Part I - Scheduler Simulator

Student 1: Wenxuan Han 101256669
Student 2: Tony Yao 101298080
2025-12-01
Github Repository Link: https://github.com/toast23/Assignment_3_P1.git

Objective

Utilize various metrics to compare how algorithms perform under variable I/O-CPU dominant workloads.

Test Group 1: Mostly I/O Bound

Test Case 1: Sanity Check
Input: input10.txt
10, 1, 0, 100, 10, 80

EP = RR = EP_RR: execution10.txt

```
 1    +------------------------------------------------+
 2    |Time of Transition |PID | Old State | New State |
 3    +------------------------------------------------+
 4    |                 0 | 10 |       NEW |     READY |
 5    |                 0 | 10 |     READY |   RUNNING |
 6    |                10 | 10 |   RUNNING |   WAITING |
 7    |                90 | 10 |   WAITING |     READY |
 8    |                90 | 10 |     READY |   RUNNING |
 9    |               100 | 10 |   RUNNING |   WAITING |
10    |               180 | 10 |   WAITING |     READY |
11    |               180 | 10 |     READY |   RUNNING |
12    |               190 | 10 |   RUNNING |   WAITING |
13    |               270 | 10 |   WAITING |     READY |
14    |               270 | 10 |     READY |   RUNNING |
15    |               280 | 10 |   RUNNING |   WAITING |
16    |               360 | 10 |   WAITING |     READY |
17    |               360 | 10 |     READY |   RUNNING |
18    |               370 | 10 |   RUNNING |   WAITING |
19    |               450 | 10 |   WAITING |     READY |
20    |               450 | 10 |     READY |   RUNNING |
21    |               460 | 10 |   RUNNING |   WAITING |
22    |               540 | 10 |   WAITING |     READY |
23    |               540 | 10 |     READY |   RUNNING |
24    |               550 | 10 |   RUNNING |   WAITING |
25    |               630 | 10 |   WAITING |     READY |
26    |               630 | 10 |     READY |   RUNNING |
27    |               640 | 10 |   RUNNING |   WAITING |
28    |               720 | 10 |   WAITING |     READY |
29    |               720 | 10 |     READY |   RUNNING |
30    |               730 | 10 |   RUNNING |   WAITING |
31    |               810 | 10 |   WAITING |     READY |
32    |               810 | 10 |     READY |   RUNNING |
33    |               820 | 10 |   RUNNING |TERMINATED |
34    +------------------------------------------------+
35
36    +-------------SIMULATION METRICS--------------+
37    |Throughput: 0.0012 processes completed/ms
38    |Average Wait Time: 0.0000 ms
39    |Average Turnaround Time: 820.00 ms
40    |Average Response Time: 10.00 ms
41    +---------------------------------------------+
```

Test Case 2: High Priority Wait Time
Input: input11.txt
50, 1, 0, 300, 0, 0
10, 1, 10, 50, 10, 50

EP: execution11.txt

```
+-----------------------------------------------+
|Time of Transition |PID | Old State | New State |
+-----------------------------------------------+
|              0 | 50 |       NEW |      READY |
|              0 | 50 |     READY |    RUNNING |
|             10 | 10 |       NEW |      READY |
|            300 | 50 |   RUNNING |TERMINATED |
|            300 | 10 |     READY |    RUNNING |
|            310 | 10 |   RUNNING |    WAITING |
|            360 | 10 |   WAITING |      READY |
|            360 | 10 |     READY |    RUNNING |
|            370 | 10 |   RUNNING |    WAITING |
|            420 | 10 |   WAITING |      READY |
|            420 | 10 |     READY |    RUNNING |
|            430 | 10 |   RUNNING |    WAITING |
|            480 | 10 |   WAITING |      READY |
|            480 | 10 |     READY |    RUNNING |
|            490 | 10 |   RUNNING |    WAITING |
|            540 | 10 |   WAITING |      READY |
|            540 | 10 |     READY |    RUNNING |
|            550 | 10 |   RUNNING |TERMINATED |
+-----------------------------------------------+

+-------------SIMULATION METRICS-------------+
|Throughput: 0.0036 processes completed/ms
|Average Wait Time: 145.0000 ms
|Average Turnaround Time: 420.00 ms
|Average Response Time: 155.00 ms
+-------------------------------------------+
```

