SIMULATION REPORT FOR SCHEDULING ALGORITHMS

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After successful implementation of the Scheduling Algorithms, this report highlights some conclusion about the algorithm

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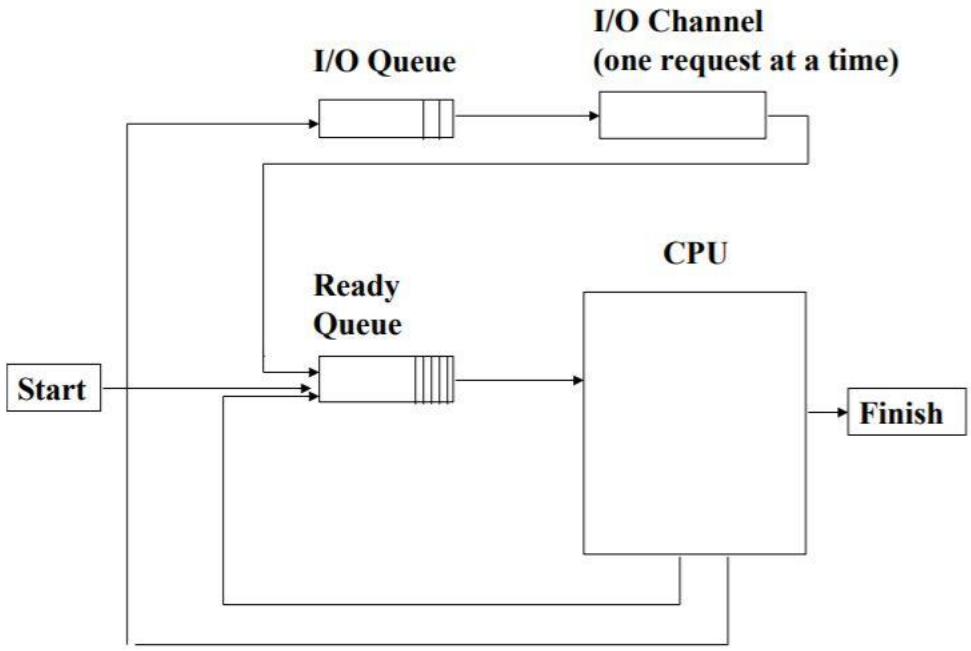
I. Introduction

This is this stimulation of the system behavior for the whole period of the execution, while computing and collecting the following statistics: CPU utilization, throughput, turnaround time, and waiting time for various scheduling algorithms.

- First Come First Serve
- Shortest Job First
- Round Robin

Following the system architecture



All processes are in the start state with different arrival time. Once the process is in the ready queue they go to CPU for processing one by one depending on the scheduling algorithm. From CPU the go to I/O queue if they need input channel. Input channel is provided one by one to the process and in the mean time they wait for their turn and CPU function normally during this time. Once Input has been fetched the process goes back to the ready state in the ready queue and the process continues in the similar fashion. Once the process is complete the completion time is recorded, and the process is terminated.

For different algorithm we use different strategies:

FCFS: as the name indicate the process is executed in the order of arrival.

SJF: once the process arrives, they are sorted in the order of burst time and they are executed in this new order. One thing is for sure that the SJF is better than FCFS(though they work in similar way) because the waiting time is considerably lower as the process with less burst time are executed first.

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Exponential average (Aging) –

$Tn+1 = \alpha tn + (1 - \alpha)Tn$

where α = is smoothing factor and $0 <= \alpha <= 1$,

tn = actual burst time of nth process,
Tn = predicted burst time of nth process.

General term,

$\alpha tn + (1 - \alpha)\alpha tn-1 + (1 - \alpha)2\alpha tn-2...+ (1 - \alpha)j\alpha tn-j...+ (1 - \alpha)n+1T0$

T0 is a constant or overall system average.

RR: This is completely different from SJF and FCFS. There is a time quantum in play which do context switching. Process are executed and once the time quantum is reached the process is transferred to waiting queue and the other process is start execution. This thing is repeated till all the process are executed.

II. Requirement & Assumption

There are few assumptions.

Once the process is being executed the other processes wait.

One process at a time can use input/output channel.

III. Random number generation algorithm

Pseudo-Random Number Generation is a useful algorithm. The random number generation algorithm is based on it. The desired sequence is $X_n+1=(aX_n + c) \bmod m$

m, $0 < m$: the modulus

a, $0 < a < m$: the multiplier

c, $0 \leq c < m$: the increment

X_0, $0 < X0 < m$: the seed (start value)

This method is one of the best-known and effective generator algorithms, the sequence $X_0, X_1,\ldots,X_n$ can meet every integer in the range of [0, m-1] randomly. Different parameters will bring a completely different random integer sequence. To ensure every time when we run the simulation can have different and random results, we set X0 equal to the current time mod m, current time will be calculated in second, other parameters will be assigning to large integers.

