Graduate Systems (CSE638)

PA01: Processes and Threads

INDRAPRASTHA INSTITUTE *of* INFORMATION TECHNOLOGY DELHI

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GitHub Repo URL: https://github.com/rahul25035/GRS_PA01

AI Usage Declaration

I used AI tools to help me while doing this assignment. I mainly used them for:

1. Writing and improving the I/O parts in the C codes (Part B, Part C, and Part D)
2. Getting help with awk commands to calculate stats inside the shell script loops (Part C and Part D)
3. Deciding how the output of the stats should look
4. Writing the plotting script for Part D
5. Improving the format and wording of the report and README
6. Debugging help - finding errors and fixing issues

I checked and tested everything myself before submitting. The final work and responsibility is mine.

Name: Rahul Pardasani

Date: 22nd January, 2026

1. Problem Statement

This assignment compares **process-based parallelism (fork)** and **thread-based parallelism (pthread)** by running three worker functions (**cpu**, **mem**, **io**) and measuring CPU usage, memory impact, I/O activity, and execution time.

2. System & Experimental Setup

2.1 Machine Details

- **OS:** Linux
- **No. of CPU cores:** 2
- **RAM:** 8 GB

2.2 Tools Used

- gcc (compilation)
- make
- top (CPU%)
- taskset (CPU pinning)
- iostat (disk stats)
- time (execution time)

2.3 Fixed Parameters Used

- **Last digit of roll number:** 5
- **Loop count (N):** (last digit × 10^3) = 5000
  (If last digit is 0, used 9 → N = 9000)

3. Part A : Program Implementations

3.1 Program A (Processes using fork())

File: MT25035_Part_A_Program_A.c

Goal: Create **2 child processes** using fork().

Implementation Summary:

- The parent process calls fork() twice.
- Each child prints its PID and exits.
- The parent waits for both child processes using wait().

Observed Output:

```None
Child 1: pid=<pid>

Child 2: pid=<pid>
```

3.2 Program B (Threads using pthread)

File: MT25035_Part_A_Program_B.c

Goal: Create **2 threads** using pthread.

Implementation Summary:

- Two threads are created using pthread_create().
- Each thread prints its thread ID.
- The main thread waits using pthread_join().

Observed Output:

```None
Thread 1 running

Thread 2 running
```

3.3 Images

```
● @rahul25035 ➜ /workspaces/GRS_PA01 (main) $ make partA
  gcc -Wall MT25035_PartA_A.c -o a.out
  gcc -Wall MT25035_PartA_B.c -o b.out -pthread
  ./a.out cpu 2
  Child 1: pid=118372
  Child 2: pid=118373
  ./b.out cpu 2
  Thread 1 running
  Thread 2 running
```

4. Part B : Worker Functions

Files:

- MT25035_Part_B_Program_A.c (process-based workers)
- MT25035_Part_B_Program_B.c (thread-based workers)

All worker functions execute a loop with **ITER = 5000**, derived from the last digit of the roll number (5×10^3).

4.1 Worker: cpu (CPU-Intensive)

Work Done:

- Performs deeply nested loops with arithmetic operations.
- No I/O or large memory allocation involved.

Expected Behavior:

- High CPU usage
- Minimal memory and I/O usage

4.2 Worker: mem (Memory-Intensive)

Work Done:

- Allocates a 256 MB buffer using malloc().

- Repeatedly accesses memory pages to stress RAM.

Expected Behavior:

- High memory usage
- Moderate CPU usage

4.3 Worker: io (I/O-Intensive)

Work Done:

- Repeatedly writes 4 KB buffers to a file using write().
- Forces disk writes using fsync().

Expected Behavior:

- High disk I/O activity
- Lower CPU and memory utilization due to I/O wait

5. Part C : Experiments (2 processes/threads)

Files:

- Script: MT25035_Part_C_main.sh
- Data CSV: MT25035_Part_C_results.csv

5.1 Measurement Method

For each variant (A/B + cpu/mem/io):

- Used taskset to pin execution to 0 and 1 CPU cores.
- Sampled CPU% using top at regular intervals.
- Observed disk behavior using iostat.
- Measured elapsed time using time.

5.2 Results Table (Part C)

The following results summarize the automated measurements recorded in MT25035_Part_C_results.csv. CPU usage is reported relative to the two CPU cores to which the program was pinned using taskset.

