OS Project 1 (Group 34)

Design

The purpose of a scheduler is, by definition, to schedule which process should be run next. It consists of a (infinite) loop where in each iteration a process is chosen and the scheduler context switches to the chosen process by modifying the priority of the processes. Specifically, the previous process is reduced in priority and the next to be run is increased. A unit of execution time is allocated to the chosen process. Then the scheduler starts all over again and chooses the next process according to policy. The policies and its implementation is introduced as follows:

- First in first out (FIFO)
  Processes that have earlier ready time is completed first. Thus, we iterate over all of the processes and choose the process with minimum ready time which has not been completed and let it run until it is complete.
- Round Robin (RR)
  Each running process share the same amount of specific execution time. When no process is executing, an arbitrary process which is ready is chosen (WLOG the process with minimum index). When a process is running and its allocated execution time has not expired, it continutes to run. Otherwise, the next process (by index) which is ready and not finished is chosen.
- Shortest Job First (SJF)
  Processes that have shortest execution time is completed first. Thus, we iterate over all of the processes and choose the process with minimum execution time which has not been completed and let it run until it is complete.
- Preemptive Shortest Job First (PSJF)
  Processes that have shortest **remaining** execution time is chosen first. Thus, we iterate over all of the processes and choose the process with positive minimum remaining execution time as the next process.

Some edge cases include:

- There may not be a process to be run at some time (gap in ready time). In this case, the scheduler still has to iterate the unit time loop and simulate passing of time.
- Since each time a process is executed, unit time is deducted from its total execution time (variable in the process struct). So when the execution time of a process reaches zero, it implies that the process has exited and the ending time is recorded (with respect to the scheduler clock).
- When all processes are completed, the scheduler breaks from the scheduling loop and exits.

For initialization, a process is forked and executed for designated period of time (total execution time) when it is ready. In order to prevent the forked process from competing resources with the scheduler, it is moved to another core to run. Such design allows the measurement of unit time between scheduler and forked processes to be as precise as possible, that is, to minimize the time gap between when a child process is finished and when the scheduler thinks the process is finished.

Calculation of theoretical value

All of the calculations is based on a pre-defined unit time. We will not re-introduce the calculation as it is basically the same as the description in design.

Comparison between theory and experiments

Proof of Execution

FIFO

1. FIFO_1

```
[ 1758.913996] [project1] 2373 1556631347.460246019 1556631348.905838649
[ 1760.989143] [project1] 2374 1556631347.461093004 1556631350.980775768
[ 1762.807118] [project1] 2375 1556631347.460380540 1556631352.798961719
[ 1764.350271] [project1] 2376 1556631347.460449886 1556631354.342123938
[ 1765.727237] [project1] 2377 1556631347.509992893 1556631355.719107764
```

2. FIFO_2

```
[ 2043.400293] [project1] 2386 1556631417.276994724 1556631633.447184359
[ 2058.248342] [project1] 2387 1556631419.637455913 1556631648.296749821
[ 2060.237533] [project1] 2388 1556631419.908877099 1556631650.286147851
[ 2060.581877] [project1] 2389 1556631420.221579468 1556631650.630532937
```

3. FIFO_3

```
[ 2179.037690] [project1] 2432 1556631743.486894795 1556631769.095848348
[ 2194.340670] [project1] 2433 1556631746.129255477 1556631784.399877133
[ 2202.293926] [project1] 2434 1556631746.629010202 1556631792.353626211
[ 2204.919817] [project1] 2435 1556631747.380967530 1556631794.979678820
[ 2207.817358] [project1] 2436 1556631748.277513780 1556631797.877393459
[ 2210.455871] [project1] 2437 1556631748.297451706 1556631800.516052206
[ 2220.533265] [project1] 2438 1556631748.758236237 1556631810.594140050
```