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IV. Data Structure for the simulation

Data Structure used for the stimulation is basic array. Each time a random process is generated it is pushed into the waiting queue and when the process is terminated the queue is decreased by one. This thing continues till all process are executed successfully.

V. System environment

The experiment implements in the Windows 7 or more, the memory is 8GB, with a 2.4GHz Intel Core i5 processor. We build the experiment based on VS Code, the programming language is JavaScript.

VI. Experiment

My experiment assumption is:

Case 1: FCFS

1. Input request time 3 second
2. Number of processes 10
3. Arrival time is randomly generated from 0 to 120 seconds using Math.floor(Math.random() * 120)
4. Burst time is randomly generated from 0 to 30 seconds using Math.floor(Math.random() * 30)
5. Inter input output arrival time for each process respectively 30,35,40,45,50,55,60,65,70,75

Output for FCFS

```
P   AT  BT   CT      TT      WT
0   65  415  522     457     872
1   6   227  770     764     991
2   98  524  1336    1238    1762
3   16  156  1504    1488    1644
4   115 582  2122    2007    2589
5   110 7    2129    2019    2026
6   17  54   2183    2166    2220
7   45  59   2242    2197    2256
8   65  160  2411    2346    2506
9   77  241  2664    2587    2828
Average Turnaround Time: 1726.9
Average Waiting Time: 1969.4
CPU Utilization: 79.49510106805543
```

Case 2: SJF

1. Input request time 3 second
2. Number of processes 10

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3. Arrival time is randomly generated from 0 to 120 seconds using Math.floor(Math.random() * 120)
4. Burst time is randomly generated from 0 to 30 seconds using Math.floor(Math.random() * 30)
5. Inter input output arrival time for each process respectively 30,35,40,45,50,55,60,65,70,75

Output for SJF

```
P   AT  BT  CT    TT    WT
5   110 7   117   7     14
6   17  54  177   160   214
7   45  59  242   197   256
3   16  156 410   394   550
8   65  160 582   517   677
1   6   227 824   818   1045
9   77  241 1080  1003  1244
0   65  415 1516  1451  1866
2   98  524 2064  1966  2490
4   115 582 2670  2555  3137
Average Turnaround Time: 906.8
Average Waiting Time: 1149.3
CPU Utilization: 75.6089911134344
```

Case 3: Round Robin(we have 5 different quantum values

1. Number of processes are 10
2. Quantum time for different cases 20,25,30,35,40
3. Arrival time is randomly generated from 0 to 120 seconds using Math.floor(Math.random() * 120)
4. Burst time is randomly generated from 0 to 30 seconds using Math.floor(Math.random() * 30)

Output for RR

```
-----------------------------------RR(20)----------------------------------------
P   AT  BT  CT    WT
0   110 7   1139  1132
1   17  54  805   751
2   45  59  155   96
3   16  156 363   207
4   65  160 1077  917
5   6   227 2059  1832
6   77  241 1533  1292
7   65  415 2304  1889
8   98  524 428   1489
9   115 582 2316  1734
Sequence of process  ->P0->P1->P2->P0->P1->P2->P3->P0->P1->P2->P4->P5->P0->P1-
>P3->P6->P0->P1->P3->P4->P5->P6->P7->P0->P4->P5->P8->P9->P1->P4->P5->P6->P7->P0-
```

