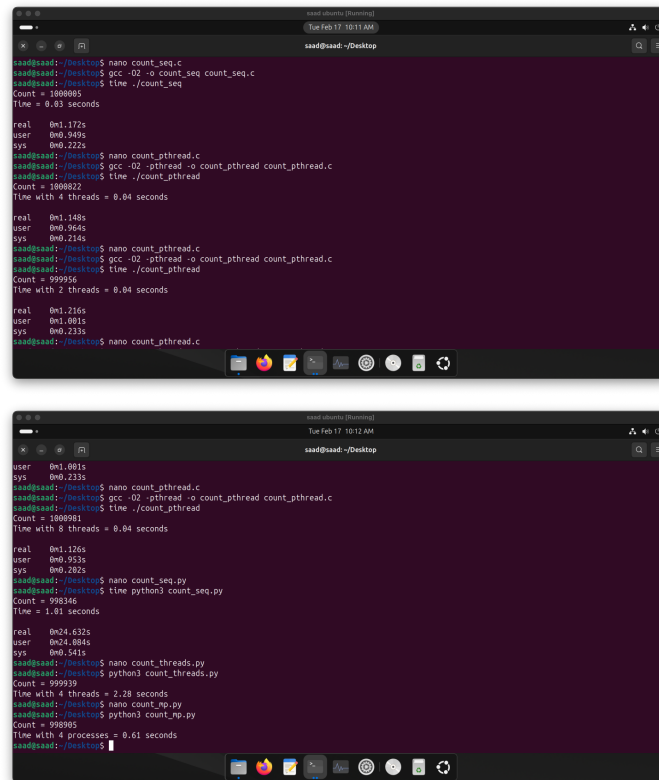


PDC Lab 1

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The image shows two screenshots of a terminal window. The top screenshot displays the execution of a C sequential program and a C pthreads program. The bottom screenshot displays the execution of a C pthreads program and a C sequential program.

```
saad@saad:~/Desktop$ nano count_seq.c
saad@saad:~/Desktop$ gcc -O2 -o count_seq count_seq.c
saad@saad:~/Desktop$ time ./count_seq
Count = 1000005
Time = 0.83 seconds

real    0m1.172s
user    0m0.949s
sys     0m0.222s
saad@saad:~/Desktop$ nano count_thread.c
saad@saad:~/Desktop$ gcc -O2 -pthread -o count_thread count_thread.c
saad@saad:~/Desktop$ time ./count_thread
Count = 1000022
Time with 4 threads = 0.04 seconds

real    0m1.148s
user    0m0.964s
sys     0m0.214s
saad@saad:~/Desktop$ nano count_thread.c
saad@saad:~/Desktop$ gcc -O2 -pthread -o count_thread count_thread.c
saad@saad:~/Desktop$ time ./count_thread
Count = 999956
Time with 2 threads = 0.04 seconds

real    0m1.216s
user    0m1.081s
sys     0m0.233s
saad@saad:~/Desktop$ nano count_thread.c

user    0m1.081s
sys     0m0.233s
saad@saad:~/Desktop$ nano count_thread.c
saad@saad:~/Desktop$ gcc -O2 -pthread -o count_thread count_thread.c
saad@saad:~/Desktop$ time ./count_thread
Count = 1000981
Time with 8 threads = 0.04 seconds

real    0m1.126s
user    0m0.953s
sys     0m0.282s
saad@saad:~/Desktop$ nano count_seq.py
saad@saad:~/Desktop$ time python3 count_seq.py
Count = 998346
Time = 1.81 seconds

real    0m24.632s
user    0m24.084s
sys     0m0.541s
saad@saad:~/Desktop$ nano count_threads.py
saad@saad:~/Desktop$ python3 count_threads.py
Count = 99939
Time with 4 threads = 2.28 seconds

real    0m24.632s
user    0m24.084s
sys     0m0.541s
saad@saad:~/Desktop$ nano count_np.py
saad@saad:~/Desktop$ python3 count_np.py
Count = 998905
Time with 4 processes = 0.61 seconds
saad@saad:~/Desktop$
```

Figure 1: Execution of C Sequential and C Pthreads Programs

Program Version	Execution Time (seconds)
C Sequential	0.03
C Pthreads (2 threads)	0.04
C Pthreads (4 threads)	0.04
C Pthreads (8 threads)	0.04
Python Sequential	1.01
Python Threads (4 threads)	2.28
Python Multiprocessing (4 processes)	0.61

Table 1: Execution Time Comparison

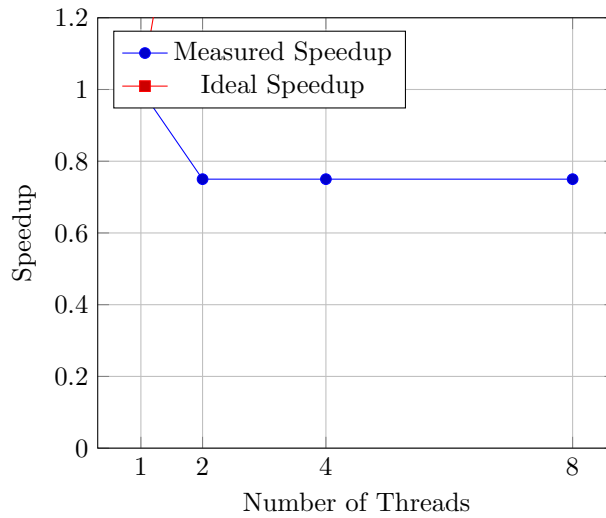


Figure 2: Speedup vs Number of Threads for C Pthreads

1 Self-Assessment Answers

1. A process is an independent program with its own memory space, making communication expensive but isolated, while a thread is a lightweight execution unit within a process that shares memory, allowing faster communication but requiring synchronization. Thread creation is cheaper than process creation.
2. A mutex is required to prevent race conditions when multiple threads update the shared global counter simultaneously. Without mutual exclusion, increments can interleave and produce incorrect results.
3. The `lscpu` output shows the total logical CPUs, physical cores per socket, and threads per core. The number of cores is obtained from `Core(s) per`

`socket`, and hyper-threading is indicated by `Thread(s) per core`. The total CPUs equals cores multiplied by threads per core.

4. The measured speedup was not linear and remained below one, indicating no performance gain. This occurs due to thread creation overhead, memory bandwidth saturation, and the sequential portion of the program as described by Amdahl's Law.
5. Python threading is slower for CPU-bound tasks because of the Global Interpreter Lock (GIL), which allows only one thread to execute Python bytecode at a time, preventing true parallelism.
6. False sharing occurs when independent variables modified by different threads reside on the same cache line, causing frequent cache invalidations and increased memory coherence traffic, which degrades performance.
7. Using private counters allows each thread to accumulate results without locking. Only a single synchronized update is required at the end, greatly reducing lock contention and improving scalability.
8. In Python, threads are suitable for I/O-bound workloads where waiting releases the GIL, while multiprocessing should be used for CPU-bound tasks to achieve true parallel execution across multiple cores.

2 Reflection

Parallelising the counting task showed that adding threads does not guarantee speedup. The pthread implementation was limited by memory bandwidth and thread overhead. Shared memory access became the main performance bottleneck. Mutex synchronization ensured correctness but reduced scalability. This behavior reflected the effect of Amdahl's Law in practice. Python threading performed poorly due to the Global Interpreter Lock. True parallelism was achieved only with multiprocessing. However, multiprocessing introduced additional memory overhead. The experiments highlighted the impact of hardware constraints on performance. Efficient parallel design requires minimizing contention and overhead.