RR: execution11.txt

```
+-----------------------------------------------+
|Time of Transition |PID | Old State | New State |
+-----------------------------------------------+
|              0 | 50 |       NEW |      READY |
|              0 | 50 |     READY |    RUNNING |
|             10 | 10 |       NEW |      READY |
|            100 | 50 |   RUNNING |      READY |
|            100 | 10 |     READY |    RUNNING |
|            110 | 10 |   RUNNING |    WAITING |
|            110 | 50 |     READY |    RUNNING |
|            160 | 10 |   WAITING |      READY |
|            210 | 50 |   RUNNING |      READY |
|            210 | 10 |     READY |    RUNNING |
|            220 | 10 |   RUNNING |    WAITING |
|            220 | 50 |     READY |    RUNNING |
|            270 | 10 |   WAITING |      READY |
|            320 | 50 |   RUNNING |TERMINATED |
|            320 | 10 |     READY |    RUNNING |
|            330 | 10 |   RUNNING |    WAITING |
|            380 | 10 |   WAITING |      READY |
|            380 | 10 |     READY |    RUNNING |
|            390 | 10 |   RUNNING |    WAITING |
|            440 | 10 |   WAITING |      READY |
|            440 | 10 |     READY |    RUNNING |
|            450 | 10 |   RUNNING |TERMINATED |
+-----------------------------------------------+

+-------------SIMULATION METRICS-------------+
|Throughput: 0.0044 processes completed/ms
|Average Wait Time: 105.0000 ms
|Average Turnaround Time: 380.00 ms
|Average Response Time: 155.00 ms
+-------------------------------------------+
```

EP_RR: execution11.txt

```
+-------------------------------------------------+
|Time of Transition |PID | Old State | New State |
+-------------------------------------------------+
|                0 | 50 |        NEW |     READY |
|                0 | 50 |      READY |   RUNNING |
|               10 | 10 |        NEW |     READY |
|               10 | 50 |    RUNNING |     READY |
|               10 | 10 |      READY |   RUNNING |
|               20 | 10 |    RUNNING |   WAITING |
|               20 | 50 |      READY |   RUNNING |
|               70 | 10 |    WAITING |     READY |
|               70 | 50 |    RUNNING |     READY |
|               70 | 10 |      READY |   RUNNING |
|               80 | 10 |    RUNNING |   WAITING |
|               80 | 50 |      READY |   RUNNING |
|              130 | 10 |    WAITING |     READY |
|              130 | 50 |    RUNNING |     READY |
|              130 | 10 |      READY |   RUNNING |
|              140 | 10 |    RUNNING |   WAITING |
|              140 | 50 |      READY |   RUNNING |
|              190 | 10 |    WAITING |     READY |
|              190 | 50 |    RUNNING |     READY |
|              190 | 10 |      READY |   RUNNING |
|              200 | 10 |    RUNNING |   WAITING |
|              200 | 50 |      READY |   RUNNING |
|              250 | 10 |    WAITING |     READY |
|              250 | 50 |    RUNNING |     READY |
|              250 | 10 |      READY |   RUNNING |
|              260 | 10 |    RUNNING |TERMINATED |
|              260 | 50 |      READY |   RUNNING |
|              350 | 50 |    RUNNING |TERMINATED |
+-------------------------------------------------+

+-------------SIMULATION METRICS--------------+
|Throughput: 0.0057 processes completed/ms
|Average Wait Time: 25.0000 ms
|Average Turnaround Time: 300.00 ms
|Average Response Time: 155.00 ms
+---------------------------------------------+
```

Test Case 3: I/O Frequency Overhead

Input: input12.txt

10, 1, 0, 5, 1, 1
20, 1, 0, 5, 1, 1

EP = RR = EP_RR: execution12.txt

```
+-----------------------------------------------+
|Time of Transition |PID | Old State | New State |
+-----------------------------------------------+
|               0 | 10 |       NEW |     READY |
|               0 | 20 |       NEW |     READY |
|               0 | 10 |     READY |   RUNNING |
|               1 | 10 |   RUNNING |   WAITING |
|               1 | 20 |     READY |   RUNNING |
|               2 | 20 |   RUNNING |   WAITING |
|               2 | 10 |   WAITING |     READY |
|               2 | 10 |     READY |   RUNNING |
|               3 | 10 |   RUNNING |   WAITING |
|               3 | 20 |   WAITING |     READY |
|               3 | 20 |     READY |   RUNNING |
|               4 | 20 |   RUNNING |   WAITING |
|               4 | 10 |   WAITING |     READY |
|               4 | 10 |     READY |   RUNNING |
|               5 | 10 |   RUNNING |   WAITING |
|               5 | 20 |   WAITING |     READY |
|               5 | 20 |     READY |   RUNNING |
|               6 | 20 |   RUNNING |   WAITING |
|               6 | 10 |   WAITING |     READY |
|               6 | 10 |     READY |   RUNNING |
|               7 | 10 |   RUNNING |   WAITING |
|               7 | 20 |   WAITING |     READY |
|               7 | 20 |     READY |   RUNNING |
|               8 | 20 |   RUNNING |   WAITING |
|               8 | 10 |   WAITING |     READY |
|               8 | 10 |     READY |   RUNNING |
|               9 | 10 |   RUNNING |TERMINATED |
|               9 | 20 |   WAITING |     READY |
|               9 | 20 |     READY |   RUNNING |
|              10 | 20 |   RUNNING |TERMINATED |
+-----------------------------------------------+

+-------------SIMULATION METRICS--------------+
|Throughput: 0.2000 processes completed/ms
|Average Wait Time: 0.5000 ms
|Average Turnaround Time: 9.50 ms
|Average Response Time: 1.00 ms
+---------------------------------------------+
```