4. FIFO_4

```
[ 2277.466166] [project1] 2447 1556631861.143768415 1556631867.530361828
[ 2278.852697] [project1] 2448 1556631864.945710170 1556631868.916950324
[ 2279.404469] [project1] 2449 1556631864.949473611 1556631869.468779359
[ 2280.891986] [project1] 2450 1556631867.532886692 1556631870.956300147
```

5. FIFO_5

```
[ 2338.999603] [project1] 2456 1556631905.533206259 1556631929.067143561
[ 2352.327416] [project1] 2457 1556631908.228971805 1556631942.395282013
[ 2360.452154] [project1] 2458 1556631908.232871423 1556631950.519917466
[ 2363.054497] [project1] 2459 1556631909.025110044 1556631953.122410477
[ 2365.631515] [project1] 2460 1556631909.041374653 1556631955.699441745
[ 2368.076945] [project1] 2461 1556631909.634175001 1556631958.144887600
[ 2378.097921] [project1] 2462 1556631909.640903330 1556631968.165932524
```

SJF

1. SJF_1

```
[  843.842940] [project1] 2249 1556630427.200894195 1556630433.805332658
[  848.285088] [project1] 2250 1556630429.593082094 1556630438.247405634
[  860.248714] [project1] 2251 1556630429.865197225 1556630450.210698014
[  881.890439] [project1] 2248 1556630427.199755326 1556630471.852012468
```

2. SJF_2

```
[  936.051250] [project1] 2269 1556630525.749996995 1556630526.011138642
[  936.740369] [project1] 2271 1556630526.020863556 1556630526.699935136
[  948.307810] [project1] 2270 1556630525.750085306 1556630538.267269418
[  958.980200] [project1] 2272 1556630526.049680478 1556630548.939249091
[  976.927430] [project1] 2273 1556630526.097075041 1556630566.885774052
```

3. SJF_3

```
[ 1017.902400] [project1] 2279 1556630598.112851669 1556630607.859024179
[ 1017.932788] [project1] 2282 1556630600.512966835 1556630607.889411594
[ 1017.955640] [project1] 2283 1556630600.533021107 1556630607.912256065
[ 1028.694456] [project1] 2284 1556630600.748625174 1556630618.650582416
[ 1039.231643] [project1] 2285 1556630601.100909106 1556630629.187323010
[ 1052.305865] [project1] 2280 1556630598.107272454 1556630642.260629446
[ 1070.573301] [project1] 2281 1556630598.109158847 1556630660.527542211
[ 1093.563940] [project1] 2286 1556630601.357124051 1556630683.517099545
```

4. SJF_4

```
[ 1141.811992] [project1] 2294 1556630722.507476697 1556630731.762775831
[ 1144.742221] [project1] 2295 1556630728.049654756 1556630734.692860485
[ 1155.464995] [project1] 2296 1556630731.292933785 1556630745.415120669
[ 1158.312516] [project1] 2298 1556630745.357331420 1556630748.262455474
[ 1163.270019] [project1] 2297 1556630739.868936959 1556630753.219681647
```

5. SJF_5

```
[ 1196.802993] [project1] 2304 1556630779.571349138 1556630786.750844287
[ 1198.801149] [project1] 2305 1556630783.552998469 1556630788.748058707
[ 1200.543181] [project1] 2306 1556630785.500902067 1556630790.491009386
[ 1202.267473] [project1] 2307 1556630786.751307580 1556630792.215243807
```

