0.01087     3954979     0.00051      0.19409
     0.00872    0.00007     0.00879     4889849     0.00041      0.15698
  times for array with leading dimension of1000
     0.00795    0.00010     0.00805     5340622     0.00037      0.14373
     0.00806    0.00008     0.00814     5280917     0.00038      0.14536
     0.00798    0.00034     0.00832     5163564     0.00039      0.14866
     0.00839    0.00013     0.00852     5047813     0.00040      0.15207
Rolled Double   Precision 4889849 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 500
Rolled Double Precision Linpack

Rolled Double Precision Linpack

     norm. resid      resid          machep         x[0]-1        x[n-1]-1
       5.8         1.27986510e-12  2.22044605e-16  5.59552404e-14  3.39728246e-14
    times are reported for matrices of order    500
      dgefa     dgesl     total       kflops      unit       ratio
  times for array with leading dimension of 1001
     0.01644   0.00118   0.01762    4756771    0.00042    0.31471
     0.01858   0.00097   0.01954    4289247    0.00047    0.34902
     0.02135   0.00019   0.02154    3891803    0.00051    0.38466
     0.01544   0.00010   0.01555    5392425    0.00037    0.27762
  times for array with leading dimension of1000
     0.01483   0.00053   0.01536    5457544    0.00037    0.27430
     0.01616   0.00049   0.01666    5033523    0.00040    0.29741
     0.01681   0.00015   0.01696    4943878    0.00040    0.30280
     0.01474   0.00010   0.01484    5650174    0.00035    0.26495
Rolled Double  Precision 5392425 Kflops : 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 600
Rolled Double Precision Linpack

Rolled Double Precision Linpack

     norm. resid      resid          machep         x[0]-1        x[n-1]-1
       6.5         1.72245551e-12  2.22044605e-16 -1.32893696e-13 -6.48370246e-14
    times are reported for matrices of order    600
      dgefa     dgesl     total       kflops      unit       ratio
  times for array with leading dimension of 1001
     0.02737   0.00028   0.02764    5235322    0.00038    0.49362
     0.02913   0.00131   0.03043    4755677    0.00042    0.54341
     0.03049   0.00031   0.03080    4698549    0.00043    0.55002
     0.02704   0.00017   0.02720    5320138    0.00038    0.48576
  times for array with leading dimension of1000
     0.04441   0.00188   0.04629    3126647    0.00064    0.82654
     0.02777   0.00026   0.02803    5162671    0.00039    0.50057
     0.02748   0.00025   0.02772    5220026    0.00038    0.49507
     0.02772   0.00019   0.02791    5185331    0.00039    0.49838
Rolled Double  Precision 5185331 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 700
Rolled Double Precision Linpack

Rolled Double Precision Linpack


     norm. resid        resid          machep          x[0]-1          x[n-1]-1
       8.4         2.59992028e-12  2.22044605e-16  1.25899291e-13  9.99200722e-15
     times are reported for matrices of order   700
       dgefa      dgesl       total        kflops      unit         ratio
  times for array with leading dimension of 1001
     0.07303    0.00055     0.07358      3121175     0.00064      1.31388
     0.07882    0.00082     0.07964      2883451     0.00069      1.42220
     0.05975    0.00076     0.06051      3795436     0.00053      1.08046
     0.05557    0.00034     0.05591      4107508     0.00049      0.99837
  times for array with leading dimension of1000
     0.04993    0.00049     0.05042      4554855     0.00044      0.90032
     0.04838    0.00047     0.04885      4701539     0.00043      0.87223
     0.04418    0.00030     0.04449      5161991     0.00039      0.79443
     0.04129    0.00022     0.04151      5532348     0.00036      0.74125
Rolled Double  Precision 4107508 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 800
Rolled Double Precision Linpack

Rolled Double Precision Linpack


     norm. resid        resid          machep          x[0]-1          x[n-1]-1
       0.6         7.50333129e-10  2.22044605e-16  3.60801188e+03  1.33388383e+03
     times are reported for matrices of order   800
       dgefa      dgesl       total        kflops      unit         ratio
  times for array with leading dimension of 1001
     0.13862    0.00087     0.13950      2456027     0.00081      2.49105
     0.13265    0.00113     0.13378      2560944     0.00078      2.38900
     0.10475    0.00066     0.10541      3250293     0.00062      1.88232
     0.08625    0.00039     0.08664      3954479     0.00051      1.54713
  times for array with leading dimension of1000
     0.09937    0.00049     0.09987      3430696     0.00058      1.78334
     0.06568    0.00047     0.06615      5179653     0.00039      1.18118
     0.08924    0.00046     0.08969      3819802     0.00052      1.60168
     0.07405    0.00031     0.07436      4607476     0.00043      1.32786
Rolled Double  Precision 3954479 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 900
Rolled Double Precision Linpack

Rolled Double Precision Linpack


    norm. resid        resid          machep         x[0]-1          x[n-1]-1
     10.4         4.16555679e-12  2.22044605e-16  2.13606910e-13  2.55351296e-14
    times are reported for matrices of order    900
     dgefa      dgesl       total        kflops      unit       ratio
  times for array with leading dimension of 1001
    0.16261    0.00070     0.16331      2985892    0.00067     2.91621
    0.15586    0.00066     0.15652      3115365    0.00064     2.79502
    0.12804    0.00066     0.12870      3788958    0.00053     2.29813
    0.14146    0.00054     0.14199      3434140    0.00058     2.53557
  times for array with leading dimension of1000
    0.19525    0.00088     0.19613      2486183    0.00080     3.50236
    0.13033    0.00060     0.13093      3724166    0.00054     2.33811
    0.09744    0.00079     0.09823      4963912    0.00040     1.75416
    0.15702    0.00051     0.15753      3095471    0.00065     2.81298
Rolled Double   Precision 3095471 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 1000
Rolled Double Precision Linpack

