CS 4310 Operating Systems
Project
Simulating Job Scheduler and Performance Analysis

Description:

Simulating Job Scheduler of the Operating Systems by programming the following four scheduling algorithms that we covered in the class:

a. First-Come-First-Serve (FCFS)
b. Shortest-Job-First (SJF)
c. Round-Robin with Time Slice = 2 (RR-2)
d. Round-Robin with Time Slice = 5 (PR-5)

The project generates multiple testing cases with inputs of 5 jobs, 10 jobs, and 15 jobs, 20 cases each, for 60 files. The program will read process burst times from a file, job.txt, and execute the four algorithms above. A sample input file of five jobs is given as follows (burst time in ms):

[Begin of job.txt]
Job1
7
Job2
18
Job3
10
Job4
4
Job5
12
[End of job.txt]

Note: you can assume that

(1) There are no more than 30 jobs in the input file (job.txt).
(2) Processes arrive in the order they are read from the file for FCFS, RR-2 and RR-5.
(3) All jobs arrive at time 0.
(4) FCFS uses the order of the jobs, Job1, Job2, Job3, …

Part1
Design & Testing (45 points)

a. Design the program by providing pseudocode or flowchart for each CPU scheduling algorithm.

<Insert answers here>

1. First Come First Serve (FCFS)

```
FCFS Pesudo code

/**
* The method simulate Fist Come First Serve(FCFS) scheduling algorithm
* @Param file jobList, the job list on the text file
* @Return double ataRslt, calculation result for Averatge Turnover Time
*/
1. Read file
2. Make a data frame with integer 2D array // Method A
3. Create a job completion table
4. Make an empty array for Average Turnover Time
5. Record job completion // Method B
6. Display job completion table // Method C
7. Calculate Averatge Turnover Time // Method D
8. Dipaly the result.


//Method A
/**
* The method reads the text files and create 2D array
* Corresponding column 1:JobID, column2: rmnOfTime
* @Param file Object,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> dataFrm, simulate Table with 2 columns
*/
1. Create empty 2D array jobList
2. Set loop which iteartes the data file until the end of files
3.    Read current job id from the file object
4.    Record the current job id on the data fram column 1
5.    Read the job time
6.    Record the job time on the data frae 2nd column

//Method B
/**
* The method accepts 2D integer arraylist data Frme
* It records the job process with anotehr 2D array
* Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete job ID
* @Param ArayList<Integer><Integer> dataFrm,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
*/
1. Set start time <- 0, and end time <- 0
2. Set loop where an iterator iteartes dataFrm and jobRcrd from the first JobID to the last JobId (Top to Bottom)
3.    Read JobID from dataFrm
4.    Record JobId on JobRcd 1st column // JobID
5.    Record startTime on JobRcd 2nd column // startTime
6.    Read JobTime from dataFrm
7.    Calculate endTime <- startTime + JobTime
8.    Record endTime on JobRcd 3rd column // End Time
9.    Record JobID on JobRcd 4th column as a completed task // Complete JobID
10.  Upate startTime <- endTime
11.  Move next row until the last JobId
12. Return jobRcrd

```

```
52
53
54
55  //Method C
56  /**
57  * The method accepts 2D integer arraylist JobRcd
58  * It prints the job process with anotehr 2D array table format
59  * Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete Job ID
60  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
61  * @Return void
62  */
63  1. Accept jobRcrd
64  2. Create string headColumns
65  3. Create string jobCompletion
66  4. Set loop where an iterator iterates JobRcd from the 1st row to the last row
67  5.    Display the 1st column // JobID
68  6.    Display the 2nd column // Start Time
69  7.    Display the 3rd coumn  // End Time
70  8.    Display the 4th column with the jobCompletion string // complete Job ID
71  9.    Move to the nect row
72
73
74  //Method D
75  /**
76  * The method reads jobRcd and calculates the Average Turnover Time
77  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log
78  * @Return double aveTrnovrTime, average turn over time.
79  */
80  1. Accept jobRcrd
81  2. Set Su <- 0
82  2. Set loop where the iterator iterates the jobRcrd's last column
83  3.    Check the last column != 0
84  4.    Read the same row column 3 // End Time
85  5.    Add sum += endTime
86  6.    Move to the next row
87  7. Devide the Sum by the number of row
88  8. Return the restult
```

