

Project 3 Report

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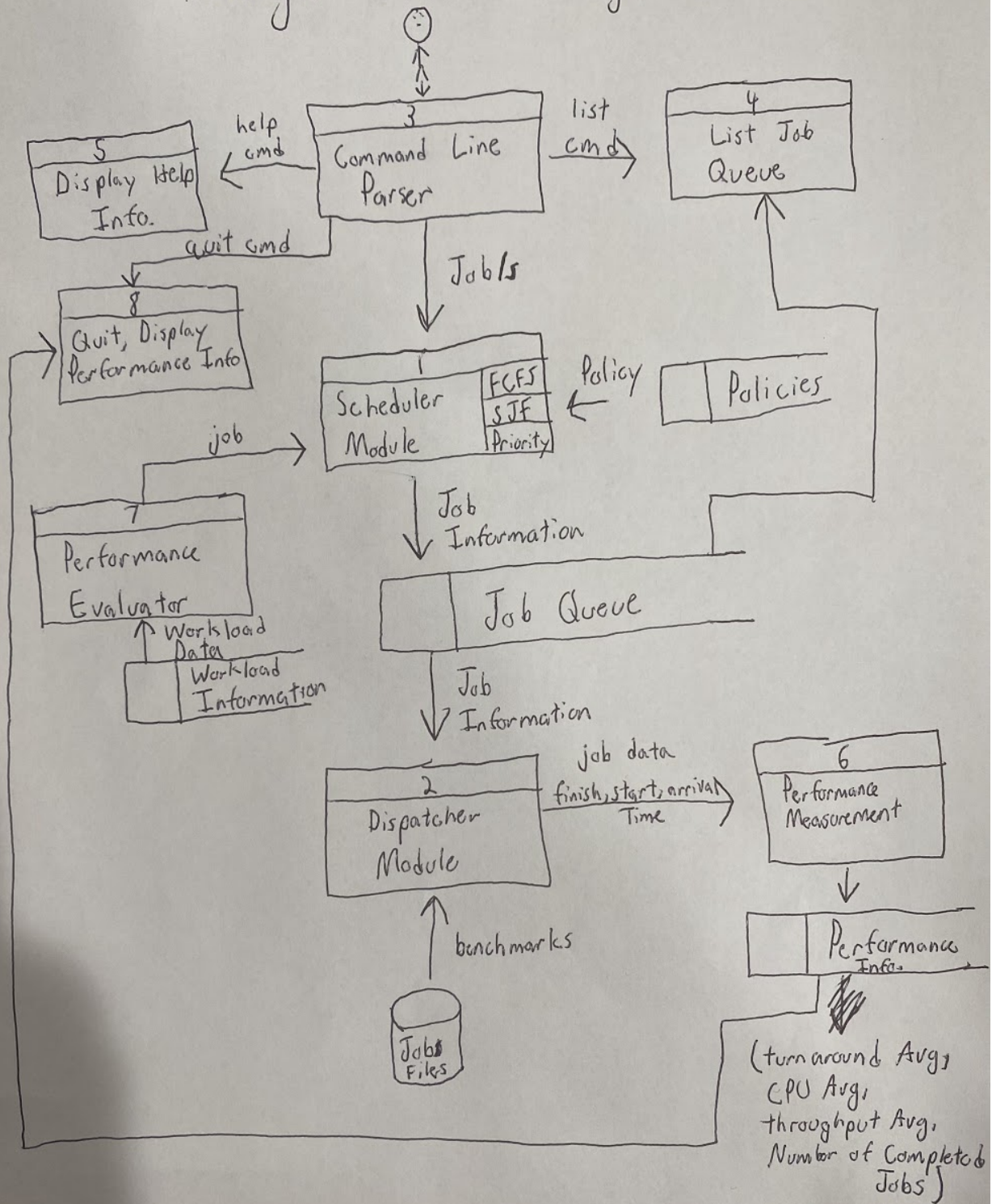
COMP-7500

03/21/2021

Design:

The AUBatch program is designed to perform the functions of a batch scheduling system. The program will take a series of processes and place them in a queue based on a predetermined scheduling policy, and then execute those processes based on their order in the queue. While this happens a series of performance evaluators will be recording metrics on the jobs executed, such as CPU Time, Turnaround Time, Throughput, etc. For AUBatch, the program will first accept user input through a command line parser that will tell the scheduler which jobs to schedule. The scheduler will then place those jobs in the queue based on which scheduling policy has been selected. The scheduler can also reorder the queue if the scheduling algorithm is changed mid-run. The user may also change the scheduling policy from the command line. The dispatcher module will then read the queue and then begin executing those jobs. After completion of the job, an information module will calculate relevant performance metrics, that will then be displayed on exiting the program. A Design Flow Diagram is provided below.

Design Flow Diagram



Implementation:

AUbatch is implemented in the C language, divided into five files. These five files are “main.c”, “command_line_parse.c”, “dispatch.c”, “schedule.c”, “info.c”, and “eval.c”. These files each contain a respective primary function, titled respectively after the file name. There is also a header file, “header.h” that contains structs for job buffers and metrics storage. As well as some common variables. These files utilize separate compilation with a makefile. Enter “make build” in the terminal to compile these five files into the single “aubatch” executable. Enter “make clean” to remove the executable. Execution begins in the “main.c” file, which will create two threads using the “pthread” library. These two threads begin the execution of “command_line_parse” and “dispatch,” each located in their respective “.c” files. The “dispatch” function immediately pauses and waits for a job to enter the queue.

The “command_line_parse” function will wait for a command or commands from the user. These commands include a help menu, a list command to display running statuses, a quit command that also displays performance metrics, a series of policy commands that will switch the current scheduling policy (default is FCFS), and a test command that commences running of several benchmark processes for automated performance evaluation. While the command line parser is waiting for input, it will unlock the queue. The “run” command accepts the file name of a benchmark process, an estimated CPU time, and an assigned priority, as input. The command line parser will then lock the queue, take this information and pass it to the scheduler.

The scheduler will then place this information and place the job in the job queue, where its location is dependent on the scheduling policy. The dispatcher will now detect that there is a job, or jobs in the queue. It will then keep a lock on the queue and then create a child process. The child process will begin execution of these jobs using the “execv()” function. During this execution, the parent process will unlock the queue and record information such as start, finish, and arrival time. The scheduler contains the capability to change the scheduling policy while processes are executing. However, this is designed to be non-preemptive, and processes that have started execution will continue to completion. Upon completion of the job, this recorded information is passed into the “info” function, contained in its own file. This info function will take this recorded information and perform various calculations, such as determining waiting average, turnaround average, and throughput. These performance metrics are stored in a struct initialized in the “header.h” file. These metrics are displayed to the user on a successful exit of AUbatch using the “quit” command.

Performance Metrics:

A series of five example jobs were created for AUBatch. These jobs perform simple arithmetic operations and then sleep for a determined amount of time. For example, "job_5.c" will perform simple math and then sleep for five seconds. When these processes are running, information such as arrival time, start time, and finish time is recorded. This information is then sent to the "info" function which will calculate additional metrics and store them in a struct. This information is displayed to the user when using the "quit" command to exit the program. The "run" command requires three arguments: the path to the desired process, an estimated execution time, and a priority. An example usage of the "run" command is provided below.

Framework:

"[run] <job> <execution time> <priority>"

In Use:

"run jobs/job_5 5 3"

The "test" command will use the "run" command on all processes that exist in the "benchmark" folder of the project's root directory. These benchmark files are copies of the processes that exist within the "jobs" folder. The "test" command generates random priorities from one to a max, which is given from the command line. The "test" command also determines the CPU time from the file passed in. An example usage of the "test" command is provided below.

Framework:

"[test] <benchmark folder> <policy> <number of jobs> <priority variance> "

In Use:

"run ./benchmark fcfs 5 10"

Using the “test” command we are able to load all five jobs into the queue and execute them to receive their performance metrics. The following metrics were gained from running this performance evaluation using the following command..