Rolled Double Precision Linpack


    norm. resid        resid          machep         x[0]-1          x[n-1]-1
      9.5         4.22017976e-12  2.22044605e-16  1.09912079e-13  5.08926234e-13
    times are reported for matrices of order   1000
     dgefa      dgesl       total        kflops      unit       ratio
  times for array with leading dimension of 1001
    0.25643    0.00075     0.25718      2600005    0.00077     4.59248
    0.21447    0.00087     0.21533      3105239    0.00064     3.84527
    0.21109    0.00090     0.21199      3154296    0.00063     3.78546
    0.19782    0.00083     0.19865      3366046    0.00059     3.54733
  times for array with leading dimension of1000
    0.20647    0.00089     0.20736      3224635    0.00062     3.70289
    0.19605    0.00075     0.19680      3397783    0.00059     3.51420
    0.20296    0.00071     0.20367      3283008    0.00061     3.63705
    0.21596    0.00072     0.21668      3085950    0.00065     3.86930
Rolled Double   Precision 3085950 Kflops ; 10 Reps
```

➔ DP and UNROLL (-DDP -DUNROLL)

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 100
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack


      norm. resid         resid          machep         x[0]-1         x[n-1]-1
       1.7          7.41628980e-14  2.22044605e-16 -1.49880108e-14 -1.89848137e-14
    times are reported for matrices of order    100
      dgefa      dgesl      total       kflops      unit        ratio
  times for array with leading dimension of 1001
    0.00010     0.00001     0.00011     6299694     0.00032     0.00195
    0.00010     0.00001     0.00011     6417445     0.00031     0.00191
    0.00010     0.00001     0.00011     6477987     0.00031     0.00189
    0.00011     0.00000     0.00011     6208559     0.00032     0.00198
  times for array with leading dimension of1000
    0.00010     0.00001     0.00011     6477987     0.00031     0.00189
    0.00010     0.00001     0.00011     6477987     0.00031     0.00189
    0.00010     0.00001     0.00011     6186186     0.00032     0.00198
    0.00010     0.00000     0.00011     6346272     0.00032     0.00193
Unrolled Double  Precision 6208559 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 200
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack


      norm. resid         resid          machep         x[0]-1         x[n-1]-1
       3.4          2.99982261e-13  2.22044605e-16  6.90558721e-14 -5.50670620e-14
    times are reported for matrices of order    200
      dgefa      dgesl      total       kflops      unit        ratio
  times for array with leading dimension of 1001
    0.00079     0.00002     0.00081     6683128     0.00030     0.01446
    0.00079     0.00003     0.00082     6609687     0.00030     0.01462
    0.00079     0.00002     0.00081     6716294     0.00030     0.01439
    0.00080     0.00002     0.00082     6594388     0.00030     0.01466
  times for array with leading dimension of1000
    0.00081     0.00002     0.00083     6514240     0.00031     0.01484
    0.00083     0.00002     0.00086     6331384     0.00032     0.01527
    0.00081     0.00002     0.00083     6561616     0.00030     0.01473
    0.00080     0.00001     0.00081     6683953     0.00030     0.01446
Unrolled Double  Precision 6594388 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 300
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack

     norm. resid        resid          machep           x[0]-1        x[n-1]-1
       5.4          7.13873405e-13  2.22044605e-16  2.99760217e-14 -1.40998324e-13
    times are reported for matrices of order   300
     dgefa     dgesl      total       kflops     unit       ratio
  times for array with leading dimension of 1001
    0.00358    0.00005    0.00363    5001376    0.00040    0.06491
    0.00304    0.00007    0.00311    5849421    0.00034    0.05550
    0.00289    0.00004    0.00293    6211138    0.00032    0.05227
    0.00334    0.00006    0.00340    5344701    0.00037    0.06074
  times for array with leading dimension of1000
    0.00290    0.00004    0.00294    6187883    0.00032    0.05246
    0.00312    0.00004    0.00316    5749526    0.00035    0.05646
    0.00288    0.00005    0.00294    6192098    0.00032    0.05243
    0.00297    0.00003    0.00300    6061616    0.00033    0.05356
Unrolled Double  Precision 5344701 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 400
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack

     norm. resid        resid          machep           x[0]-1        x[n-1]-1
       6.9          1.22923893e-12  2.22044605e-16 -4.85167462e-14 -2.32036612e-13
    times are reported for matrices of order   400
     dgefa     dgesl      total       kflops     unit       ratio
  times for array with leading dimension of 1001
    0.00710    0.00006    0.00716    6000372    0.00033    0.12793
    0.00743    0.00014    0.00757    5680807    0.00035    0.13512
    0.00770    0.00008    0.00778    5525278    0.00036    0.13893
    0.00746    0.00006    0.00752    5719583    0.00035    0.13421
  times for array with leading dimension of1000
    0.00698    0.00008    0.00705    6093078    0.00033    0.12598
    0.00724    0.00017    0.00741    5801170    0.00034    0.13232
    0.00864    0.00016    0.00880    4887626    0.00041    0.15705
    0.00697    0.00005    0.00703    6115007    0.00033    0.12553
Unrolled Double  Precision 5719583 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 500
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack

      norm. resid        resid         machep          x[0]-1          x[n-1]-1
       5.8           1.27986510e-12  2.22044605e-16  5.59552404e-14  3.39728246e-14
    times are reported for matrices of order    500
      dgefa     dgesl      total       kflops     unit       ratio
 times for array with leading dimension of 1001
    0.01388    0.00039    0.01427    5874384    0.00034    0.25484
    0.01449    0.00020    0.01469    5707607    0.00035    0.26229