RR

1. RR_1
```
[ 1262.958553] [project1] 2314 1556630851.290699432 1556630852.903206753
[ 1265.176050] [project1] 2315 1556630851.344724621 1556630855.120560061
[ 1267.383502] [project1] 2316 1556630851.291030364 1556630857.327917435
[ 1269.332616] [project1] 2317 1556630851.330497567 1556630859.276900445
[ 1271.091166] [project1] 2318 1556630851.294281899 1556630861.035398366
```
2. RR_2
```
[ 1363.634488] [project1] 2324 1556630929.460264202 1556630953.600496409
[ 1367.814481] [project1] 2325 1556630931.531435976 1556630957.781353646
```
3. RR_3
```
[ 1448.419088] [project1] 2335 1556630998.344989363 1556631038.398586562
[ 1449.868492] [project1] 2331 1556630989.027175532 1556631039.848144240
[ 1451.223275] [project1] 2332 1556630993.894737287 1556631041.203076152
[ 1475.248215] [project1] 2338 1556631004.562731035 1556631065.230388781
[ 1480.417043] [project1] 2337 1556631002.365115937 1556631070.399660832
[ 1482.696343] [project1] 2336 1556631001.588857573 1556631072.679171792
```
4. RR_4
```
[ 1522.053394] [project1] 2347 1556631097.365370035 1556631112.039043461
[ 1527.513797] [project1] 2348 1556631097.725294344 1556631117.499785235
[ 1533.173322] [project1] 2349 1556631097.745335411 1556631123.159632645
[ 1542.472885] [project1] 2346 1556631097.065414457 1556631132.459683013
[ 1556.750862] [project1] 2345 1556631096.612931478 1556631146.738272824
[ 1564.564778] [project1] 2350 1556631098.969067232 1556631154.552577803
[ 1567.921886] [project1] 2344 1556631095.006761250 1556631157.909878738
```
5. RR_5
```
[ 1617.338258] [project1] 2361 1556631192.638722909 1556631207.327919011
[ 1624.181787] [project1] 2362 1556631192.621138616 1556631214.171638284
[ 1629.948264] [project1] 2364 1556631193.333479524 1556631219.938216250
[ 1643.196062] [project1] 2360 1556631191.605190138 1556631233.186310820
[ 1662.778572] [project1] 2359 1556631191.589277556 1556631252.769261216
[ 1671.744832] [project1] 2365 1556631193.338402906 1556631261.735683657
[ 1675.946122] [project1] 2358 1556631189.626487458 1556631265.937024787
```

PSJF

1. PSJF_1
```
[  205.395072] [project1] 2017 1556629787.129076175 1556629795.422199398
[  217.322048] [project1] 2016 1556629784.480869455 1556629807.351514940
[  233.124175] [project1] 2015 1556629781.717235937 1556629823.156187381
[  256.716070] [project1] 2014 1556629779.004148569 1556629846.751334579
```
2. PSJF_2
```
[  493.043436] [project1] 2168 1556630080.241355318 1556630083.105488534
[  499.057629] [project1] 2167 1556630076.547902107 1556630089.120357078
[  508.478094] [project1] 2170 1556630092.605062736 1556630098.541855523
[  511.611785] [project1] 2173 1556630098.596997633 1556630101.675896993
[  519.319308] [project1] 2169 1556630085.228900175 1556630109.383520685
```
3. PSJF_3
```
[  587.918007] [project1] 2180 1556630176.193153679 1556630177.913947239
[  589.899988] [project1] 2181 1556630178.060948818 1556630179.901189190
[  591.232942] [project1] 2182 1556630179.917964347 1556630181.233423108
[  595.448597] [project1] 2179 1556630174.406567301 1556630185.447041144
```
4. PSJF_4
```
[  680.790648] [project1] 2229 1556630267.025689391 1556630270.764404298
[  686.477757] [project1] 2228 1556630266.725347029 1556630276.450578727
[  698.550581] [project1] 2230 1556630269.421317174 1556630288.521582285
[  717.041946] [project1] 2227 1556630266.725237284 1556630307.010515998
```
5. PSJF_5
```
[  763.041174] [project1] 2238 1556630352.752979220 1556630353.004922477
[  763.789339] [project1] 2240 1556630353.014406118 1556630353.752855091
[  776.460763] [project1] 2239 1556630352.750279063 1556630366.423482485
[  787.555755] [project1] 2241 1556630353.068901062 1556630377.518536264
[  805.753176] [project1] 2242 1556630353.096923630 1556630395.715926128
```

Results (unit: seconds)