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```
>P9->P1->P6->P7->P4->P5->P0->P1->P9->P6->P7->P0->P4->P5->P9->P4->P5->P6->P7->P0-
>P6->P7->P9->P4->P5->P0->P9->P6->P7->P0->P5->P9->P6->P7->P5->P9->P6->P7->P5->P9-
>P6->P7->P5->P9->P6->P7->P5->P9->P6->P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P5-
>P9->P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P9->P7->P9->P7->P9->P7-
>P9->P7->P9->P7->P9->P7->P9->P7->P9->P9->P9->P9
Average Waiting Time: 975.4
Average Compilation Time: 1217.9
CPU Utilization: 80.08867723129978
-----------------------------------RR(25)-------------------------------------
P   AT  BT  CT    WT
0   110 7   1184   1177
1   17  54  915    861
2   45  59  240    181
3   16  156 378    222
4   65  160 1152   992
5   6   227 2069   1842
6   77  241 1508   1267
7   65  415 2284   1869
8   98  524 428    1489
9   115 582 2316   1734
Sequence of process  ->P0->P1->P2->P0->P1->P2->P3->P0->P4->P5->P1->P2->P3->P6-
>P0->P1->P3->P4->P5->P7->P0->P6->P8->P9->P1->P4->P5->P6->P7->P0->P4->P5->P9->P1-
>P0->P6->P7->P4->P5->P1->P7->P9->P6->P0->P4->P5->P9->P7->P0->P6->P9->P4->P5->P6-
>P7->P0->P5->P7->P9->P6->P5->P9->P7->P6->P9->P5->P7->P6->P5->P9->P7->P9->P5->P7-
>P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P7->P9->P7->P9-
>P7->P9->P7->P9->P7->P9->P9->P9->P9
Average Waiting Time: 1004.9
Average Compilation Time: 1247.4
CPU Utilization: 80.55956389289722
-----------------------------------RR(30)-------------------------------------
P   AT  BT  CT    WT
0   110 7   1129   1122
1   17  54  895    841
2   45  59  165    106
3   16  156 343    187
4   65  160 1127   967
5   6   227 2039   1812
6   77  241 1553   1312
7   65  415 2294   1879
8   98  524 478    1476
9   115 582 2316   1734
Sequence of process  ->P0->P1->P2->P0->P3->P1->P2->P4->P5->P0->P1->P3->P6->P0-
>P4->P5->P7->P1->P6->P8->P9->P4->P5->P0->P7->P1->P6->P9->P4->P5->P0->P1->P7->P6-
>P0->P4->P5->P9->P7->P6->P9->P4->P5->P0->P6->P7->P9->P5->P7->P6->P5->P9->P7->P6-
```

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```
>P9->P5->P7->P6->P5->P9->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->
>P7->P9->P7->P9->P7->P9->P7->P9->P7->P9->P9->P9
Average Waiting Time: 991.4
Average Compilation Time: 1233.9
CPU Utilization: 80.34686765540158
-----------------------------------RR(35)-----------------------------------
P   AT  BT  CT    WT
0   110 7   1064   1057
1   17  54  895    841
2   45  59  190    131
3   16  156 418    262
4   65  160 1129   969
5   6   227 2054   1827
6   77  241 1463   1222
7   65  415 2274   1859
8   98  524 448    1486
9   115 582 2316   1734
Sequence of process  ->P0->P1->P2->P0->P3->P1->P2->P4->P5->P0->P6->P1->P3->P7->
>P4->P5->P8->P0->P6->P9->P1->P4->P5->P7->P0->P6->P9->P1->P7->P4->P5->P0->P6->P9->
>P7->P0->P4->P5->P6->P9->P7->P5->P6->P9->P7->P5->P6->P9->P7->P5->P9->P7->P5->P9->
>P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P9->P7->P9->P7->P9->P7->P9->P9->P9
Average Waiting Time: 982.6
Average Compilation Time: 1225.1
CPU Utilization: 80.20569749408212
-----------------------------------RR(40)-----------------------------------
P   AT  BT  CT    WT
0   110 7   1119   1112
1   17  54  745    691
2   45  59  215    156
3   16  156 463    307
4   65  160 1017   857
5   6   227 2079   1852
6   77  241 1593   1352
7   65  415 2304   1889
8   98  524 508    1632
9   115 582 2316   1734
Sequence of process  ->P0->P1->P2->P3->P0->P1->P2->P4->P5->P6->P0->P1->P3->P7->
>P4->P5->P8->P9->P6->P0->P1->P7->P4->P5->P9->P6->P0->P7->P4->P5->P9->P6->P0->P7->
>P5->P9->P6->P7->P5->P9->P6->P7->P5->P9->P6->P7->P5->P9->P7->P5->P9->P7->P5->P9->
>P7->P5->P9->P7->P9->P7->P9->P7->P9->P7->P9->P9
Average Waiting Time: 993.4
Average Compilation Time: 1235.9
CPU Utilization: 80.3786714135448
```

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Final comparison of CPU utilization of all the Scheduling Algorithms:

```
-------CPU utilization comparison Table-----

Algorithm       CPU Utilization
FCFS            79.49510106805543
SJF             75.6089911134344
RR(Q=20)        80.08867723129978
RR(Q=25)        80.55956389289722
RR(Q=30)        80.34686765540158
RR(Q=35)        80.20569749408212
RR(Q=40)        80.3786714135448
```

We can note that CPU utilization for Round Robin are more than FCFS and SJF as context switching is involved in round robin.

CPU utilization for SJF is minimum as it sorts the processes in ascending order and then perform the algorithm.

