实验内容：2000*2000 的矩阵，分块大小为 4

实验环境：

```
wyo@PC: ~/hpc_rec/hpc_prac

                                movdiri movdir64b fsrm serialize flush_l1d arch_capabilities
wyo@PC:~/hpc_rec/hpc_practice/lab5-thread/thread$ lscpu
Architecture:                    x86_64
CPU op-mode(s):                  32-bit, 64-bit
Byte Order:                      Little Endian
Address sizes:                   39 bits physical, 48 bits virtual
CPU(s):                          20
On-line CPU(s) list:             0-19
Thread(s) per core:              2
Core(s) per socket:              10
Socket(s):                       1
Vendor ID:                       GenuineIntel
CPU family:                      6
Model:                           154
Model name:                      12th Gen Intel(R) Core(TM) i7-12700H
Stepping:                        3
CPU MHz:                         2688.001
BogoMIPS:                        5376.00
Virtualization:                  VT-x
Hypervisor vendor:               Microsoft
Virtualization type:             full
L1d cache:                       480 KiB
L1i cache:                       320 KiB
L2 cache:                        12.5 MiB
L3 cache:                        24 MiB
Vulnerability Itlb multihit:     Not affected
Vulnerability L1tf:              Not affected
Vulnerability Mds:               Not affected
Vulnerability Meltdown:          Not affected
Vulnerability Mmio stale data:   Not affected
```

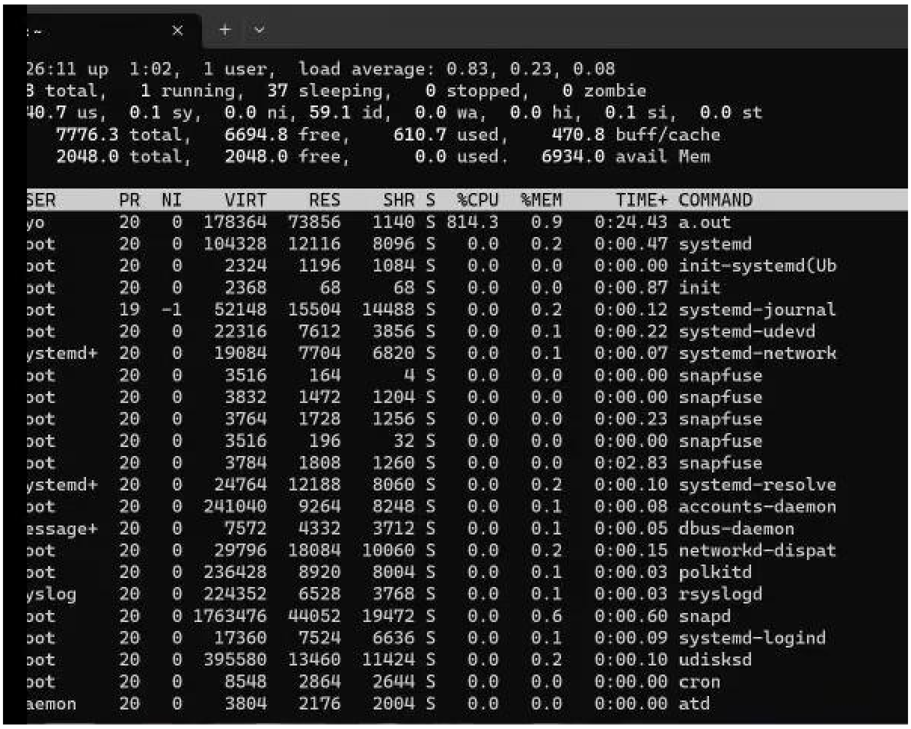
单线程下 CPU 利用率

```
wyo@PC: ~

- 15:22:56 up 59 min,  1 user,  load average: 0.29, 0.07, 0.02
ks:  38 total,   2 running,  36 sleeping,   0 stopped,   0 zombie
u(s):  5.0 us,  0.0 sy,  0.0 ni, 95.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
 Mem :   7776.3 total,   6700.4 free,    605.2 used,    470.7 buff/cache
 Swap:   2048.0 total,   2048.0 free,      0.0 used.   6939.5 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 1773 wyo       20   0   96252  77876   1044 R 100.0   1.0   0:19.87 a.out
    1 root      20   0  104328  12116   8096 S   0.0   0.2   0:00.47 systemd
    2 root      20   0    2324   1196   1084 S   0.0   0.0   0:00.00 init-systemd(Ub
    5 root      20   0    2368     68     68 S   0.0   0.0   0:00.87 init
   56 root      19  -1   52148  15504  14488 S   0.0   0.2   0:00.12 systemd-journal
   81 root      20   0   22316   7612   3856 S   0.0   0.1   0:00.22 systemd-udevd
   93 systemd+  20   0   19084   7704   6820 S   0.0   0.1   0:00.07 systemd-network
  275 root      20   0    3516    164      4 S   0.0   0.0   0:00.00 snapfuse
  276 root      20   0    3832   1472   1204 S   0.0   0.0   0:00.00 snapfuse
  278 root      20   0    3764   1728   1256 S   0.0   0.0   0:00.23 snapfuse
  279 root      20   0    3516    196     32 S   0.0   0.0   0:00.00 snapfuse
  282 root      20   0    3784   1808   1260 S   0.0   0.0   0:02.83 snapfuse
  289 systemd+  20   0   24764  12188   8060 S   0.0   0.2   0:00.10 systemd-resolve
  292 root      20   0  241040   9264   8248 S   0.0   0.1   0:00.08 accounts-daemon
  293 message+  20   0    7572   4332   3712 S   0.0   0.1   0:00.05 dbus-daemon
  296 root      20   0   29796  18084  10060 S   0.0   0.2   0:00.15 networkd-dispat
  298 root      20   0  236428   8920   8004 S   0.0   0.1   0:00.03 polkitd
  300 syslog    20   0  224352   6528   3768 S   0.0   0.1   0:00.03 rsyslogd
  301 root      20   0 1763476  44052  19472 S   0.0   0.6   0:00.58 snapd
  305 root      20   0   17360   7524   6636 S   0.0   0.1   0:00.09 systemd-logind
  306 root      20   0  395580  15484  11424 S   0.0   0.2   0:00.10 udisksd
  333 root      20   0    8548   2864   2644 S   0.0   0.0   0:00.00 cron
  341 daemon    20   0    3804   2176   2004 S   0.0   0.0   0:00.00 atd
```