FIFO

1. FIFO_1

Process	exp start	exp end	theory start	theory end
P1	0	1.44559263	0	1.25
P2	0.00084698	3.520529749	0	2.5
P3	0.00013452	5.3387157	0	3.75
P4	0.00020386	6.881877919	0	5
P5	0.04974687	8.258861745	0	6.25

2. FIFO_2

Process	exp start	exp end	theory start	theory end
P1	0	216.170189635	0	200
P2	2.360461189	231.019755097	0.25	212.5
P3	2.631882375	233.009153127	0.5	215
P4	2.944584744	233.353538213	0.75	217.5

3. FIFO_3

Process	exp start	exp end	theory start	theory end
P1	0	25.608953553	0	20
P2	2.642360682	40.912982338	0.5	32.5
P3	3.142115407	48.866731416	0.75	40
P4	3.894072735	51.492784025	1	42.5
P5	4.790618985	54.390498664	1.25	45
P6	4.810556911	57.029157411	1.25	47.5
P7	5.271341442	67.107245255	1.5	57.5

4. FIFO_4

Process	exp start	exp end	theory start	theory end
P1	0	6.386593413	0	5
P2	3.801941755	7.773181909	1.25	6.25
P3	3.805705196	8.325010944	1.25	6.75
P4	6.389118277	9.812531732	3.75	8

5. FIFO_5

Process	exp start	exp end	theory start	theory end
P1	0	23.533937302	0	20
P2	2.695765546	36.862075754	0.5	32.5
P3	2.699665164	44.986711207	0.5	40
P4	3.491903785	47.589204218	1	42.5
P5	3.508168394	50.166235486	1	45
P6	4.100968742	52.611681341	1.5	47.5
P7	4.107697071	62.632726265	1.5	57.5

SJF

1. SJF_1

Process	exp start	exp end	theory start	theory end
P2	0.001138868	6.605577332	0	5
P3	2.393326768	11.047650308	0.25	7.5
P4	2.665441899	23.010942688	0.5	17.5
P1	0	44.652257142	0	350

2. SJF_2

Process	exp start	exp end	theory start	theory end
P1	0	0.261141647	0	0.25
P3	0.270866561	0.949938141	0.25	0.75
P2	0.000088310	12.487272423	0	10.75
P4	0.299683483	23.189252096	0.25	20.75
P5	0.347078046	41.135777057	0.25	38.25

3. SJF_3

Process	exp start	exp end	theory start	theory end
P1	0.005579215	9.751751725	0	7.5
P4	2.405694381	9.78213914	0.25	7.525
P5	2.425748653	9.804983611	0.25	7.55
P6	2.64135272	20.543309962	0.5	17.55
P7	2.993636652	31.080050556	0.75	27.55
P2	0	44.153356992	0	40.05
P3	0.001886393	62.420269757	0	57.55
P8	3.249851597	85.409827081	1	80.05

4. SJF_4

Process	exp start	exp end	theory start	theory end
P1	0	9.255299134	0	7.5
P2	5.542176059	12.185383788	2.5	10
P3	8.785457088	22.907643972	5	20
P5	22.849854723	25.754978777	17.5	22.5
P4	17.361460262	30.73220495	12.5	27.5

5. SJF_5

Process	exp start	exp end	theory start	theory end
P1	0	7.179495149	0	5
P2	3.981649331	9.176709569	1.25	6.25
P3	5.929552929	10.919660248	2.5	6.25
P4	7.179958442	12.643894669	3.75	7.5

RR

1. RR_1

Process	exp start	exp end	theory start	theory end
P1	0	1.612507321	0	1.25
P2	0.054025189	3.829860629	0	2.5
P3	0.000330932	6.037218003	0	3.75
P4	0.039798135	7.986201013	0	5
P5	0.003582467	9.744698934	0	6.25

2. RR_2

Process	exp start	exp end	theory start	theory end
P1	0	24.140232207	0	18.75
P2	2.071171774	28.321089444	0.5	22.5