Command:

“test ./benchmarks <policy> 5 10 ”

*replace <policy> with any of the three scheduling policies: *fcfs*, *sjf*, *pri*.

	Waiting Avg.	Turn Avg.	Throughput
FCFS	42.50s	71.50s	0.0140 No/s
SJF	24.75s	53.50s	0.0187 No/s
Priority	70.00s	117.00s	0.0085 No/s

Lessons Learned:

The C language continues to remain a challenge, and I do not foresee myself utilizing the C language in personal projects outside of school or work assignments. This project was easier to understand in the design phase, and implementation took many days of trial and error. The design of the scheduling algorithms was not a difficult task, and I feel that implementing these algorithms helped me understand them better as opposed to just a theoretical learning standpoint. This project helped me with the understanding of the pthread library immensely. Understanding the mutex locks and condition variables was something I struggled with greatly in class, but writing the code helped me learn the flow of the locks and conditions. Finally, this was my first time using separate compilation using a makefile. I had always put off attempting to learn them, believing them to be too difficult, only to later find out that it was one of the easiest steps of this project.

I was unable to get the “test” command to correctly determine CPU time. As a result, any job within the “benchmark” folder must end in “_<runtime>” or the Shortest Job First algorithm will not compute correctly. Example: “job_5” has a CPU time of 5.

Basics Script:

```
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m make build  
[?2004l
```

```
[H[2J[3Jgcc -pthread -o aubatch main.c command_line_parse.c dispatch.c schedule.c info.c  
eval.c
```

BUILD COMPLETE

```
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch  
[?2004l
```

Press ? For Help Menu:

> help

AUBatch Help Menu

[run] <job> <time> <priority>

[list] List Job Status

[fcfs] Change Policy to FCFS

[sjf] Change Policy To SJF

[pri] Change Policy To Priority

[quit] Exit AUBatch

[help] Print Help Menu

> ?

AUBatch Help Menu

[run] <job> <time> <priority>

[list] List Job Status

[fcfs] Change Policy to FCFS

[sjf] Change Policy To SJF

[pri] Change Policy To Priority

[quit] Exit AUBatch

[help] Print Help Menu

> list

Scheduling Policy: FCFS

Jobs In Queue: 0

> fcfs

FCFS Is Current Policy!

> sjf

Policy Changed To SJF

0 Waiting Jobs Rescheduled

> pri

Policy Changed To pri

0 Waiting Jobs Rescheduled

> foo

foo

: Command Not Found

> quit

Waiting Time Avg: 0.00s

Turnaround Time Avg: 0.00s

Throughput: 0.0000 No./s

Total Jobs Completed: 0

[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m exit

[?2004l

exit

Script done on 2022-03-21 19:30:00-05:00 [COMMAND_EXIT_CODE="0"]

Run Script:

```
Script started on 2022-03-21 19:38:02-05:00 [TERM="xterm-256color" TTY="/dev/pts/1"
COLUMNS="336" LINES="18"]
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l
Press ? For Help Menu:
> fcfs
FCFS Is Current Policy!
> run jobs/job_20 20 3
Job jobs/job_20 Submitted.
Estimated Wait Time: 0s
Policy: FCFS
> run jobs/job_20 20 6
Job jobs/job_20 Submitted.
Estimated Wait Time: 0s
Policy: FCFS
> run jobs/job_20 20 9
Job jobs/job_20 Submitted.
Estimated Wait Time: 20s
Policy: FCFS
> list
Scheduling Policy: FCFS
Jobs In Queue: 2


| Job | CPU Time | Pri | Arrival Time | Status  |
|-----|----------|-----|--------------|---------|
| 1   | 20       | 3   | 19:38:16     | Running |
| 2   | 20       | 6   | 19:38:22     | Waiting |
| 3   | 20       | 9   | 19:38:28     | Waiting |


> list
Scheduling Policy: FCFS
Jobs In Queue: 0
> quit
Waiting Time Avg: 14.00s
Turnaround Time Avg: 34.00s
Throughput: 0.0294 No./s
Total Jobs Completed: 3
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m
ex[K[K./aubatch
[?2004l
Press ? For Help Menu:
> sjf
Policy Changed To SJF
0 Waiting Jobs Rescheduled
> run jobs/job_20 20 3
```


Job jobs/job_20 Submitted.