Test Group 2: Mostly CPU Bound

Test Case 1: High Priority Wait Time
Input: input13.txt
50, 1, 0, 500, 0, 0
10, 1, 50, 50, 0, 0

EP: execution13.txt

```
+-----------------------------------------------+
|Time of Transition |PID | Old State | New State |
+-----------------------------------------------+
|               0 | 50 |       NEW |     READY |
|               0 | 50 |     READY |   RUNNING |
|              50 | 10 |       NEW |     READY |
|             500 | 50 |   RUNNING |TERMINATED |
|             500 | 10 |     READY |   RUNNING |
|             550 | 10 |   RUNNING |TERMINATED |
+-----------------------------------------------+

+-------------SIMULATION METRICS--------------+
|Throughput: 0.0036 processes completed/ms
|Average Wait Time: 225.0000 ms
|Average Turnaround Time: 500.00 ms
|Average Response Time: 275.00 ms
+---------------------------------------------+
```

RR: execution13.txt

```
+--------------------------------------------------+
|Time of Transition |PID | Old State | New State |
+--------------------------------------------------+
|               0 | 50 |        NEW |     READY |
|               0 | 50 |      READY |   RUNNING |
|              50 | 10 |        NEW |     READY |
|             100 | 50 |    RUNNING |     READY |
|             100 | 10 |      READY |   RUNNING |
|             150 | 10 |    RUNNING |TERMINATED |
|             150 | 50 |      READY |   RUNNING |
|             250 | 50 |    RUNNING |     READY |
|             250 | 50 |      READY |   RUNNING |
|             350 | 50 |    RUNNING |     READY |
|             350 | 50 |      READY |   RUNNING |
|             450 | 50 |    RUNNING |     READY |
|             450 | 50 |      READY |   RUNNING |
|             550 | 50 |    RUNNING |TERMINATED |
+--------------------------------------------------+

+-------------SIMULATION METRICS--------------+
|Throughput: 0.0036 processes completed/ms
|Average Wait Time: 50.0000 ms
|Average Turnaround Time: 325.00 ms
|Average Response Time: 275.00 ms
+---------------------------------------------+
```

EP_RR: execution13.txt

```
+--------------------------------------------------+
|Time of Transition |PID | Old State | New State |
+--------------------------------------------------+
|               0 | 50 |        NEW |     READY |
|               0 | 50 |      READY |   RUNNING |
|              50 | 10 |        NEW |     READY |
|              50 | 50 |    RUNNING |     READY |
|              50 | 10 |      READY |   RUNNING |
|             100 | 10 |    RUNNING |TERMINATED |
|             100 | 50 |      READY |   RUNNING |
|             200 | 50 |    RUNNING |     READY |
|             200 | 50 |      READY |   RUNNING |
|             300 | 50 |    RUNNING |     READY |
|             300 | 50 |      READY |   RUNNING |
|             400 | 50 |    RUNNING |     READY |
|             400 | 50 |      READY |   RUNNING |
|             500 | 50 |    RUNNING |     READY |
|             500 | 50 |      READY |   RUNNING |
|             550 | 50 |    RUNNING |TERMINATED |
+--------------------------------------------------+

+-------------SIMULATION METRICS--------------+
|Throughput: 0.0036 processes completed/ms
|Average Wait Time: 25.0000 ms
|Average Turnaround Time: 300.00 ms
|Average Response Time: 275.00 ms
+---------------------------------------------+
```

Test Case 2: Synced Arrival Time
Input: input14.txt
10, 1, 0, 300, 0, 0
50, 1, 0, 10, 0, 0

EP: execution14.txt

```
+----------------------------------------------+
|Time of Transition |PID | Old State | New State |
+----------------------------------------------+
|                 0 | 10 |       NEW |     READY |
|                 0 | 50 |       NEW |     READY |
|                 0 | 10 |     READY |   RUNNING |
|               300 | 10 |   RUNNING |TERMINATED |
|               300 | 50 |     READY |   RUNNING |
|               310 | 50 |   RUNNING |TERMINATED |
+----------------------------------------------+

+-------------SIMULATION METRICS-------------+
|Throughput: 0.0065 processes completed/ms
|Average Wait Time: 150.0000 ms
|Average Turnaround Time: 305.00 ms
|Average Response Time: 155.00 ms
+----------------------------------------------+
```