2. Shortest Job First (SJF)

```
SJF Pesudo code

/**
* The method simulate Shortest Job First(SJF) scheduling algorithm
* @Param file jobList, the job list on the text file
* @Return double ataRslt, calculation result for Averatge Turnover Time
*/
1. Read file
2. Make a data frame with integer 2D array // Method A
3. Sort the data frame decending order by the column 2 // Job Time
3. Create a job completion table
4. Make an empty array for Average Turnover Time
5. Record job completion // Method B
6. Display job completion table // Method C
7. Calculate Averatge Turnover Time // Method D
8. Dipaly the result.


//Method A
/**
* The method reads the text files and create 2D array
* Corresponding column 1:JobID, column2: rmnOfTime
* @Param file Object,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> dataFrm, simulate Table with 2 columns
*/
1. Create empty 2D array jobList
2. Set loop which iteartes the data file until the end of files
3.    Read current job id from the file object
4.    Record the current job id on the data fram column 1
5.    Read the job time
6.    Record the job time on the data frae 2nd column

//Method B
/**
* The method accepts 2D integer arraylist data Frme
* It records the job process with anotehr 2D array
* Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete job ID
* @Param ArayList<Integer><Integer> dataFrm,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
*/
1. Set start time <- 0, and end time <- 0
2. Set loop where an iterator iteartes dataFrm and jobRcrd from the first JobID to the last JobId (Top to Bottom)
3.    Read JobID from dataFrm
4.    Record JobId on JobRcd 1st column // JobID
5.    Record startTime on JobRcd 2nd column // startTime
6.    Read JobTime from dataFrm
7.    Calculate endTime <- startTime + JobTime
8.    Record endTime on JobRcd 3rd column // End Time
9.    Record JobID on JobRcd 4th column as a completed task // Complete JobID
10.  Upate startTime <- endTime
11.  Move next row until the last JobId
12. Return jobRcrd

```

```
55
56  //Method C
57  /**
58  * The method accepts 2D integer arraylist JobRcd
59  * It records the job process with anotehr 2D array table format
60  * Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete Job ID
61  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
62  * @Return void
63  */
64  1. Accept jobRcrd
65  2. Create string headColumns
66  3. Create string jobCompletion
67  4. Set loop where an iterator iterates JobRcd from the 1st row to the last row
68  5.    Display the 1st column // JobID
69  6.    Display the 2nd column // Start Time
70  7.    Display the 3rd coumn  // End Time
71  8.    Display the 4th column with the jobCompletion string // complete Job ID
72  9.    Move to the nect row
73
74
75  //Method D
76  /**
77  * The method reads jobRcd and calculates the Average Turnover Time
78  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log
79  * @Return double aveTrnovrTime, average turn over time.
80  */
81  1. Accept jobRcrd
82  2. Set Su <- 0
83  2. Set loop where the iterator iterates the jobRcrd's last column
84  3.    Check the last column != 0
85  4.    Read the same row column 3 // End Time
86  5.    Add sum += endTime
87  6.    Move to the next row
88  7. Devide the Sum by the number of row
89  8. Return the restult
```

3. Round Robin Time Slice 2 (RR2)

```
RR2 Pesudo code

/**
* The method simulate Round Robin(RR) 2 scheduling algorithm
* @Param file jobList, the job list on the text file
* @Return double ataRslt, calculation result for Averatge Turnover Time
*/
1. Read file
2. Make a data frame with integer 2D array // Method A
3. Sort the data frame decending order by the column 2 // Job Time
3. Create a job completion table
4. Make an empty array for Average Turnover Time
5. Record job completion // Method B
6. Display job completion table // Method C
7. Calculate Averatge Turnover Time // Method D
8. Dipaly the result.


//Method A
/**
* The method reads the text files and create 2D array
* Corresponding column 1:JobID, column2: rmnOfTime
* @Param file Object,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> dataFrm, simulate Table with 2 columns
*/
1. Create empty 2D array jobList
2. Set loop which iteartes the data file until the end of files
3.    Read current job id from the file object
4.    Record the current job id on the data fram column 1
5.    Read the job time
6.    Record the job time on the data frae 2nd column

//Method B
/**
* The method accepts 2D integer arraylist data Frme
* It records the job process with anotehr 2D array
* Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete job ID
* @Param ArayList<Integer><Integer> dataFrm,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
*/
1. Set start time <- 0, and end time <- 0
2. Set RR <- 2
3. Set loop where an iterator iteartes dataFrm and jobRcrd until the all the JobTime are 0
4. Calculate current row for jobRcrd // i % the number of row in jobRcd
5. Read JobID from dataFrm
6.    Record JobId on JobRcd 1st column // JobID
7.    Record startTime on JobRcd 2nd column // startTime
8.    Read JobTime from dataFrm
      if JobTime > RR
         Calculate endTime <- startTime + RR
         Update JobTime <- JobTime - RR
      else // JobTime =< RR
         Calculate endTime <- startTime + JobTime
         Update JobTime <- JobTime - JobTime // Make 0
9.    Record endTime on JobRcd 3rd column // End Time
10.  Record JobID on JobRcd 4th column as a completed task // Complete JobID
11.  Upate startTime <- endTime
12.  Move next row until the last JobId
13. Return jobRcrd
```

```
63  //Method C
64  /**
65  * The method accepts 2D integer arraylist JobRcd
66  * It records the job process with anotehr 2D array table format
67  * Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete Job ID
68  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
69  * @Return void
70  */
71  1. Accept jobRcrd
72  2. Create string headColumns
73  3. Create string jobCompletion
74  4. Set loop where an iterator iterates JobRcd from the 1st row to the last row
75  5.    Display the 1st column // JobID
76  6.    Display the 2nd column // Start Time
77  7.    Display the 3rd coumn  // End Time
78  8.    Display the 4th column with the jobCompletion string // complete Job ID
79  9.    Move to the next row
80
81
82  //Method D
83  /**
84  * The method reads jobRcd and calculates the Average Turnover Time
85  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log
86  * @Return double aveTrnovrTime, average turn over time.
87  */
88  1. Accept jobRcrd
89  2. Set Su <- 0
90  2. Set loop where the iterator iterates the jobRcrd's last column
91  3.    Check the last column != 0
92  4.    Read the same row column 3 // End Time
93  5.    Add sum += endTime
94  6.    Move to the next row
95  7. Devide the Sum by the number of row
96  8. Return the restult
```