Estimated Wait Time: 0s

Policy: SJF

> run jobs/job_20 20 5

Job jobs/job_20 Submitted.

Estimated Wait Time: 0s

Policy: SJF

> run jobs/job_20 20 7

Job jobs/job_20 Submitted.

Estimated Wait Time: 20s

Policy: SJF

> list

Scheduling Policy: SJF

Jobs In Queue: 2

Job	CPU Time	Pri	Arrival Time	Status
1	20	3	19:41:10	Running
2	20	5	19:41:15	Waiting
3	20	7	19:41:22	Waiting

> list

Scheduling Policy: SJF

Jobs In Queue: 0

> quit

Waiting Time Avg: 14.33s

Turnaround Time Avg: 34.33s

Throughput: 0.0291 No./s

Total Jobs Completed: 3

[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l

Press ? For Help Menu:

> pri

Policy Changed To pri

0 Waiting Jobs Rescheduled

> run jobs/job_20 20 8

Job jobs/job_20 Submitted.

Estimated Wait Time: 0s

Policy: pri

> run jobs/job_20 20 5

Job jobs/job_20 Submitted.

Estimated Wait Time: 0s

Policy: pri

> run jobs/job_20 20 9

Job job/job_20 Submitted.
Estimated Wait Time: 20s
Policy: pri

> list
Scheduling Policy: pri

Jobs In Queue: 2

Job	CPU Time	Pri	Arrival Time	Status
1	20	8	19:44:03	Running
2	20	5	19:44:09	Waiting
3	20	9	19:44:18	Waiting

> list
Scheduling Policy: pri

Jobs In Queue: 0

> quit
Waiting Time Avg: 13.00s
Turnaround Time Avg: 26.33s
Throughput: 0.0380 No./s
Total Jobs Completed: 3
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l

Press ? For Help Menu:

> run job_ /job_30 30 8

Job job/job_30 Submitted.

Estimated Wait Time: 0s

Policy: FCFS

> run jobs/job_60 60 5

Job jobs/job_60 Submitted.

Estimated Wait Time: 0s

Policy: FCFS

> run jobs/job_120 120 3

Job jobs/job_120 Submitted.

Estimated Wait Time: 0s

Policy: FCFS

> list

Scheduling Policy: FCFS

Jobs In Queue: 1

Job	CPU Time	Pri	Arrival Time	Status
2	60	5	19:49:29	Running
3	120	3	19:49:38	Waiting

> list

Scheduling Policy: FCFS

```

Jobs In Queue: 0
> quit
Waiting Time Avg:    17.00s
Turnaround Time Avg:    77.00s
Throughput:    0.0130 No./s
Total Jobs Completed: 3
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l
Press ? For Help Menu:
> run jobs/job_120          sjf
Policy Changed To SJF
0 Waiting Jobs Rescheduled
> run jobs/job_120 120 8
Job jobs/job_120 Submitted.
Estimated Wait Time: 0s
Policy: SJF
> run jobs/job_60 60 4
Job jobs/job_60 Submitted.
Estimated Wait Time: 0s
Policy: SJF
> run jobs/job_30 30 4
Job jobs/job_30 Submitted.
Estimated Wait Time: 0s
Policy: SJF
> list
Scheduling Policy: SJF
Jobs In Queue: 2

```

Job	CPU Time	Pri	Arrival Time	Status
1	120	8	19:53:54	Running
3	30	4	19:54:08	Waiting
2	60	4	19:54:01	Waiting

```

> list
Scheduling Policy: SJF
Jobs In Queue: 0
> quit
Waiting Time Avg:    53.00s
Turnaround Time Avg:    128.00s
Throughput:    0.0078 No./s
Total Jobs Completed: 2
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m exit
[?2004l
exit

```

Script done on 2022-03-21 19:57:12-05:00 [COMMAND_EXIT_CODE="0"]