    0.01506    0.00025    0.01531    5476082    0.00037    0.27338
    0.01337    0.00008    0.01345    6231989    0.00032    0.24022
 times for array with leading dimension of1000
    0.01278    0.00031    0.01309    6401935    0.00031    0.23384
    0.01339    0.00048    0.01386    6046836    0.00033    0.24757
    0.01336    0.00023    0.01359    6167844    0.00032    0.24271
    0.01271    0.00008    0.01279    6555779    0.00031    0.22835
Unrolled Double  Precision 6231989 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 600
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack

      norm. resid        resid         machep          x[0]-1          x[n-1]-1
       6.5           1.72245551e-12  2.22044605e-16 -1.32893696e-13 -6.48370246e-14
    times are reported for matrices of order    600
      dgefa     dgesl      total       kflops     unit       ratio
 times for array with leading dimension of 1001
    0.02325    0.00029    0.02355    6146267    0.00033    0.42046
    0.02703    0.00021    0.02724    5311995    0.00038    0.48650
    0.02753    0.00033    0.02786    5194171    0.00039    0.49754
    0.02277    0.00013    0.02291    6317692    0.00032    0.40906
 times for array with leading dimension of1000
    0.02604    0.00077    0.02681    5398187    0.00037    0.47873
    0.03066    0.00138    0.03204    4516149    0.00044    0.57223
    0.02442    0.00023    0.02465    5870994    0.00034    0.44018
    0.02410    0.00012    0.02423    5973402    0.00033    0.43263
Unrolled Double  Precision 5973402 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 700
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack


     norm. resid         resid            machep          x[0]-1          x[n-1]-1
       8.4            2.59992028e-12  2.22044605e-16  1.25899291e-13  9.99200722e-15
     times are reported for matrices of order    700
       dgefa      dgesl       total        kflops       unit        ratio
  times for array with leading dimension of 1001
     0.05770    0.00040     0.05810      3952610      0.00051     1.03750
     0.05352    0.00048     0.05400      4252559      0.00047     0.96432
     0.04368    0.00037     0.04405      5213082      0.00038     0.78664
     0.04774    0.00040     0.04814      4770729      0.00042     0.85958
  times for array with leading dimension of1000
     0.12217    0.00058     0.12275      1870910      0.00107     2.19189
     0.09776    0.00062     0.09839      2334116      0.00086     1.75691
     0.06569    0.00053     0.06622      3467988      0.00058     1.18248
     0.04166    0.00019     0.04185      5487598      0.00036     0.74729
Unrolled Double   Precision 4770729 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 800
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack


     norm. resid         resid            machep          x[0]-1          x[n-1]-1
       0.6            7.50333129e-10  2.22044605e-16  3.60801188e+03  1.33388383e+03
     times are reported for matrices of order    800
       dgefa      dgesl       total        kflops       unit        ratio
  times for array with leading dimension of 1001
     0.09157    0.00051     0.09208      3720944      0.00054     1.64423
     0.09880    0.00062     0.09942      3446121      0.00058     1.77536
     0.06811    0.00068     0.06879      4980569      0.00040     1.22839
     0.09045    0.00029     0.09074      3775765      0.00053     1.62036
  times for array with leading dimension of1000
     0.08714    0.00049     0.08763      3909861      0.00051     1.56479
     0.06350    0.00059     0.06409      5346066      0.00037     1.14441
     0.07461    0.00052     0.07513      4560395      0.00044     1.34157
     0.07295    0.00067     0.07362      4653852      0.00043     1.31463
Unrolled Double   Precision 3775765 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 900
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack

     norm. resid       resid           machep          x[0]-1          x[n-1]-1
     10.4          4.16555679e-12  2.22044605e-16  2.13606910e-13  2.55351296e-14
     times are reported for matrices of order    900
      dgefa      dgesl      total       kflops      unit       ratio
   times for array with leading dimension of 1001
     0.14036    0.00057    0.14093     3460089     0.00058    2.51655
     0.11596    0.00046    0.11641     4188635     0.00048    2.07884
     0.08540    0.00048    0.08587     5678386     0.00035    1.53345
     0.11556    0.00040    0.11595     4205361     0.00048    2.07057
   times for array with leading dimension of1000
     0.16218    0.00073    0.16291     2993168     0.00067    2.90913
     0.10444    0.00083    0.10527     4632045     0.00043    1.87984
     0.10194    0.00098    0.10292     4737993     0.00042    1.83780
     0.14452    0.00062    0.14513     3359796     0.00060    2.59167
Unrolled Double  Precision 3359796 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 1000
Unrolled Double Precision Linpack

Unrolled Double Precision Linpack

     norm. resid       resid           machep          x[0]-1          x[n-1]-1
      9.5          4.22017976e-12  2.22044605e-16  1.09912079e-13  5.08926234e-13
     times are reported for matrices of order   1000
      dgefa      dgesl      total       kflops      unit       ratio
   times for array with leading dimension of 1001
     0.24802    0.00091    0.24894     2686088     0.00074    4.44530
     0.19983    0.00076    0.20059     3333533     0.00060    3.58193
     0.18892    0.00076    0.18968     3525217     0.00057    3.38716
     0.23652    0.00074    0.23725     2818357     0.00071    4.23668
   times for array with leading dimension of1000
     0.22279    0.00077    0.22356     2990967     0.00067    3.99218
     0.26410    0.00097    0.26507     2522623     0.00079    4.73336
     0.39108    0.00085    0.39193     1706087     0.00117    6.99875
     0.22932    0.00063    0.22994     2907972     0.00069    4.10612
Unrolled Double  Precision 2818357 Kflops ; 10 Reps
```