4. Round Robin Time Slice 5

```
RR5 Pesudo code

/**
* The method simulate Round Robin(RR) 5 scheduling algorithm
* @Param file jobList, the job list on the text file
* @Return double ataRslt, calculation result for Averatge Turnover Time
*/
1. Read file
2. Make a data frame with integer 2D array // Method A
3. Sort the data frame decending order by the column 2 // Job Time
3. Create a job completion table
4. Make an empty array for Average Turnover Time
5. Record job completion // Method B
6. Display job completion table // Method C
7. Calculate Averatge Turnover Time // Method D
8. Dipaly the result.


//Method A
/**
* The method reads the text files and create 2D array
* Corresponding column 1:JobID, column2: rmnOfTime
* @Param file Object,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> dataFrm, simulate Table with 2 columns
*/
1. Create empty 2D array jobList
2. Set loop which iteartes the data file until the end of files
3.    Read current job id from the file object
4.    Record the current job id on the data fram column 1
5.    Read the job time
6.    Record the job time on the data frae 2nd column

//Method B
/**
* The method accepts 2D integer arraylist data Frme
* It records the job process with anotehr 2D array
* Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete job ID
* @Param ArayList<Integer><Integer> dataFrm,  jobList which shows the job ID and  the remaining time
* @Return ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
*/
1. Set start time <- 0, and end time <- 0
2. Set RR <- 2
3. Set loop where an iterator iteartes dataFrm and jobRcrd until the all the JobTime are 0
4. Calculate current row for jobRcrd // i % the number of row in jobRcd
5. Read JobID from dataFrm
6.    Record JobId on JobRcd 1st column // JobID
7.    Record startTime on JobRcd 2nd column // startTime
8.    Read JobTime from dataFrm
      if JobTime > RR
         Calculate endTime <- startTime + RR
         Update JobTime <- JobTime - RR
      else // JobTime =< RR
         Calculate endTime <- startTime + JobTime
         Update JobTime <- JobTime - JobTime // Make 0
9.    Record endTime on JobRcd 3rd column // End Time
10.  Record JobID on JobRcd 4th column as a completed task // Complete JobID
11.  Upate startTime <- endTime
12.  Move next row until the last JobId
13. Return jobRcrd
```

```
63  //Method C
64  /**
65  * The method accepts 2D integer arraylist JobRcd
66  * It records the job process with anotehr 2D array table format
67  * Corresponding column 1:JobID, column 2: Start Time, column 3: End Time, column 4: complete Job ID
68  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log until all the job is completed
69  * @Return void
70  */
71  1. Accept jobRcrd
72  2. Create string headColumns
73  3. Create string jobCompletion
74  4. Set loop where an iterator iterates JobRcd from the 1st row to the last row
75  5.    Display the 1st column // JobID
76  6.    Display the 2nd column // Start Time
77  7.    Display the 3rd coumn  // End Time
78  8.    Display the 4th column with the jobCompletion string // complete Job ID
79  9.    Move to the next row
80
81
82  //Method D
83  /**
84  * The method reads jobRcd and calculates the Average Turnover Time
85  * @Param ArayList<Integer><Integer> jobRcrd,  job record which makes a work log
86  * @Return double aveTrnovrTime, average turn over time.
87  */
88  1. Accept jobRcrd
89  2. Set Su <- 0
90  2. Set loop where the iterator iterates the jobRcrd's last column
91  3.    Check the last column != 0
92  4.    Read the same row column 3 // End Time
93  5.    Add sum += endTime
94  6.    Move to the next row
95  7. Devide the Sum by the number of row
96  8. Return the restult
```

b. Design the program correctness testing cases. Give at least 3 testing cases to test your program, and give the expected correct **average turnaround time** (for each testing case) in order to test the correctness of each algorithm.

<Complete the following table>

Testing case #	Input (table of jobs with its job# and length	Expected output for FCFS (√ if Correct after testing in Part 3)	Expected output for SJF (√ if Correct after testing in Part 3)	Expected output for RR-2 (√ if Correct after testing in Part 3)	Expected output for RR-5 (√ if Correct after testing in Part 3)
1 (5 jobs)	Job1 7 Job2 18 Job3 10 Job4 4 Job5 12	✅	✅	✅	✅
2 (10 jobs)	Job1 23 Job2 8 Job3 2 Job4 24 Job5 14 Job6 8 Job7 27 Job8 28 Job9 10 Job10 25	✅	✅	✅	✅
3 (15 jobs)	Job1 16 Job2 29	✅	✅	✅	✅

	Job3 9 Job4 15 Job5 13 Job6 8 Job7 13 Job8 1 Job9 3 Job10 1 Job11 12 Job12 4 Job13 9 Job14 1 Job15 22				

c. Design testing strategy for the programs. Discuss about how to generate and structure the randomly generated inputs for experimental study later in Part 3.