In case of round robin as we increase the Quantum, value waiting time is directly affected. More the quantum value more is the waiting time. There is not much change in CPU utilization as we are using 10 processes and burst time range is smaller. If we take large values there is effect on CPU utilization also. I have checked in one of my experiment

Arrival tile range from 0 to 120000

Burst time range from 0 to 600000

CPU utilization is as follows:

-------CPU utilization comparison Table-----

```
Algorithm               CPU Utilization
FCFS                    81.17587810026686
SJF                     72.72950719506251
RR(Q=20)                82.0354467113017
RR(Q=25)                83.03521171997785
RR(Q=30)                85.03499784545643
RR(Q=35)                85.66784785478575
RR(Q=40)                86.08788769198123
```

CPU utilization increases as quantum value increases.

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VII. References

Lecture slides for assumption and basic requirement

www.wikipedia.com

Random number generator: https://www.geeksforgeeks.org/pseudo-random-number-generator-prng/

VIII. APPENDIX SECTION

CODE:

```
let st = 0;//defining start time to be zero hence initializing it globally
let iob= 3;//I/o bound time in in s
let idel=0;
let tot=0;
let cpu= [];
let k = 0;
/*
var fs = require('fs');
var util = require('util');
var log_file = fs.createWriteStream(__dirname + '/debug.log', {flags : 'w'});
var log_stdout = process.stdout;

console.log = function(d) { //
  log_file.write(util.format(d) + '\n');
  log_stdout.write(util.format(d) + '\n');
};
*/


function FCFS(arrivalTime, burstTime,IOTime){
  st=0;
  let output = 'P\tAT\tBT\tCT\tTT\tWT\n',
      objCollection = [],
      AT = [],
      BT = [],
      comp,
      tat,
      waiting,
      att = [],
      awt = [],
      IO = [];

      st=arrivalTime[0];
```

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```
      console.log("initialization or start of process");

  for(var x = 0; x < arrivalTime.length; x++)
    objCollection.push({ A: arrivalTime[x], B: burstTime[x], C: IOTime[x] });


  for(var x = 0; x < objCollection.length; x++){
    //initialix=zing aray with the random values recived
    AT.push(objCollection[x].A);
    BT.push(objCollection[x].B);
    IO.push(objCollection[x].C);

    //calculation

    console.log("process ",x," in READY state");
    comp = CT(BT[x],IO[x],x);

    tat = TT(comp,AT[x]);

    waiting = WT(tat,BT[x]);

    //storing values in output string, AT and BT array are used.
    output += `${x}\t${AT[x]}\t${BT[x]}\t${comp}\t${tat}\t${waiting}\n`;
    console.log("-----------------------------------------------------------------
-----------------------");
    //pushing to array att and awt for later purposes.
    att.push(tat);
    awt.push(waiting);
  }

  //Passing att and awt arrays to these functions
  output += `Average Turnaround Time: ${averageTT(att,
objCollection.length)}\nAverage Waiting Time: ${averageWT(awt,
objCollection.length)}`;
  cpu[k]= ((((tot-idel)/tot)*100));
  output+=  `\nCPU Utilization: ${cpu[k]}`;
  k++;
  idel=0;
  tot=0;
  return output;
}


function SJF(arrivalTime, burstTime,IOTime){
  st=0;
```

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```
let output = 'P\tAT\tBT\tCT\tTT\tWT\n',
    objCollection = [],
    AT = [],
    BT = [],
    p=[0,1,2,3,4,5,6,7,8,9],
    comp,
    tat,
    waiting,
    att = [],
    awt = [],
    pos,
    //arrivalTimeNew=[0,0,0,0,0,0,0,0,0,0],
    temp1,i,j,
    IO = [];

    for(i=0;i<burstTime.length;i++)
  {
      pos=i;
      for(j=i+1;j<burstTime.length;j++)
      {
          if(burstTime[j]<burstTime[pos])
              pos=j;
      }

      temp1=burstTime[i];
      burstTime[i]=burstTime[pos];
      burstTime[pos]=temp1;

      temp1=arrivalTime[i];
      arrivalTime[i]=arrivalTime[pos];
      arrivalTime[pos]=temp1;

      temp1=p[i];
      p[i]=p[pos];
      p[pos]=temp1;


  }

 st=arrivalTime[0];


  console.log("initialization or start of process");
for(var x = 0; x < 10; x++)
  objCollection.push({ A: arrivalTime[x], B: burstTime[x], C: IOTime[x] });
```

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```
  for(var x = 0; x < objCollection.length; x++){
    //initialix=zing aray with the random values recived
    AT.push(objCollection[x].A);
    BT.push(objCollection[x].B);
    IO.push(objCollection[x].C);