Program + Function	**CPU Usage**	**Memory Usage**	**I/O Activity**
A + cpu	Very High (~185%)	Low (~1.2 MB)	Low
A + mem	High (~136%)	High (~411 MB)	Low
A + io	Low (~7%)	Low (~1.7 MB)	High (~8k KB/s)
B + cpu	High (~155%)	Low (~1.4 MB)	Low
B + mem	Very High (~165%)	High (~513 MB)	Low
B + io	Low (~7%)	Low (~1.4 MB)	Very High (~25k KB/s)

5.3 Screenshots

```
● @rahul25035 →/workspaces/GRS_PA01 (main) $ make partC
  chmod +x MT25035_PartC_main.sh
  ./MT25035_PartC_main.sh
  Compiling programs...
  Compilation done
  ==================================

  components=2
  Prog        CPU%      Mem         IO        Time(s)
  ------------------------------------------------------------
  A+cpu       175.84    1.82MB      97.53     7.00
  B+cpu       184.30    1.40MB      29.60     6.91
  A+mem       169.92    411.31MB    40.00     6.84
  B+mem       145.98    410.80MB    19.06     6.60
  A+io        9.12      1.41MB      8237.00   5.15
  B+io        9.10      0.94MB      26642.00  5.29

  Results saved to MT25035_PartC_results.csv
```

5.4 Analysis (Part C)

- **CPU Workload:** Both variants saturate the two pinned cores (~175-185%), confirming the task is computation-heavy.
- **Memory Workload:** High memory usage (~411-513 MB) causes a slight CPU dip compared to the CPU task due to memory access latency.
- **I/O Workload:** CPU usage drops to minimum (~9%) as workers spend most time in I/O wait for disk writes.
- **Process vs. Thread:** Thread-based (B) I/O shows significantly higher throughput (~25k vs ~8k KB/s) in this sample, suggesting lower overhead.

6. Part D : Automation and Plots (vary processes/threads)

Files:

- MT25035_Part_D_main.sh
- MT25035_Part_D_plots.sh
- MT25035_Part_D_Program_A.c

- MT25035_Part_D_Program_B.c
- Data CSV: MT25035_Part_D_results.csv

6.1 Experiment Plan

- **Program A (Processes):** {2, 3, 4, 5, 6, 7 , 8}
- **Program B (Threads):** {2, 3, 4, 5, 6, 7, 8}

All experiments use **ITER = 5000** and the same worker logic as Part C.

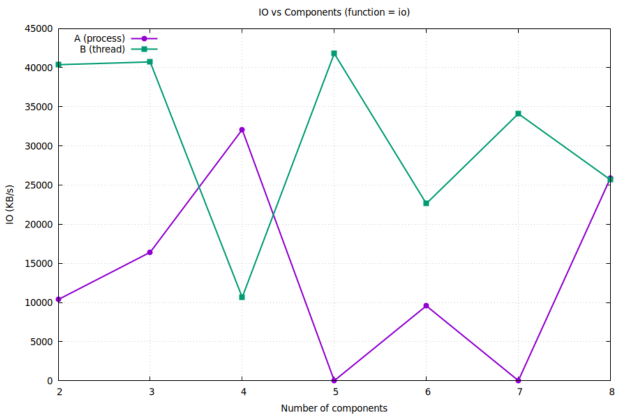
6.2 Collected Metrics

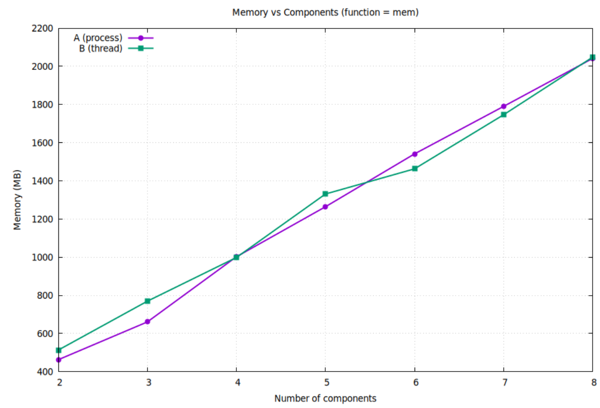
For each run, the following were recorded using the automated script:

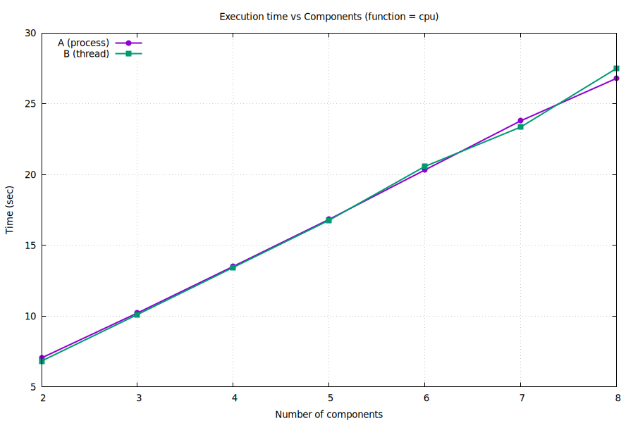
- Average CPU utilization (top)
- Execution time (time)
- Memory usage (RSS from top)
- Disk I/O activity (iostat, write rate / utilization)