Hint 1: To study the performance evaluation of the four job scheduling algorithms, this project will use three different input sizes, 5 jobs, 10 jobs and 15 jobs. It is the easiest to use a random number generator for generating the inputs. Note that you need to decide the maximum value of job length (use at least 20). However, student should store each data set in various sizes and use the same data set for each job scheduling algorithm.

The performance of average Turnaround Time of each input data size (5 jobs, 10 jobs and 15 jobs) can be calculated after an experiment is conducted in 20 trail (with 20 input sets of jobs). We can denote the results as the set X which contains the 20 computed Turnaround Times of 20 trails, where $X = \{x_1, x_2, x_3 \ldots x_{20}\}$*, from the simulator.*

For each data size (5 jobs, 10 jobs and 15 jobs):

$$\textit{Average Turnaround Time} = \frac{\sum_{i=1}^{20} Xi}{20}$$

The student should decide the maximum value of the job length (at least 20).

<Insert answers here>

The preprocessing of the four algorithms' execution is generating job data samples. There are 3 groups: 5 jobs, 10 jobs, and 20 jobs groups. Each group has 20 samples. The file contains JobID and the time length of jobs between 1 and 30. After generating a total of 60 samples, the program extracts data from files and executes the four different algorithms, records the average turnover time for each sample, and records the result on CSV files. The last row has the mean of the average turnover time.

Part 2
Implementation (45 points)

a. Code each program based on the design (pseudocode or flow chart) in Part 1(a).

<Generate four programs and stored them in four files, needed to be submitted>

Please see submitted java files.

b. Document the program appropriately.

<Generate documentation inside the four program files>

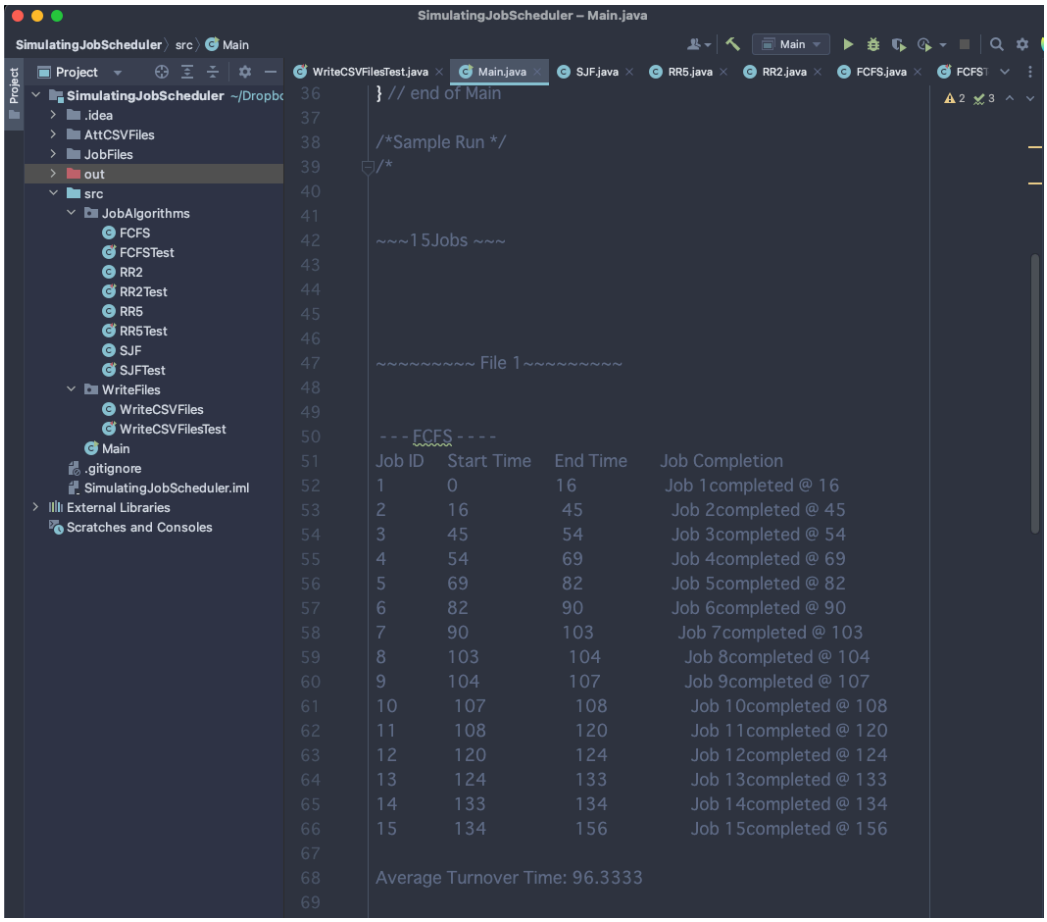
Please see submitted java files.