    //calculation

    console.log("process ",p[x]," in READY state");
    comp = CT(BT[x],IO[x],p[x]);

    tat = TT(comp,AT[x]);

    waiting = WT(tat,BT[x]);

    //storing values in output string, AT and BT array are used.
    output +=
`${p[x]}\t${arrivalTime[x]}\t${burstTime[x]}\t${comp}\t${tat}\t${waiting}\n`;
    console.log("-----------------------------------------------------------------
-----------------------");
    //pushing to array att and awt for later purposes.
    att.push(tat);
    awt.push(waiting);
  }

  //Passing att and awt arrays to these functions
  output += `Average Turnaround Time: ${averageTT(att,
objCollection.length)}\nAverage Waiting Time: ${averageWT(awt,
objCollection.length)}`;
  cpu[k]= ((((tot-idel)/tot)*100));
  output+=  `\nCPU Utilization: ${cpu[k]}`;
  k++;
  idel=0;
  tot=0;

  return output;
}

function RR(name,arrivalTime, burstTime,quant)
{
  let output = 'P\tAT\tBT\tCT\tWT\n',
  objCollection = [],
  seq = ' ',
```

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```
  AT = [],
  BT = [],
  comp = [],
  res = 0,
  resc = 0,
  waiting = [],
  t = 0;

for(var x = 0; x < arrivalTime.length; x++)
objCollection.push({ A: arrivalTime[x], B: burstTime[x]});
objCollection.sort(function(a, b){
return a.A - b.A;
});

for(var x = 0; x < objCollection.length; x++){
//initialix=zing aray with the random values recived
AT.push(objCollection[x].A);
BT.push(objCollection[x].B);
}
//calculation

while (true) {
  let flag = true;
  for (var i = 0; i < 10; i++) {
      if (AT[i] <= t) {
          if (AT[i] <= quant) {
              if (BT[i] > 0) {
                  flag = false;
                  if (BT[i] > quant) {
                      t = t + quant;
                      BT[i] = BT[i] - quant;
                      AT[i] = AT[i] + quant;
                      seq += `->` + name[i];
                  }
                  else {
                      t = t + BT[i];
                      comp[i] = t - arrivalTime[i];
                      waiting[i] = t - burstTime[i] - arrivalTime[i];
                      BT[i] = 0;
                      seq += `->` + name[i];
                  }
              }
          }
          else if (AT[i] > quant) {
              for (var j = 0; j < 10; j++) {
```

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```
                if (AT[j] < AT[i]) {
                    if (BT[j] > 0) {
                         flag = false;
                        if (BT[j] > quant) {
                            t = t + quant;
                            BT[j] = BT[j] - quant;
                            AT[j] = AT[j] + quant;
                            seq += `->` + name[j];
                        }
                        else {
                            t = t + BT[j];
                            comp[j] = t - arrivalTime[j];
                            waiting[j] = t - burstTime[j] - arrivalTime[j];
                            BT[j] = 0;
                            seq += `->` + name[j];
                        }
                    }
                }
            }
            if (BT[i] > 0) {
                flag = false;
                if (BT[i] > quant) {
                    t = t + quant;
                    BT[i] = BT[i] - quant;
                    AT[i] = AT[i] + quant;
                    seq += `->` + name[i];
                }
                else {
                    t = t + BT[i];
                    comp[i] = t - arrivalTime[i];
                    waiting[i] = t - burstTime[i] - arrivalTime[i];
                    BT[i] = 0;
                    seq += `->` + name[i];
                }
            }
        }
    }
    else if (AT[i] > t) {
        t++;
        i--;
    }
}
if (flag) {
    break;
}
```

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```
}
for(var x = 0; x < 10; x++){
//storing values in output string, AT and BT array are used.
output +=
`${x}\t${arrivalTime[x]}\t${burstTime[x]}\t${comp[x]}\t${waiting[x]}\n`;
}

for(var i= 0; i<10; i++){

  res = res + waiting[i];
  resc = resc + comp[i];
}
//pushing to array att and awt for later purposes.
output += `Sequence of process ${seq}\n`
//Passing att and awt arrays to these functions
output += `Average Waiting Time: ${(res / 10)}\nAverage Compilation Time:
${(resc/10)}`;
cpu[k] = (((res)/resc)*100);
output+=  `\nCPU Utilization: ${cpu[k]}`;
k++;
return output;
}


//completion time.
function CT(bt,io,x)
{


    console.log("process ",x," EXECUTING");
  if (bt<=io)
  {

    st+=bt;
    //console.log("st if= ",st );
    console.log("process ",x," TERMINATED AT ", st);
    return st;
  }
  else
  {
    console.log("Input/Output operation stated for process ",x+1);
    var temp = bt;
   // console.log("process ",x+1," in I/O queue");
    while(temp)
    {
```