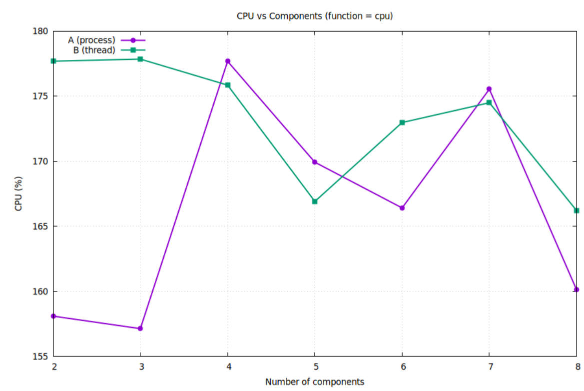
All raw values are available in MT25035_Part_D_results.csv.

6.3 Plots and Images (Part D)










```
@rahul25035 →/workspaces/GRS_PA01 (main) $ make partD

components=2
Prog   CPU%    Mem       IO         Time(s)
------------------------------------------------
A+cpu  158.10  1.88MB    34.37      7.050
B+cpu  177.68  1.00MB    50.40      6.830
A+mem  173.14  463.05MB  8.80       7.090
B+mem  171.76  513.51MB  67.79      7.100
A+io   9.10    1.59MB    10377.00   5.230
B+io   9.55    1.03MB    40374.00   5.230

components=3
Prog   CPU%    Mem       IO         Time(s)
------------------------------------------------
A+cpu  157.14  1.96MB    17.64      10.220
B+cpu  177.84  1.27MB    36.57      10.110
A+mem  141.47  661.00MB  61.84      9.670
B+mem  183.46  769.64MB  23.43      10.340
A+io   16.18   2.50MB    16419.00   5.940
B+io   5.46    1.10MB    40731.20   6.370

components=4
Prog   CPU%    Mem       IO         Time(s)
------------------------------------------------
A+cpu  177.67  2.38MB    2877.67    13.510
B+cpu  175.84  1.38MB    78.64      13.440
A+mem  178.17  1002.28MB 55.56      15.200
B+mem  188.72  998.55MB  37.60      15.300
A+io   15.10   2.88MB    32086.40   6.830
B+io   15.46   1.20MB    10668.00   6.750
```

```
components=5
Prog   CPU%    Mem       IO         Time(s)
------------------------------------------------
A+cpu  169.92  2.60MB    9314.18    16.830
B+cpu  166.91  1.38MB    90.46      16.770
A+mem  181.48  1264.40MB 21.53      20.110
B+mem  192.39  1331.20MB 87.61      20.250
A+io   11.90   2.19MB    21.33      7.930
B+io   18.80   1.15MB    41805.33   8.040

components=6
Prog   CPU%    Mem       IO         Time(s)
------------------------------------------------
A+cpu  166.41  3.60MB    10514.77   20.320
B+cpu  172.97  1.51MB    58.15      20.570
A+mem  179.59  1541.27MB 43.70      25.870
B+mem  175.21  1462.97MB 51.37      24.490
A+io   19.73   3.62MB    9578.00    8.780
B+io   11.46   1.50MB    22636.00   7.720

components=7
Prog   CPU%    Mem       IO         Time(s)
------------------------------------------------
A+cpu  175.53  4.00MB    5457.05    23.790
B+cpu  174.49  1.39MB    36.49      23.350
A+mem  180.10  1790.11MB 22.28      30.720
B+mem  177.32  1746.19MB 68.82      29.670
A+io   15.62   3.33MB    32.67      8.180
B+io   16.30   1.50MB    34113.33   8.370
```

```
components=8
Prog   CPU%    Mem       IO         Time(s)
-----------------------------------------------------
A+cpu  160.12  3.18MB    4862.41    26.790
B+cpu  166.21  1.38MB    47.89      27.490
A+mem  179.61  2041.34MB 62.11      34.190
B+mem  169.43  2048.00MB 69.80      34.460
A+io   18.20   4.00MB    25892.67   9.150
B+io   15.35   1.50MB    25678.67   8.700

Results saved to MT25035_PartD_results.csv
Making Plots...
Plots created: cpu_vs_components.png, mem_vs_components.png, io_vs_components.png, time_vs_components.png
```

6.4 Observations & Discussion (Part D)

Linear Scaling (Time): Execution time for CPU and Memory tasks increases linearly with the number of components (2 to 8).

Linear Scaling (Memory): Memory usage grows by ~256 MB per component, reaching ~2 GB at 8 components.

CPU Saturation: CPU usage remains consistently high (~160-180%) regardless of component count because the 2 pinned cores stay fully saturated.

I/O Noise: I/O throughput is highly fluctuating ("noisy") due to OS disk buffering and write caching.

Resource Efficiency: Program B (threads) uses significantly less memory for non-memory tasks (e.g., 1.38 MB vs 3.18 MB for CPU task) because threads share an address space.