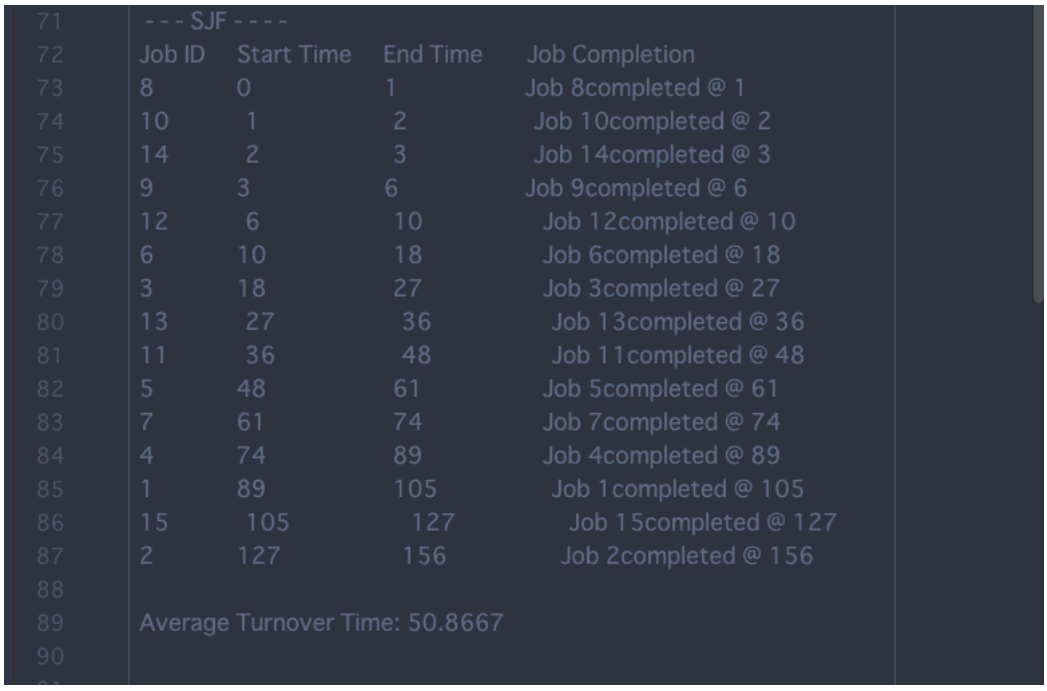
c. Test you program using the designed testing input data given in the table in Part 1(b), Make sure each program generates the correct answer by marking a "√" if it is correct for each testing case for each program column in the table. Repeat the process of debugging if necessary.

<Complete the four columns of the four algorithms in the table @Part 1(b)>

d. For each program, capture a screen shot of the execution (Compile&Run) using the testing case in Part 1(b) to show how this program works properly

<Insert totally four screen shots, one for each program, here>


SimulatingJobScheduler – Main.java
SimulatingJobScheduler 〉 src 〉 Main
Main
Project
SimulatingJobScheduler ~/Dropbo
.idea
AttCSVFiles
JobFiles
out
src
JobAlgorithms
FCFS
FCFSTest
RR2
RR2Test
RR5
RR5Test
SJF
SJFTest
WriteFiles
WriteCSVFiles
WriteCSVFilesTest
Main
.gitignore
SimulatingJobScheduler.iml
External Libraries
Scratches and Consoles
WriteCSVFilesTest.java
Main.java
SJF.java
RR5.java
RR2.java
FCFS.java
} // end of Main
/*Sample Run */
/*
~~~15Jobs ~~~
~~~~~~~~~~ File 1~~~~~~~~~~
- - - FCFS - - - -
Job ID Start Time End Time Job Completion
1 0 16 Job 1completed @ 16
2 16 45 Job 2completed @ 45
3 45 54 Job 3completed @ 54
4 54 69 Job 4completed @ 69
5 69 82 Job 5completed @ 82
6 82 90 Job 6completed @ 90
7 90 103 Job 7completed @ 103
8 103 104 Job 8completed @ 104
9 104 107 Job 9completed @ 107
10 107 108 Job 10completed @ 108
11 108 120 Job 11completed @ 120
12 120 124 Job 12completed @ 124
13 124 133 Job 13completed @ 133
14 133 134 Job 14completed @ 134
15 134 156 Job 15completed @ 156
Average Turnover Time: 96.3333