➔ SP and UNROLL (-DSP -DUNROLL)

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 100
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

    norm. resid      resid          machep        x[0]-1        x[n-1]-1
      1.6          3.80277634e-05  1.19209290e-07 -1.38282776e-05 -7.51018524e-06
    times are reported for matrices of order    100
      dgefa      dgesl      total       kflops      unit       ratio
  times for array with leading dimension of 1001
    0.00008     0.00001     0.00008     8373980     0.00024     0.00146
    0.00008     0.00001     0.00008     8477363     0.00024     0.00145
    0.00007     0.00000     0.00008     8803418     0.00023     0.00139
    0.00007     0.00000     0.00008     8848795     0.00023     0.00139
  times for array with leading dimension of1000
    0.00007     0.00001     0.00008     8803405     0.00023     0.00139
    0.00007     0.00001     0.00008     8917762     0.00022     0.00137
    0.00007     0.00000     0.00008     9035075     0.00022     0.00136
    0.00008     0.00000     0.00008     8313158     0.00024     0.00147
Unrolled Single  Precision 8313158 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 200
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

    norm. resid      resid          machep        x[0]-1        x[n-1]-1
      2.2          1.05794519e-04  1.19209290e-07 -1.94907188e-05  6.55651093e-06
    times are reported for matrices of order    200
      dgefa      dgesl      total       kflops      unit       ratio
  times for array with leading dimension of 1001
    0.00050     0.00001     0.00051     10531778    0.00019     0.00918
    0.00051     0.00001     0.00053     10271979    0.00019     0.00941
    0.00055     0.00001     0.00056     9615156     0.00021     0.01005
    0.00052     0.00001     0.00053     10307186    0.00019     0.00938
  times for array with leading dimension of1000
    0.00054     0.00001     0.00055     9806755     0.00020     0.00986
    0.00052     0.00001     0.00053     10156355    0.00020     0.00952
    0.00054     0.00001     0.00055     9771360     0.00020     0.00989
    0.00054     0.00001     0.00055     9894595     0.00020     0.00977
Unrolled Single  Precision 9894596 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 300
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

     norm. resid        resid           machep           x[0]-1         x[n-1]-1
       4.2          3.02433968e-04  1.19209290e-07  1.60932541e-05 -3.67164612e-05
    times are reported for matrices of order    300
      dgefa      dgesl       total        kflops     unit        ratio
  times for array with leading dimension of 1001
     0.00189     0.00003     0.00192     9463821   0.00021      0.03430
     0.00184     0.00003     0.00186     9763696   0.00020      0.03325
     0.00188     0.00003     0.00190     9553333   0.00021      0.03398
     0.00194     0.00002     0.00196     9257091   0.00022      0.03507
  times for array with leading dimension of1000
     0.00192     0.00004     0.00196     9266061   0.00022      0.03504
     0.00180     0.00006     0.00185     9811095   0.00020      0.03309
     0.00180     0.00007     0.00187     9721931   0.00021      0.03339
     0.00196     0.00003     0.00199     9115067   0.00022      0.03562
Unrolled Single  Precision 9115068 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 400
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

     norm. resid        resid           machep           x[0]-1         x[n-1]-1
       6.2          5.91099262e-04  1.19209290e-07 -5.63263893e-05  4.31537628e-05
    times are reported for matrices of order    400
      dgefa      dgesl       total        kflops     unit        ratio
  times for array with leading dimension of 1001
     0.00537     0.00010     0.00546     7873016   0.00025      0.09750
     0.00509     0.00005     0.00514     8361538   0.00024      0.09180
     0.00572     0.00011     0.00583     7372092   0.00027      0.10413
     0.00532     0.00005     0.00537     8001986   0.00025      0.09593
  times for array with leading dimension of1000
     0.00460     0.00006     0.00466     9230534   0.00022      0.08316
     0.00427     0.00004     0.00431     9966751   0.00020      0.07702
     0.00418     0.00004     0.00423    10171936   0.00020      0.07546
     0.00443     0.00005     0.00448     9595237   0.00021      0.08000
Unrolled Single  Precision 8001986 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 500
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack


     norm. resid         resid         machep         x[0]-1        x[n-1]-1
       4.0         4.72068787e-04  1.19209290e-07  5.26905060e-05  3.26633453e-05
    times are reported for matrices of order    500
     dgefa      dgesl      total      kflops      unit      ratio
  times for array with leading dimension of 1001
    0.00806    0.00006    0.00812    10323030    0.00019    0.14502
    0.00838    0.00027    0.00865     9691715    0.00021    0.15446
    0.00883    0.00009    0.00892     9400465    0.00021    0.15925
    0.00903    0.00006    0.00909     9224719    0.00022    0.16228
  times for array with leading dimension of1000
    0.00840    0.00008    0.00848     9884846    0.00020    0.15145
    0.00884    0.00025    0.00909     9226636    0.00022    0.16225
    0.01030    0.00033    0.01063     7887969    0.00025    0.18979
    0.00893    0.00007    0.00900     9314398    0.00021    0.16072
Unrolled Single  Precision 9224720 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 600
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack


     norm. resid         resid         machep         x[0]-1        x[n-1]-1
       6.6         9.40270722e-04  1.19209290e-07  1.31130219e-05  2.53915787e-05
    times are reported for matrices of order    600
     dgefa      dgesl      total      kflops      unit      ratio
  times for array with leading dimension of 1001
    0.01489    0.00036    0.01525     9486726    0.00021    0.27241
    0.01636    0.00020    0.01655     8742826    0.00023    0.29559
    0.01766    0.00012    0.01779     8137194    0.00025    0.31759
    0.01495    0.00008    0.01503     9629446    0.00021    0.26837
  times for array with leading dimension of1000
    0.01358    0.00022    0.01379    10493793    0.00019    0.24627
    0.01439    0.00039    0.01478     9790939    0.00020    0.26395
    0.01522    0.00020    0.01542     9383389    0.00021    0.27541
    0.01348    0.00008    0.01356    10675560    0.00019    0.24207
Unrolled Single  Precision 9629446 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 700
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

     norm. resid         resid          machep         x[0]-1          x[n-1]-1
       8.0          1.33043528e-03  1.19209290e-07  4.64916229e-05  5.29289246e-05
     times are reported for matrices of order    700
       dgefa       dgesl       total       kflops       unit        ratio
    times for array with leading dimension of 1001
      0.02374     0.00038     0.02413     9518638     0.00021     0.43082
      0.02591     0.00022     0.02614     8786267     0.00023     0.46673
      0.02414     0.00028     0.02442     9403657     0.00021     0.43609
      0.02330     0.00011     0.02341     9809309     0.00020     0.41806
    times for array with leading dimension of1000
      0.02245     0.00033     0.02278    10081500     0.00020     0.40677
      0.02446     0.00017     0.02462     9326136     0.00021     0.43971
      0.02232     0.00014     0.02246    10226522     0.00020     0.40100
      0.02322     0.00025     0.02348     9782190     0.00020     0.41921
Unrolled Single  Precision 9782190 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 800
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

     norm. resid         resid          machep         x[0]-1          x[n-1]-1
       0.4          2.32666016e-01  1.19209290e-07 -7.36740967e+02 -7.82062531e+00
     times are reported for matrices of order    800
       dgefa       dgesl       total       kflops       unit        ratio
    times for array with leading dimension of 1001
      0.03529     0.00036     0.03564     9612630     0.00021     0.63646
      0.03885     0.00031     0.03917     8747502     0.00023     0.69941
      0.03420     0.00019     0.03439     9962296     0.00020     0.61413
      0.03349     0.00014     0.03362    10189304     0.00020     0.60044
    times for array with leading dimension of1000
      0.03265     0.00110     0.03375    10152709     0.00020     0.60261
      0.03137     0.00018     0.03155    10858703     0.00018     0.56343
      0.03013     0.00020     0.03033    11297296     0.00018     0.54155
      0.03212     0.00016     0.03229    10611328     0.00019     0.57656
Unrolled Single  Precision 10189304 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 900
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

     norm. resid        resid           machep          x[0]-1          x[n-1]-1
      10.8          2.31945515e-03  1.19209290e-07  1.78813934e-05  3.85046005e-05
     times are reported for matrices of order    900
       dgefa     dgesl      total         kflops      unit        ratio
   times for array with leading dimension of 1001
      0.05643    0.00145    0.05788    8424672      0.00024     1.03357
      0.05360    0.00027    0.05387    9051456      0.00022     0.96200
      0.04858    0.00019    0.04878    9996925      0.00020     0.87102
      0.04691    0.00017    0.04707    10358892     0.00019     0.84058
   times for array with leading dimension of1000
      0.04732    0.00104    0.04835    10084173     0.00020     0.86348
      0.04434    0.00029    0.04463    10925589     0.00018     0.79698
      0.04892    0.00029    0.04922    9907567      0.00020     0.87887
      0.05520    0.00019    0.05539    8802743      0.00023     0.98918
Unrolled Single  Precision 8802744 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 1000
Unrolled Single Precision Linpack