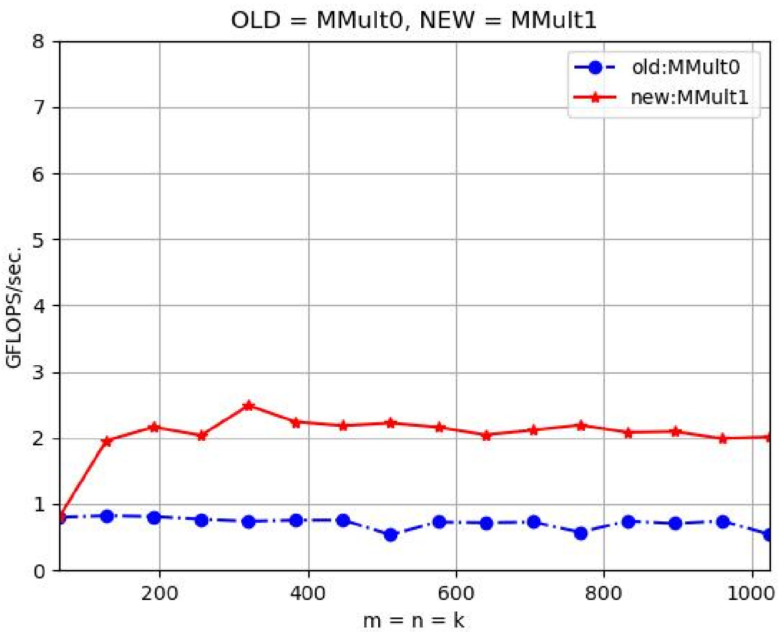
多线程（10 线程）下 CPU 利用率



```
:~            ×    +  ⌄
26:11 up  1:02,  1 user,  load average: 0.83, 0.23, 0.08
3 total,   1 running,  37 sleeping,   0 stopped,   0 zombie
40.7 us,  0.1 sy,  0.0 ni, 59.1 id,  0.0 wa,  0.0 hi,  0.1 si,  0.0 st
  7776.3 total,   6694.8 free,    610.7 used,    470.8 buff/cache
  2048.0 total,   2048.0 free,      0.0 used.   6934.0 avail Mem

SER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
yo       20   0  178364  73856   1140 S 814.3   0.9   0:24.43 a.out
oot      20   0  104328  12116   8096 S   0.0   0.2   0:00.47 systemd
oot      20   0    2324   1196   1084 S   0.0   0.0   0:00.00 init-systemd(Ub
oot      20   0    2368     68     68 S   0.0   0.0   0:00.87 init
oot      19  -1   52148  15504  14488 S   0.0   0.2   0:00.12 systemd-journal
oot      20   0   22316   7612   3856 S   0.0   0.1   0:00.22 systemd-udevd
ystemd+  20   0   19084   7704   6820 S   0.0   0.1   0:00.07 systemd-network
oot      20   0    3516    164      4 S   0.0   0.0   0:00.00 snapfuse
oot      20   0    3832   1472   1204 S   0.0   0.0   0:00.00 snapfuse
oot      20   0    3764   1728   1256 S   0.0   0.0   0:00.23 snapfuse
oot      20   0    3516    196     32 S   0.0   0.0   0:00.00 snapfuse
oot      20   0    3784   1808   1260 S   0.0   0.0   0:02.83 snapfuse
ystemd+  20   0   24764  12188   8060 S   0.0   0.2   0:00.10 systemd-resolve
oot      20   0  241040   9264   8248 S   0.0   0.1   0:00.08 accounts-daemon
essage+  20   0    7572   4332   3712 S   0.0   0.1   0:00.05 dbus-daemon
oot      20   0   29796  18084  10060 S   0.0   0.2   0:00.15 networkd-dispat
oot      20   0  236428   8920   8004 S   0.0   0.1   0:00.03 polkitd
yslog    20   0  224352   6528   3768 S   0.0   0.1   0:00.03 rsyslogd
oot      20   0 1763476  44052  19472 S   0.0   0.6   0:00.60 snapd
oot      20   0   17360   7524   6636 S   0.0   0.1   0:00.09 systemd-logind
oot      20   0  395580  13460  11424 S   0.0   0.2   0:00.10 udisksd
oot      20   0    8548   2864   2644 S   0.0   0.0   0:00.00 cron
aemon    20   0    3804   2176   2004 S   0.0   0.0   0:00.00 atd
```

对比可知多线程下 CPU 利用率对比单线程下显著提高，且利用率接近线程倍数



红线为多线程，蓝线为 naive dgemm

分析可知：多线程＞单线程＞naive dgemm