RR: execution14.txt

```
+----------------------------------------------+
|Time of Transition |PID | Old State | New State |
+----------------------------------------------+
|                 0 | 10 |       NEW |     READY |
|                 0 | 50 |       NEW |     READY |
|                 0 | 10 |     READY |   RUNNING |
|               100 | 10 |   RUNNING |     READY |
|               100 | 50 |     READY |   RUNNING |
|               110 | 50 |   RUNNING |TERMINATED |
|               110 | 10 |     READY |   RUNNING |
|               210 | 10 |   RUNNING |     READY |
|               210 | 10 |     READY |   RUNNING |
|               310 | 10 |   RUNNING |TERMINATED |
+----------------------------------------------+

+-------------SIMULATION METRICS-------------+
|Throughput: 0.0065 processes completed/ms
|Average Wait Time: 55.0000 ms
|Average Turnaround Time: 210.00 ms
|Average Response Time: 155.00 ms
+----------------------------------------------+
```

EP_RR: execution14.txt

```
+----------------------------------------------+
|Time of Transition |PID | Old State | New State |
+----------------------------------------------+
|                 0 | 10 |       NEW |     READY |
|                 0 | 50 |       NEW |     READY |
|                 0 | 10 |     READY |   RUNNING |
|               100 | 10 |   RUNNING |     READY |
|               100 | 10 |     READY |   RUNNING |
|               200 | 10 |   RUNNING |     READY |
|               200 | 10 |     READY |   RUNNING |
|               300 | 10 |   RUNNING |TERMINATED |
|               300 | 50 |     READY |   RUNNING |
|               310 | 50 |   RUNNING |TERMINATED |
+----------------------------------------------+

+-------------SIMULATION METRICS-------------+
|Throughput: 0.0065 processes completed/ms
|Average Wait Time: 150.0000 ms
|Average Turnaround Time: 305.00 ms
|Average Response Time: 155.00 ms
+----------------------------------------------+
```

Analysis

Test Group 1: Mostly I/O Bound

EP performed poorly in test case 2 where the second process arrived later than the first. Despite being higher priority, the second process is forced to wait for the first lower priority process due to EP's nonpreemptive behaviour. This scenario is called the convoy effect where other processes can be held up by slower processes and have no choice but to wait which drastically increases average wait time.

This can be found in the data:
EP average wait time → 145 ms
RR average wait time → 105 ms
EP_RR average wait time → 25 ms

On the other hand, EP_RR performed the best in test case 2 by a large margin due its preemptive behavior with priority ruling which allows it to address the main weaknesses from EP and RR. EP_RR does not suffer from the convey effect unlike EP due to preemption (EP and quantum). EP_RR does better than RR due to its priority ruling as it is able to be preempted when a higher priority process exists instead of waiting for the entire time quantum.

At first glance, it appears all algorithms performed the same in test case 3 but this can only happen in an ideal situation which is impossible. In reality, overhead exists and is a very real problem. This simulator assumes immediate I/O availability and execution which means any kind of interrupt latency results in zero. If you include overhead from context switching as well (which is a realistic concern), EP will actually perform much better compared to RR and EP_RR as its nonpreemptive behaviour limits overhead.

Test Group 2: Mostly CPU Bound

The results of test case 1 interestingly differ from test case 2 in group 1. As expected, EP_RR yields the shortest average wait time of 25 ms followed by RR and EP with 50 ms and 225 ms respectively (same explanation as test case 2 group 1). The difference is that all algorithms share the same throughput of 0.0036 processes completed/ms. This can be explained by the absence of I/O operations allowing a CPU uptime of 100%. Therefore, the scheduling of the processes proves irrelevant in this context as the simulation time is fixed → all simulations terminate at 550 ms.

Test case 2 yields similar results as seen through the same shared throughput rate. However, the benefits of pure RR are fully observed here for the first time as it performs better than EP and EP_RR in terms of average wait time and consequently, average TAT. This can be attributed to the fact that in the scenario where processes share the same arrival time, EP_RR acts as an

inefficient EP. EP_RR runs exactly like EP by using priority to pick the process, but differs in that the current process will eventually be preempted due to the time quantum. This preemption does not do anything meaningful as the algorithm will use EP to decide the next process again causing the same process to run immediately after. The smaller low priority process has to ultimately wait for the higher priority process to run which explains the matching data of EP and EP_RR in this test case. RR shines here as it gives all jobs a fair chance to run which allows the low priority process to run reducing average wait time. Additionally, in a real life scenario, EP_RR will perform even worse than on paper compared to RR due to more preemptions (quantum and EP) which increases overhead.