Unrolled Single Precision Linpack

     norm. resid        resid           machep          x[0]-1          x[n-1]-1
      11.3          2.70068645e-03  1.19209290e-07  1.62243843e-04  -6.65783882e-05
     times are reported for matrices of order   1000
       dgefa     dgesl      total         kflops      unit        ratio
   times for array with leading dimension of 1001
      0.07312    0.00033    0.07345    9103823      0.00022     1.31159
      0.07063    0.00031    0.07094    9426204      0.00021     1.26673
      0.06308    0.00023    0.06331    10562286     0.00019     1.13048
      0.06656    0.00030    0.06686    10000459     0.00020     1.19399
   times for array with leading dimension of1000
      0.09922    0.00066    0.09988    6694494      0.00030     1.78363
      0.08818    0.00049    0.08866    7541748      0.00027     1.58325
      0.07917    0.00053    0.07970    8389583      0.00024     1.42325
      0.07061    0.00024    0.07085    9438246      0.00021     1.26512
Unrolled Single  Precision 9438246 Kflops ; 10 Reps
```

➔ SP and ROLL (-DSP -DROLL)

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 100
Rolled Single Precision Linpack

Rolled Single Precision Linpack

      norm. resid        resid         machep         x[0]-1         x[n-1]-1
        1.6         3.80277634e-05  1.19209290e-07 -1.38282776e-05 -7.51018524e-06
     times are reported for matrices of order    100
       dgefa        dgesl      total        kflops      unit       ratio
  times for array with leading dimension of 1001
    0.00007     0.00000     0.00008     8583337     0.00023     0.00143
    0.00009     0.00000     0.00010     7006800     0.00029     0.00175
    0.00007     0.00000     0.00008     8803418     0.00023     0.00139
    0.00007     0.00000     0.00007     9204645     0.00022     0.00133
  times for array with leading dimension of1000
    0.00007     0.00000     0.00008     9155543     0.00022     0.00134
    0.00009     0.00000     0.00009     7383512     0.00027     0.00166
    0.00007     0.00000     0.00007     9406381     0.00021     0.00130
    0.00007     0.00000     0.00008     9082891     0.00022     0.00135
Rolled Single   Precision 9082892 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 200
Rolled Single Precision Linpack

Rolled Single Precision Linpack

      norm. resid        resid         machep         x[0]-1         x[n-1]-1
        2.2         1.05794519e-04  1.19209290e-07 -1.94907188e-05  6.55651093e-06
     times are reported for matrices of order    200
       dgefa        dgesl      total        kflops      unit       ratio
  times for array with leading dimension of 1001
    0.00049     0.00001     0.00051    10719472     0.00019     0.00902
    0.00056     0.00001     0.00057     9463869     0.00021     0.01021
    0.00047     0.00001     0.00048    11277774     0.00018     0.00857
    0.00048     0.00001     0.00049    11117960     0.00018     0.00869
  times for array with leading dimension of1000
    0.00047     0.00001     0.00048    11184574     0.00018     0.00864
    0.00049     0.00001     0.00050    10892013     0.00018     0.00888
    0.00048     0.00001     0.00049    11115680     0.00018     0.00870
    0.00052     0.00001     0.00053    10303254     0.00019     0.00938
Rolled Single   Precision 10303254 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 300
Rolled Single Precision Linpack

Rolled Single Precision Linpack


    norm. resid        resid          machep          x[0]-1         x[n-1]-1
      4.2         3.02433968e-04  1.19209290e-07  1.60932541e-05 -3.67164612e-05
    times are reported for matrices of order    300
     dgefa      dgesl       total        kflops      unit        ratio
 times for array with leading dimension of 1001
    0.00174    0.00003     0.00177    10294450    0.00019     0.03154
    0.00180    0.00002     0.00183     9956189    0.00020     0.03261
    0.00176    0.00002     0.00179    10167787    0.00020     0.03193
    0.00184    0.00002     0.00186     9763172    0.00020     0.03325
 times for array with leading dimension of1000
    0.00214    0.00003     0.00217     8374020    0.00024     0.03877
    0.00178    0.00003     0.00180    10077596    0.00020     0.03221
    0.00198    0.00004     0.00202     8977791    0.00022     0.03616
    0.00196    0.00002     0.00199     9155458    0.00022     0.03546
Rolled Single   Precision 9155458 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 400
Rolled Single Precision Linpack

Rolled Single Precision Linpack


    norm. resid        resid          machep          x[0]-1         x[n-1]-1
      6.2         5.91099262e-04  1.19209290e-07 -5.63263893e-05  4.31537628e-05
    times are reported for matrices of order    400
     dgefa      dgesl       total        kflops      unit        ratio
 times for array with leading dimension of 1001
    0.00445    0.00006     0.00451     9522966    0.00021     0.08061
    0.00432    0.00004     0.00436     9859328    0.00020     0.07786
    0.00442    0.00006     0.00449     9578133    0.00021     0.08014
    0.00458    0.00004     0.00462     9304071    0.00021     0.08250
 times for array with leading dimension of1000
    0.00439    0.00004     0.00443     9712301    0.00021     0.07904
    0.00455    0.00004     0.00459     9367330    0.00021     0.08195
    0.00488    0.00009     0.00497     8644008    0.00023     0.08880
    0.00441    0.00004     0.00445     9657972    0.00021     0.07948
Rolled Single   Precision 9304072 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 500
Rolled Single Precision Linpack

Rolled Single Precision Linpack

       norm. resid       resid           machep          x[0]-1          x[n-1]-1
        4.0            4.72068787e-04  1.19209290e-07  5.26905060e-05  3.26633453e-05
     times are reported for matrices of order    500
        dgefa      dgesl      total       kflops      unit       ratio
   times for array with leading dimension of 1001
      0.00848    0.00006    0.00854    9819998    0.00020    0.15245
      0.00893    0.00034    0.00928    9037659    0.00022    0.16564