- - - SJF - - - -
Job ID Start Time End Time Job Completion
8 0 1 Job 8completed @ 1
10 1 2 Job 10completed @ 2
14 2 3 Job 14completed @ 3
9 3 6 Job 9completed @ 6
12 6 10 Job 12completed @ 10
6 10 18 Job 6completed @ 18
3 18 27 Job 3completed @ 27
13 27 36 Job 13completed @ 36
11 36 48 Job 11completed @ 48
5 48 61 Job 5completed @ 61
7 61 74 Job 7completed @ 74
4 74 89 Job 4completed @ 89
1 89 105 Job 1completed @ 105
15 105 127 Job 15completed @ 127
2 127 156 Job 2completed @ 156
Average Turnover Time: 50.8667

```
---RR2----
Job ID    Start Time    End Time    Job Completion
1         0             2
2         2             4
3         4             6
4         6             8
5         8             10
6         10            12
7         12            14
8         14            15          Job 8completed @ 15
9         15            17
10        17            18          Job 10completed @ 18
11        18            20
12        20            22
13        22            24
14        24            25          Job 14completed @ 25
15        25            27
1         27            29
2         29            31
3         31            33
4         33            35
5         35            37
6         37            39
7         39            41
9         41            42          Job 9completed @ 42
11        42            44
12        44            46          Job 12completed @ 46
13        46            48
15        48            50
1         50            52
2         52            54
3         54            56
4         56            58
5         58            60
6         60            62
7         62            64
11        64            66
13        66            68
15        68            70
1         70            72
2         72            74
3         74            76
4         76            78
5         78            80
6         80            82          Job 6completed @ 82
7         82            84
11        84            86
13        86            88
15        88            90
1         90            92
2         92            94
3         94            95          Job 3completed @ 95
4         95            97
5         97            99
7         99            101
11        101           103
13        103           104         Job 13completed @ 104
15        104           106
1         106           108
2         108           110
4         110           112
5         112           114
7         114           116
11        116           118         Job 11completed @ 118
15        118           120
1         120           122
2         122           124
4         124           126
5         126           127         Job 5completed @ 127
7         127           128         Job 7completed @ 128
15        128           130
1         130           132         Job 1completed @ 132
2         132           134
4         134           135         Job 4completed @ 135
15        135           137
2         137           139
15        139           141
2         141           143
15        143           145
2         145           147
15        147           149         Job 15completed @ 149
2         149           151
2         151           153
2         153           155
2         155           156         Job 2completed @ 156

Average Turnover Time: 91.4667
```

```
---RR5----
Job ID    Start Time    End Time      Job Completion
1         0             5
2         5             10
3         10            15
4         15            20
5         20            25
6         25            30
7         30            35
8         35            36            Job 8completed @ 36
9         36            39            Job 9completed @ 39
10        39            40            Job 10completed @ 40
11        40            45
12        45            49            Job 12completed @ 49
13        49            54
14        54            55            Job 14completed @ 55
15        55            60
1         60            65
2         65            70
3         70            74            Job 3completed @ 74
4         74            79
5         79            84
6         84            87            Job 6completed @ 87
7         87            92
11        92            97
13        97            101           Job 13completed @ 101
15        101           106
1         106           111
2         111           116
4         116           121           Job 4completed @ 121
5         121           124           Job 5completed @ 124
7         124           127           Job 7completed @ 127
11        127           129           Job 11completed @ 129
15        129           134
1         134           135           Job 1completed @ 135
2         135           140
15        140           145
2         145           150
15        150           152           Job 15completed @ 152
2         152           156           Job 2completed @ 156

Average Turnover Time: 95.0000
```

By now, four working programs are created and ready for experimental study in the next part, Part 3.

Part 3
Performance Analysis (60 points)

a. Run each program with the designed randomly generated input data given in Part 1(c). Generate a table for all the experimental results for performance analysis as follows.

Input Size n jobs	Average of average turnaround times (FCFS Program)	Average of average turnaround times (SFJ Program)	Average of average turnaround times (RR-2)	Average of average turnaround times (RR-5)
5 jobs	43.5	35.54	54.56	53.62
10 jobs	83.255	62.175	106.09	104.68
15 jobs	123.183333	88.7833333	157.69	157.136667

5Jobs Average Turnover Time table.

File #	FCFS	SJF	RR2	RR5
1	31.4	24	36.4	36
2	45.2	35.2	54.8	55.2
3	43.2	38.6	59.4	61.6
4	40.8	34	50.4	49
5	26.8	26	37.2	32
6	63	47.6	73.8	73.8
7	34.8	17	24.2	24.4
8	24.2	23.6	32.8	31.2
9	55	50.8	79.6	79
10	21.2	15.6	21.6	20.8
11	27.6	24.4	34	32.6
12	47.2	33.2	50.4	50.2
13	51	49	78.2	74.4
14	55.8	51.6	80.8	77
15	51	30.6	45.8	45.6
16	49	44	68.4	63
17	76.8	68.4	112.4	113.6
18	43.6	30.4	48	48
19	24.6	15	21.6	24.2
20	57.8	51.8	81.4	80.8
mean ATT	43.5	35.54	54.56	53.62

10Jobs Average Turnover Time table.