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```
        console.log("process ",x," in I/O queue")
        if (temp>io)
        {
            console.log("process ",x," in I/O channel")
        st =st+io+iob;
        temp = temp-io;
        idel+=(io+iob);
        console.log("process ",x," in READY state");
        console.log("process ",x," EXECUTING at CPU");
        }
        else
        {
        st=st+iob+temp;
        console.log("process ",x," FINAL Execution");
        temp=0;
        }

    }
    tot+=st;
    console.log("process ",x," TERMINATED at ",st);
        return st;
  }
 // st += bt;
 // return st;
}

//turnaround time.
function TT(ct, at)
{
  return ct - at;
}

//waiting time.
function WT(tt,bt){
  return tt + bt;
}

function averageTT (ttValues, noOfValues) {
  return ttValues.reduce(function(total, num){
    return total + num;
  }) / noOfValues;
}

function averageWT (wtValues, noOfValues) {
  return wtValues.reduce(function(total, num){
```

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```
    return total + num;
  }) / noOfValues;
}

let arv=[],bst=[];
for (var i=0; i<10; i++)
{
arv[i] = Math.floor(Math.random() * 120) ;// random value btw 0 to 2 minutes but
integer we convert it in "s"
bst[i] = Math.floor(Math.random() * 600) ;//random values btw 0 and 10 minutes
but integer we convert it into "s"
}
let process = ["P0","P1","P2","P3","P4","P5","P6","P7","P8","P9"];
//let io=[3,1,2];
//let io=[30,35,40,45,50,55,60,65,70,75];
let io=[30,35,40,45,50,55,60,65,70,75];//initializing input output bount time.
let fcfs = FCFS(arv,bst,io);
let sjf= SJF(arv,bst,io);
let rr1= RR(process,arv,bst,20);
let rr2= RR(process,arv,bst,25);
let rr3= RR(process,arv,bst,30);
let rr4= RR(process,arv,bst,35);
let rr5= RR(process,arv,bst,40);
let algo=["FCFS    ","SJF
","RR(Q=20)","RR(Q=25)","RR(Q=30)","RR(Q=35)","RR(Q=40)"];
//let rr= RR(arv,bst,io);
console.log("-----------------------------------FCFS----------------------------
-----------------------");
console.log(fcfs);
//console.log("CPU utilization = ",((tot-idel)/tot)*100);
console.log("-----------------------------------SJF-----------------------------
----------------------");
console.log(sjf);

//console.log("CPU utilization = ",((tot-idel)/tot)*100);
console.log("-----------------------------------RR(20)--------------------------
-------------------------");
console.log(rr1);//test
console.log("-----------------------------------RR(25)--------------------------
-------------------------");
console.log(rr2);//test
console.log("-----------------------------------RR(30)--------------------------
-------------------------");
console.log(rr3);//test
```

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```
console.log("-----------------------------------RR(35)-------------------------
-------------------------");
console.log(rr4);//test
console.log("-----------------------------------RR(40)-------------------------
-------------------------");
console.log(rr5);//test
console.log("\n-------CPU utilization comparizon Table-----");
console.log("\nAlgorithm\t\tCPU Utilization");
for(var i=0;i<7;i++)
console.log( `${(algo[i])}\t\t${(cpu[i])}`);
//console.log("CPU utilization = ",((tot-idel)/tot)*100);
//console.log(FCFS([0, 2, 4, 6], [7, 9, 6, 8],[3,5,100,4]));
```

Output: Outpiy.log file

```
initialization or start of process
process  0  in READY state
process  0  EXECUTING
Input/Output operation stated for process  1
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
```

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```
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  FINAL Execution
process  0  TERMINATED at  522
---------------------------------------------------------------------------------
------
process  1  in READY state
process  1  EXECUTING
Input/Output operation stated for process  2
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
```

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```
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  FINAL Execution
process  1  TERMINATED at  770
------------------------------------------------------------------------------
------
process  2  in READY state
process  2  EXECUTING
Input/Output operation stated for process  3
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
```

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```
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  FINAL Execution
process  2  TERMINATED at  1336
---------------------------------------------------------------------------------
------
process  3  in READY state
process  3  EXECUTING
Input/Output operation stated for process  4
process  3  in I/O queue
process  3  in I/O channel
process  3  in READY state
process  3  EXECUTING at CPU
```

```
process  3  in I/O queue
process  3  in I/O channel
process  3  in READY state
process  3  EXECUTING at CPU
process  3  in I/O queue
process  3  in I/O channel
process  3  in READY state
process  3  EXECUTING at CPU
process  3  in I/O queue
process  3  FINAL Execution
process  3  TERMINATED at  1504
--------------------------------------------------------------------------------
------
process  4  in READY state
process  4  EXECUTING
Input/Output operation stated for process  5
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
```