Test Script:

```
script started on 2022-03-21 20:00:03-05:00 [TERM="xterm-256color" TTY="/dev/pts/1"
COLUMNS="336" LINES="18"]
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l
Press ? For Help Menu:
> test ./benchmark fcfs 5 10
Job ./benchmark/job_5 Submitted.
Job ./benchmark/job_60 Submitted.
Job ./benchmark/job_20 Submitted.
Job ./benchmark/job_30 Submitted.
Job ./benchmark/job_120 Submitted.
> list
Scheduling Policy: FCFS
Jobs In Queue: 4


| Job | CPU Time | Pri | Arrival Time | Status  |
|-----|----------|-----|--------------|---------|
| 1   | 5        | 10  | 20:00:19     | Running |
| 2   | 60       | 3   | 20:00:20     | Waiting |
| 3   | 20       | 8   | 20:00:21     | Waiting |
| 4   | 30       | 8   | 20:00:22     | Waiting |
| 5   | 120      | 4   | 20:00:23     | Waiting |


> list
Scheduling Policy: FCFS
Jobs In Queue: 0
> quit
Waiting Time Avg: 42.25s
Turnaround Time Avg: 71.00s
Throughput: 0.0141 No./s
Total Jobs Completed: 4
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l
Press ? For Help Menu:
> test ./benchmark sjf 5 10
Job ./benchmark/job_5 Submitted.
Job ./benchmark/job_60 Submitted.
Job ./benchmark/job_20 Submitted.
Job ./benchmark/job_30 Submitted.
Job ./benchmark/job_120 Submitted.
> list
Scheduling Policy: SJF
Jobs In Queue: 4


| Job | CPU Time | Pri | Arrival Time | Status  |
|-----|----------|-----|--------------|---------|
| 1   | 5        | 5   | 20:04:34     | Running |


```

3	20	1	20:04:36	Waiting
4	30	2	20:04:37	Waiting
2	60	2	20:04:35	Waiting
5	120	7	20:04:38	Waiting

> list

Scheduling Policy: SJF

Jobs In Queue: 0

> quit

Waiting Time Avg: 43.00s

Turnaround Time Avg: 90.00s

Throughput: 0.0111 No./s

Total Jobs Completed: 5

[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l

Press ? For Help Menu:

> test ./benchmark pri 5 10

Job ./benchmark/job_5 Submitted.

Job ./benchmark/job_60 Submitted.

Job ./benchmark/job_20 Submitted.

Job ./benchmark/job_30 Submitted.

Job ./benchmark/job_120 Submitted.

> list

Scheduling Policy: Priority

Jobs In Queue: 4

Job	CPU Time	Pri	Arrival Time	Status
4	30	2	20:10:48	Running
1	5	5	20:10:45	Waiting
5	120	5	20:10:49	Waiting
2	60	6	20:10:46	Waiting
3	20	8	20:10:47	Waiting

> list

Scheduling Policy: Priority

Jobs In Queue: 0

> quit

Waiting Time Avg: 90.00s

Turnaround Time Avg: 137.00s

Throughput: 0.0073 No./s

Total Jobs Completed: 5

[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m exit
[?2004l

exit

Script done on 2022-03-21 20:27:31-05:00 [COMMAND_EXIT_CODE="0"]