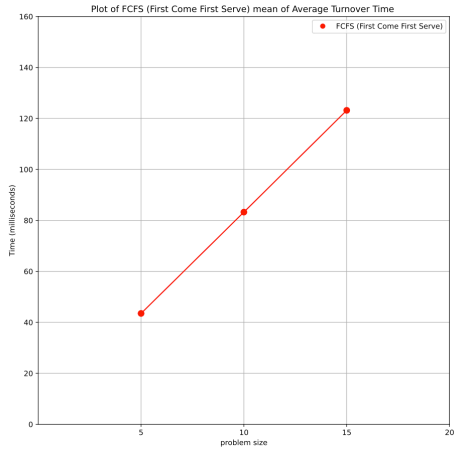
File #	FCFS	SJF	RR2	RR5
1	84.7	67.8	113.4	111.3
2	87.4	60.3	102.2	104.1
3	85.4	80.3	136.8	131
4	65.7	53.3	87.7	87.3
5	71.7	40.9	69.6	70.2
6	90.7	79.4	137.6	134.8
7	87.1	49.1	83.5	83.5
8	59.9	39.4	67.4	71
9	94.7	64.9	112.3	109.9
10	71.7	55.6	93.4	92.5
11	90.6	84.4	146.5	141.3
12	86.7	56.1	96.2	95.7
13	47.6	31.5	49.2	48.6
14	66	49.6	82.2	78
15	90.7	67.2	114.8	112.5
16	106.2	81.3	140.7	139.7
17	79	60.3	102.2	98.5
18	86.2	62.2	106.5	104.2
19	98.5	73.6	127.7	126.4
20	114.6	86.3	151.9	153.1
mean ATT	83.255	62.175	106.09	104.68

15Jobs Average Turnover Time table.

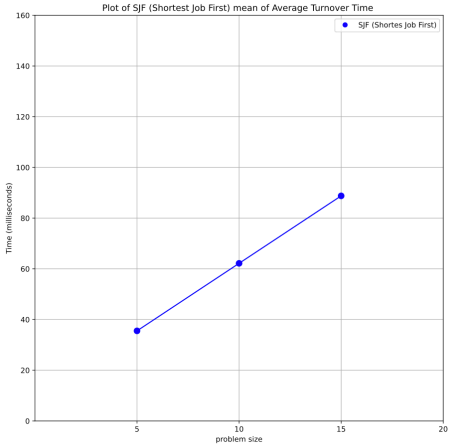
File #	FCFS	SJF	RR2	RR5
1	96.3333333	50.8666667	91.4666667	95
2	84.4	58.0666667	97.8	98.3333333
3	135.6	97.5333333	173.066667	178.133333
4	150.4	104.133333	187.066667	188.8
5	115.4	90.2	158.4	157.6
6	112.266667	67.5333333	118.066667	117.133333
7	121.933333	99.0666667	175.6	179.066667
8	118.333333	86.6	153.133333	149
9	113.866667	91.5333333	162.666667	159.333333
10	134.533333	87.1333333	155.6	162.2
11	135	93.8	169.666667	166.8
12	124.6	104.466667	186.6	183.466667
13	157.466667	103.933333	187.666667	189
14	127.666667	99.6	177	173
15	158.466667	117.133333	214.333333	210.8
16	118.8	70.4	121.866667	127.866667
17	112.266667	101.2	178.2	170.2
18	131.4	99.9333333	180.066667	178.066667
19	103.733333	68.4666667	119.133333	116.666667
20	111.2	84.0666667	146.4	142.266667
mean ATT	123.183333	88.7833333	157.69	157.136667

b. Plot a graph of each algorithm, average turnaround time vs input size (# of jobs), and summarize the performance of each algorithm based on its own graph.
<Insert totally four graphs, one for each program, here>

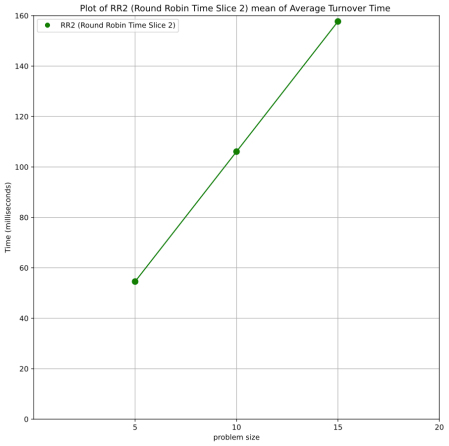
1. FCFS



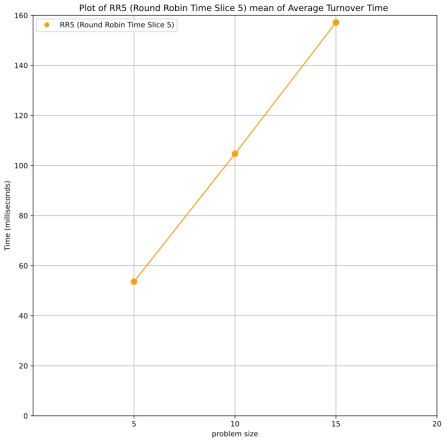
2. SJF



3. RR2



4. RR5



<Write a summary>

1. First Come First Serve (FCFS):

   As the number of jobs increases from 5 to 15, the mean ATT also increases linearly. It can be expected easily since the queue gets longer, and jobs have to wait more. As we discussed in class, FCFS generally has a higher ATT than Shortest Job First (SJF), indicating that jobs with longer processing times can increase the waiting time for subsequent jobs.