      0.00923    0.00013    0.00935    8963261    0.00022    0.16702
      0.00875    0.00006    0.00881    9516242    0.00021    0.15731
   times for array with leading dimension of1000
      0.00861    0.00006    0.00867    9671583    0.00021    0.15479
      0.00928    0.00009    0.00937    8947948    0.00022    0.16730
      0.00882    0.00015    0.00897    9344905    0.00021    0.16020
      0.00840    0.00005    0.00845    9920282    0.00020    0.15091
Rolled Single   Precision 9516242 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 600
Rolled Single Precision Linpack

Rolled Single Precision Linpack

       norm. resid       resid           machep          x[0]-1          x[n-1]-1
        6.6            9.40270722e-04  1.19209290e-07  1.31130219e-05  2.53915787e-05
     times are reported for matrices of order    600
        dgefa      dgesl      total       kflops      unit       ratio
   times for array with leading dimension of 1001
      0.01618    0.00073    0.01691    8557238    0.00023    0.30200
      0.01584    0.00159    0.01744    8300068    0.00024    0.31136
      0.01729    0.00011    0.01739    8322024    0.00024    0.31054
      0.01437    0.00008    0.01445   10015085    0.00020    0.25804
   times for array with leading dimension of1000
      0.01420    0.00018    0.01438   10062575    0.00020    0.25682
      0.01469    0.00017    0.01486    9735623    0.00021    0.26545
      0.01456    0.00022    0.01478    9791620    0.00020    0.26393
      0.01384    0.00007    0.01391   10401336    0.00019    0.24846
Rolled Single   Precision 10015086 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 700
Rolled Single Precision Linpack

Rolled Single Precision Linpack


     norm. resid        resid          machep          x[0]-1          x[n-1]-1
      8.0          1.33043528e-03  1.19209290e-07  4.64916229e-05  5.29289246e-05
     times are reported for matrices of order    700
      dgefa       dgesl        total        kflops       unit        ratio
 times for array with leading dimension of 1001
    0.02397     0.00022     0.02419     9493062     0.00021     0.43198
    0.02515     0.00017     0.02532     9068699     0.00022     0.45220
    0.02396     0.00019     0.02415     9508786     0.00021     0.43127
    0.02333     0.00011     0.02345     9794873     0.00020     0.41867
 times for array with leading dimension of1000
    0.02264     0.00035     0.02298     9991576     0.00020     0.41043
    0.02470     0.00020     0.02490     9223855     0.00022     0.44459
    0.02353     0.00016     0.02369     9693829     0.00021     0.42304
    0.02333     0.00012     0.02345     9793994     0.00020     0.41871
Rolled Single   Precision 9793994 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 800
Rolled Single Precision Linpack

Rolled Single Precision Linpack


     norm. resid        resid          machep          x[0]-1          x[n-1]-1
      0.4          2.32666016e-01  1.19209290e-07 -7.36740967e+02 -7.82062531e+00
     times are reported for matrices of order    800
      dgefa       dgesl        total        kflops       unit        ratio
 times for array with leading dimension of 1001
    0.03490     0.00086     0.03576     9580374     0.00021     0.63861
    0.03694     0.00027     0.03721     9208056     0.00022     0.66443
    0.03536     0.00021     0.03557     9633440     0.00021     0.63509
    0.03364     0.00015     0.03379     10139072    0.00020     0.60342
 times for array with leading dimension of1000
    0.03681     0.00097     0.03778     9069119     0.00022     0.67461
    0.03736     0.00024     0.03760     9111325     0.00022     0.67148
    0.03422     0.00022     0.03444     9948696     0.00020     0.61496
    0.03831     0.00014     0.03845     8909667     0.00022     0.68668
Rolled Single   Precision 8909668 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 900
Rolled Single Precision Linpack

Rolled Single Precision Linpack

      norm. resid        resid         machep         x[0]-1         x[n-1]-1
       10.8           2.31945515e-03  1.19209290e-07  1.78813934e-05  3.85046005e-05
    times are reported for matrices of order    900
      dgefa      dgesl      total        kflops      unit        ratio
  times for array with leading dimension of 1001
     0.05345    0.00158    0.05503    8861307    0.00023    0.98264
     0.05726    0.00022    0.05747    8484331    0.00024    1.02630
     0.04708    0.00025    0.04734   10301031    0.00019    0.84530
     0.04801    0.00026    0.04826   10103247    0.00020    0.86185
  times for array with leading dimension of1000
     0.08898    0.00033    0.08931    5459678    0.00037    1.59487
     0.05369    0.00028    0.05397    9035033    0.00022    0.96375
     0.04822    0.00029    0.04851   10052970    0.00020    0.86616
     0.05360    0.00021    0.05381    9062241    0.00022    0.96086
Rolled Single  Precision 9062242 Kflops ; 10 Reps
```

```
ifranl00@ubuntu:~/Documents/LAB4/linpack$ ./linpack
Size of the array: 1000
Rolled Single Precision Linpack

Rolled Single Precision Linpack

      norm. resid        resid         machep         x[0]-1         x[n-1]-1
       11.3           2.70068645e-03  1.19209290e-07  1.62243843e-04 -6.65783882e-05
    times are reported for matrices of order   1000
      dgefa      dgesl      total        kflops      unit        ratio
  times for array with leading dimension of 1001
     0.08559    0.00047    0.08607    7769322    0.00026    1.53688
     0.07997    0.00037    0.08034    8323478    0.00024    1.43455
     0.07119    0.00032    0.07151    9351065    0.00021    1.27691
     0.08260    0.00021    0.08281    8074972    0.00025    1.47870
  times for array with leading dimension of1000
     0.07617    0.00032    0.07650    8740980    0.00023    1.36603
     0.06679    0.00043    0.06722    9947282    0.00020    1.20038
     0.06690    0.00036    0.06727    9940354    0.00020    1.20121
     0.09669    0.00021    0.09690    6900889    0.00029    1.73028
Rolled Single  Precision 6900889 Kflops ; 10 Reps
```