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```
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  FINAL Execution
process  4  TERMINATED at  2122
------------------------------------------------------------------------------
------
process  5  in READY state
process  5  EXECUTING
process  5  TERMINATED AT  2129
------------------------------------------------------------------------------
------
process  6  in READY state
process  6  EXECUTING
process  6  TERMINATED AT  2183
------------------------------------------------------------------------------
------
process  7  in READY state
process  7  EXECUTING
process  7  TERMINATED AT  2242
------------------------------------------------------------------------------
------
process  8  in READY state
process  8  EXECUTING
Input/Output operation stated for process  9
process  8  in I/O queue
process  8  in I/O channel
process  8  in READY state
process  8  EXECUTING at CPU
process  8  in I/O queue
process  8  in I/O channel
process  8  in READY state
```

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```
process  8  EXECUTING at CPU
process  8  in I/O queue
process  8  FINAL Execution
process  8  TERMINATED at  2411
-------------------------------------------------------------------------------
------
process  9  in READY state
process  9  EXECUTING
Input/Output operation stated for process  10
process  9  in I/O queue
process  9  in I/O channel
process  9  in READY state
process  9  EXECUTING at CPU
process  9  in I/O queue
process  9  in I/O channel
process  9  in READY state
process  9  EXECUTING at CPU
process  9  in I/O queue
process  9  in I/O channel
process  9  in READY state
process  9  EXECUTING at CPU
process  9  in I/O queue
process  9  FINAL Execution
process  9  TERMINATED at  2664
-------------------------------------------------------------------------------
------
initialization or start of process
process  5  in READY state
process  5  EXECUTING
process  5  TERMINATED AT  117
-------------------------------------------------------------------------------
------
process  6  in READY state
process  6  EXECUTING
Input/Output operation stated for process  7
process  6  in I/O queue
process  6  in I/O channel
process  6  in READY state
process  6  EXECUTING at CPU
process  6  in I/O queue
process  6  FINAL Execution
process  6  TERMINATED at  177
-------------------------------------------------------------------------------
------
process  7  in READY state
```

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```
process  7  EXECUTING
Input/Output operation stated for process  8
process  7  in I/O queue
process  7  in I/O channel
process  7  in READY state
process  7  EXECUTING at CPU
process  7  in I/O queue
process  7  FINAL Execution
process  7  TERMINATED at  242
------------------------------------------------------------------------------
------
process  3  in READY state
process  3  EXECUTING
Input/Output operation stated for process  4
process  3  in I/O queue
process  3  in I/O channel
process  3  in READY state
process  3  EXECUTING at CPU
process  3  in I/O queue
process  3  in I/O channel
process  3  in READY state
process  3  EXECUTING at CPU
process  3  in I/O queue
process  3  in I/O channel
process  3  in READY state
process  3  EXECUTING at CPU
process  3  in I/O queue
process  3  FINAL Execution
process  3  TERMINATED at  410
------------------------------------------------------------------------------
------
process  8  in READY state
process  8  EXECUTING
Input/Output operation stated for process  9
process  8  in I/O queue
process  8  in I/O channel
process  8  in READY state
process  8  EXECUTING at CPU
process  8  in I/O queue
process  8  in I/O channel
process  8  in READY state
process  8  EXECUTING at CPU
process  8  in I/O queue
process  8  in I/O channel
process  8  in READY state
```

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```
process  8  EXECUTING at CPU
process  8  in I/O queue
process  8  FINAL Execution
process  8  TERMINATED at  582
-------------------------------------------------------------------------------
------
process  1  in READY state
process  1  EXECUTING
Input/Output operation stated for process  2
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  in I/O channel
process  1  in READY state
process  1  EXECUTING at CPU
process  1  in I/O queue
process  1  FINAL Execution
process  1  TERMINATED at  824
-------------------------------------------------------------------------------
------
process  9  in READY state
process  9  EXECUTING
Input/Output operation stated for process  10
process  9  in I/O queue
process  9  in I/O channel
process  9  in READY state
process  9  EXECUTING at CPU
process  9  in I/O queue
process  9  in I/O channel
process  9  in READY state
process  9  EXECUTING at CPU
process  9  in I/O queue
process  9  in I/O channel
process  9  in READY state
process  9  EXECUTING at CPU
```