2. Shortest Job First (SJF):

   It consistently shows the lowest mean ATT across all scenarios as discussed in class. It reduces the amount of time shorter jobs have to wait. The growing execution time is the slowest among the four algorithms. It may imply SJF is effective when there are many short jobs mixed with longer jobs, as it minimizes the overall waiting time.

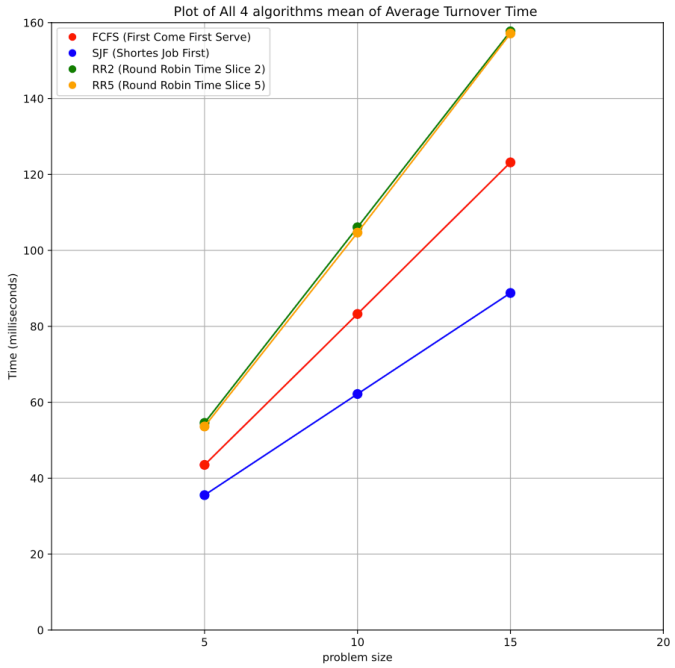
3. Round Robin (RR) with Time Slice 2:

   The mean ATT is higher compared to SJF and FCFS, especially as the number of jobs increases. It can be due to the overhead of context switching and the fact that longer jobs will take more cycles to complete. The time slice of 2 might be too short for some jobs, leading to increased overhead.

4. Round Robin (RR) with Time Slice 5:

   I expected RR5 would be more efficient than RR2 with a larger time slice. Jobs have more time to execute before being preempted, which can be more efficient for longer jobs. But it can also lead to longer waiting times for shorter jobs if they arrive behind longer jobs. The mean ATT for RR with a time slice of 5 is slightly lower than that of a time slice of 2, indicating a possible reduction in context switching overhead. However, it's still higher than SJF and FCFS.

Plot all four graphs on the same graph and compare the performance of all four algorithms. Rank four scheduling algorithms. Try giving the reasons for the findings. <Insert four-graphs-in-one graph here> <Write about explaining the results>



From the observations above and the compassion four algorithms' execution time on the same plot, we can infer the following: SJF is the most efficient in terms of average turnaround time across the board. It may be effective when many short jobs are mixed with longer ones. FCFS is predictable, and short-term jobs would be stuck waiting behind long-term jobs. Round Robin is generally fairer regarding CPU time distribution but can have higher average turnaround times. But we cannot see much difference between time slices 2 and 5.

RR2 and RR5 show a steeper ATT increase compared to SJF and FCFS. This suggests that as the problem size increases, the effect of context switching causes inefficiency in handling longer jobs and higher ATT. Comparing RR2 and RR5, we can see that RR5 generally has a slightly lower ATT than RR2. It might come from the longer time slice in RR5, which reduces the frequency of context switches, which can be particularly costly in terms of time, and improves the ATT slightly. However, both versions of Round Robin have higher ATT than SJF and FCFS as the problem size increases.

As the problem size grows from 5 to 15, the gap in performance between the algorithms also increases. It shows that the choice of algorithm becomes more critical as the number of jobs scales up. The consistent performance of SJF across different problem sizes highlights its efficiency.

The plot shows that SJF is the most efficient algorithm in this circumstance. However, the result highly depends on the experimental environment, such as hardware components, number of jobs, and time length of jobs. The choice of scheduling algorithm should be based on the specific characteristics of the workload.

c. Conclude your report with the strength and constraints of your work. At least 100 words.

(Note: It is reflection of this project. If you have a change to re-do this project again, what you like to keep and what you like to do differently in order get a better quality of results.)

<Write a conclusion about strength and constraints of your work here.>

Implementing and analyzing the scheduling algorithms discussed in our class has been a significant experience. The plots show that while SJF records are the most efficient in our simulations, their performance may vary in different computational environments or with different job arrival patterns. The project did not include priority-based scheduling algorithms, which could add another interpretation to algorithm analysis.

In future iterations of this project, I would include a variety of round-robin time slices, such as 50 and 100, to examine how the length of time slice affects algorithm performance further. Also, I could generate job batches that consist exclusively of short or long tasks to investigate how job length influences scheduling efficacy. These modifications and varying the mix of job lengths in the input files can project additional insights and enhance our understanding of scheduling algorithm characteristics.