8. **Create tables and charts with the results - performance in GFLOPS for different cases and sizes.**

SIZE	GFLOPS PER CASES			
	DP and ROLL	DP and UNROLL	SP and UNROLL	DP and UNROLL
100	5.347871	6.208559	8.313158	9.082892
200	4.806725	6.594388	9.894596	10.303254
300	4.793545	5.344701	9.115068	9.155458
400	4.889849	5.719583	8.001986	9.304072
500	5.392425	6.231989	9.22472	9.516242
600	5.185331	5.973402	9.629446	10.015086
700	4.107508	4.770729	9.78219	9.793994
800	3.954479	3.775765	10.189304	8.909668
900	3.095471	3.359796	8.802744	9.062242
1000	3.08595	2.818357	9.438246	6.900889
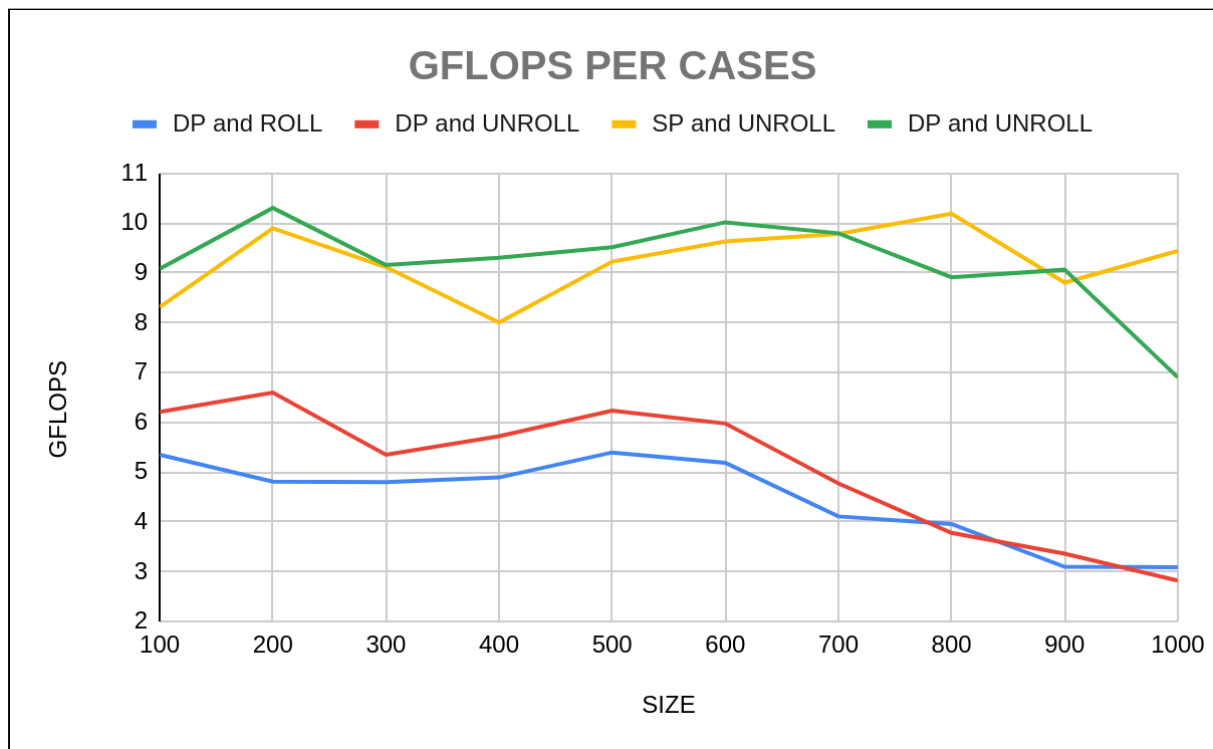
9.Compare the test results and theoretical estimates (which transfer rate from memory to the processor are achieved in individual cases? Whether Linpack performance is limited by the memory access speed, whether by the CPU processing speed?)

If we look at the results obtained in exercise 7 and its charts from exercise 8, we can see that all values are between 2 and 11 GFLOPS, when according to the calculated results in exercise 1, the maximum is 66 GFLOPS and we can take this as reference as 100 % of rate:

	minimum rate	maximum rate
DP and ROLL	4.678 %	8.17 %
DP and UNROLL	4.27 %	9.99 %
SP and UNROLL	12.12 %	15.44 %
DP and UNROLL	10.45 %	15.61 %

Linpack performance is limited for both aspect even in time, because these two considerations will affect the time of execution but LInpack is mostly determined by itself because it cannot represent all real operations to can make a consistent comparison using only this benchmark.