3. RR_3

Process	exp start	exp end	theory start	theory end
P3	0	40.053597199	6	42.5
P1	0.682186169	41.503154877	0	47.5
P2	5.549747924	42.858086789	3	48.75
P6	16.217741672	66.885399418	11.5	67.5
P5	14.020126574	72.054671469	10	72.5
P4	13.24386821	74.334182429	9	75

4. RR_4

Process	exp start	exp end	theory start	theory end
P4	2.358608785	117.032282211	1	13.75
P5	2.718533094	122.493023985	1.25	15
P6	2.738574161	128.152871395	1.25	16.25
P3	2.058653207	137.452921763	0.75	36.25
P2	1.606170228	151.731511574	0.5	45
P7	3.962305982	159.545816553	1.5	50
P1	0	162.903117488	0	57.5

5. RR_5

Process	exp start	exp end	theory start	theory end
P4	3.300320003	17.989516105	1	13.75
P5	3.28273571	24.833235378	1	15
P6	3.995076618	27.599813344	1.5	16.25
P3	2.266787232	40.847907914	0.5	36.25
P2	2.25087465	50.43085831	0.5	45
P7	0	59.397280751	1.5	50
P1	0.288084552	63.598621881	0	57.5

PSJF

1. PSJF_1

Process	exp start	exp end	theory start	theory end
P4	8.124927606	16.418050829	5	15
P3	5.476720886	28.347366371	5	25
P2	2.713087368	44.152038812	2.5	40
P1	0	67.74718601	0	62.5

2. PSJF_2

Process	exp start	exp end	theory start	theory end
P2	3.693453211	6.557586427	2.5	5
P1	0	12.572454971	0	10
P4	16.057160629	21.993953416	12.5	17.5
P5	22.049095526	25.127994886	17.5	20
P3	8.680998068	32.835618578	5	27.5

3. PSJF_3

Process	exp start	exp end	theory start	theory end
P2	1.786586378	3.507379938	1.25	2.5
P3	3.654381517	5.494621889	2.5	3.75
P4	5.511397046	6.826855807	3.75	5
P1	0	11.040473843	0	8.75

4. PSJF_4

Process	exp start	exp end	theory start	theory end
P3	0.300452107	4.039167014	0.25	2.75
P2	0.00010974500000005	9.725341443	0	7.5
P4	2.69607989	21.796345001	5	17.5
P1	0	40.285278714	0	35

5. PSJF_5

Process	exp start	exp end	theory start	theory end
P1	0.002700156	0.254643414	0	0.25
P3	0.264127055	1.002576028	0.25	0.75
P2	0	13.673203422	0	10.75
P4	0.318621999	24.768257201	0.25	20.75
P5	0.346644567	42.965647065	0.25	38.25

Discussion

> Observation: Experimental results always lag behind theoretical prediction, the more severe the more context switches

Since the scheduler simulates scheduling of processes by modifying the priorities instead of actually scheduling into CPU, there exists a difference between the actual (remaining) running time of process and the scheduler clock. Specifically, modification to process priority may not be realized instantaneously in terms of running on the CPU. There may be other high priority processes competing with the forked processes as well as the scheduler.
Another source of error may be induced from the measurement of unit time in the scheduler loop. In our theoretical prediction, we have to plug in the actual value for one unit of time to compare with the experiments results. The actual value of one unit of time is obtained by averaging over 1000 iterations of the for loop on a single core, approximately 2.5 secs. However, the measuring condition might still differ from the experiment even if we control the device and load (not running other task simultaneously).
One major assumption when calculating the theoretical values is the scheduler can instantly schedule the next process. This is not true for real world machines as

1. The scheduler still has to compete for CPU resource so it is not running constantly. However if the load is relatively light, the scheduler can occupy all of the resource.
2. The scheduling process is not instantaneous. That is, determining the next process to run requires computation costs. Basically we have to iterate over all the processes and find the next one that satisfies the condition so the complexity is O(n) where n is the total number of processes.

Contribution

Contribution is uniform across all members.