Change Policy Script:

```
Script started on 2022-03-21 20:31:03-05:00 [TERM="xterm-256color" TTY="/dev/pts/1"
COLUMNS="336" LINES="18"]
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l
Press ? For Help Menu:
> test ./benchmark fcfs 5 10
Job ./benchmark/job_5 Submitted.
Job ./benchmark/job_60 Submitted.
Job ./benchmark/job_20 Submitted.
Job ./benchmark/job_30 Submitted.
Job ./benchmark/job_120 Submitted.
> list
Scheduling Policy: FCFS
Jobs In Queue: 4


| Job | CPU Time | Pri | Arrival Time | Status  |
|-----|----------|-----|--------------|---------|
| 1   | 5        | 1   | 20:32:21     | Running |
| 2   | 60       | 4   | 20:32:22     | Waiting |
| 3   | 20       | 6   | 20:32:23     | Waiting |
| 4   | 30       | 10  | 20:32:24     | Waiting |
| 5   | 120      | 1   | 20:32:25     | Waiting |


> sjf
Policy Changed To SJF
4 Waiting Jobs Rescheduled
> list
Scheduling Policy: SJF
Jobs In Queue: 4


| Job | CPU Time | Pri | Arrival Time | Status  |
|-----|----------|-----|--------------|---------|
| 1   | 5        | 1   | 20:32:21     | Running |
| 3   | 20       | 6   | 20:32:23     | Waiting |
| 4   | 30       | 10  | 20:32:24     | Waiting |
| 2   | 60       | 4   | 20:32:22     | Waiting |
| 5   | 120      | 1   | 20:32:25     | Waiting |


> lsit ist
Scheduling Policy: SJF
Jobs In Queue: 0
> quit
Waiting Time Avg: 43.00s
Turnaround Time Avg: 90.00s
Throughput: 0.0111 No./s
Total Jobs Completed: 5
[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l
```

Press ? For Help Menu:

> test ./benchmark sjf 5 10

Job ./benchmark/job_5 Submitted.

Job ./benchmark/job_60 Submitted.

Job ./benchmark/job_20 Submitted.

Job ./benchmark/job_30 Submitted.

Job ./benchmark/job_120 Submitted.

> list

Scheduling Policy: SJF

Jobs In Queue: 4

Job	CPU Time	Pri	Arrival Time	Status
1	5	7	20:37:38	Running
3	20	9	20:37:40	Waiting
4	30	3	20:37:41	Waiting
2	60	4	20:37:39	Waiting
5	120	5	20:37:42	Waiting

> fcfs

Policy Changed To FCFS

3 Waiting Jobs Rescheduled

> list

Scheduling Policy: FCFS

Jobs In Queue: 3

Job	CPU Time	Pri	Arrival Time	Status
3	20	9	20:37:40	Running
2	60	4	20:37:39	Waiting
4	30	3	20:37:41	Waiting
5	120	5	20:37:42	Waiting

> list

Scheduling Policy: FCFS

Jobs In Queue: 0

> quit

Waiting Time Avg: 32.25s

Turnaround Time Avg: 61.00s

Throughput: 0.0164 No./s

Total Jobs Completed: 4

[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m ./aubatch
[?2004l

Press ? For Help Menu:

> test ./benchmark fcfs 5 10

Job ./benchmark/job_5 Submitted.

Job ./benchmark/job_60 Submitted.

Job ./benchmark/job_20 Submitted.

Job ./benchmark/job_30 Submitted.

Job ./benchmark/job_120 Submitted.

> list

Scheduling Policy: FCFS

Jobs In Queue: 4

Job	CPU Time	Pri	Arrival Time	Status
1	5	8	20:41:02	Running
2	60	4	20:41:03	Waiting
3	20	6	20:41:04	Waiting
4	30	5	20:41:05	Waiting
5	120	5	20:41:06	Waiting

> pri

Policy Changed To pri

4 Waiting Jobs Rescheduled

> list

Scheduling Policy: pri

Jobs In Queue: 3

Job	CPU Time	Pri	Arrival Time	Status
2	60	4	20:41:03	Running
4	30	5	20:41:05	Waiting
5	120	5	20:41:06	Waiting
3	20	6	20:41:04	Waiting

> list

Scheduling Policy: pri

Jobs In Queue: 1

Job	CPU Time	Pri	Arrival Time	Status
5	120	5	20:41:06	Running
3	20	6	20:41:04	Waiting

> list

Scheduling Policy: pri

Jobs In Queue: 0

> quit

Waiting Time Avg: 79.00s

Turnaround Time Avg: 126.00s

Throughput: 0.0079 No./s

Total Jobs Completed: 5

[?2004h[38;5;240m heckin [0m[38;5;254m ~/comp_7500/project3 [0m[48;5;m[0m exit

[?2004l

exit

Script done on 2022-03-21 20:48:25-05:00 [COMMAND_EXIT_CODE="0"]