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```
process  9  in I/O queue
process  9  in I/O channel
process  9  in READY state
process  9  EXECUTING at CPU
process  9  in I/O queue
process  9  FINAL Execution
process  9  TERMINATED at  1080
--------------------------------------------------------------------------------
------
process  0  in READY state
process  0  EXECUTING
Input/Output operation stated for process  1
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  in I/O channel
process  0  in READY state
process  0  EXECUTING at CPU
process  0  in I/O queue
process  0  FINAL Execution
process  0  TERMINATED at  1516
--------------------------------------------------------------------------------
------
process  2  in READY state
process  2  EXECUTING
Input/Output operation stated for process  3
process  2  in I/O queue
```

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```
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  in I/O channel
process  2  in READY state
process  2  EXECUTING at CPU
process  2  in I/O queue
process  2  FINAL Execution
process  2  TERMINATED at  2064
---------------------------------------------------------------------------------
------
process  4  in READY state
process  4  EXECUTING
Input/Output operation stated for process  5
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
```

```
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  in I/O channel
process  4  in READY state
process  4  EXECUTING at CPU
process  4  in I/O queue
process  4  FINAL Execution
process  4  TERMINATED at  2670
------------------------------------------------------------------------------
------
----------------------------------FCFS----------------------------------------
----------
P   AT  BT  CT  TT  WT
0   65  415 522 457 872
1   6   227 770 764 991
2   98  524 1336    1238    1762
3   16  156 1504    1488    1644
4   115 582 2122    2007    2589
5   110 7   2129    2019    2026
6   17  54  2183    2166    2220
7   45  59  2242    2197    2256
8   65  160 2411    2346    2506
9   77  241 2664    2587    2828
Average Turnaround Time: 1726.9
Average Waiting Time: 1969.4
CPU Utilization: 79.49510106805543
----------------------------------SJF-----------------------------------------
---------
P   AT  BT  CT  TT  WT
5   110 7   117 7   14
6   17  54  177 160 214
7   45  59  242 197 256
```

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```
3   16  156 410 394 550
8   65  160 582 517 677
1   6   227 824 818 1045
9   77  241 1080    1003    1244
0   65  415 1516    1451    1866
2   98  524 2064    1966    2490
4   115 582 2670    2555    3137
Average Turnaround Time: 906.8
Average Waiting Time: 1149.3
CPU Utilization: 75.6089911134344
-----------------------------------RR(20)-------------------------------------
------------
P   AT  BT  CT  WT
0   110 7   1139    1132
1   17  54  805 751
2   45  59  155 96
3   16  156 363 207
4   65  160 1077    917
5   6   227 2059    1832
6   77  241 1533    1292
7   65  415 2304    1889
8   98  524 428 -96
9   115 582 2316    1734
Sequence of process  ->P0->P1->P2->P0->P1->P2->P3->P0->P1->P2->P4->P5->P0->P1-
>P3->P6->P0->P1->P3->P4->P5->P6->P7->P0->P4->P5->P8->P9->P1->P4->P5->P6->P7->P0-
>P9->P1->P6->P7->P4->P5->P0->P1->P9->P6->P7->P0->P4->P5->P9->P4->P5->P6->P7->P0-
>P6->P7->P9->P4->P5->P0->P9->P6->P7->P0->P5->P9->P6->P7->P5->P9->P6->P7->P5->P9-
>P6->P7->P5->P9->P6->P7->P5->P9->P6->P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P5-
>P9->P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P9->P7->P9->P7->P9->P7-
>P9->P7->P9->P7->P9->P7->P9->P7->P9->P9->P9->P9
Average Waiting Time: 975.4
Average Compilation Time: 1217.9
CPU Utilization: 80.08867723129978
-----------------------------------RR(25)-------------------------------------
------------
P   AT  BT  CT  WT
0   110 7   1184    1177
1   17  54  915 861
2   45  59  240 181
3   16  156 378 222
4   65  160 1152    992
5   6   227 2069    1842
6   77  241 1508    1267
7   65  415 2284    1869
8   98  524 428 -96
```

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```
9   115 582 2316    1734
Sequence of process  ->P0->P1->P2->P0->P1->P2->P3->P0->P4->P5->P1->P2->P3->P6-
>P0->P1->P3->P4->P5->P7->P0->P6->P8->P9->P1->P4->P5->P6->P7->P0->P4->P5->P9->P1-
>P0->P6->P7->P4->P5->P1->P7->P9->P6->P0->P4->P5->P9->P7->P0->P6->P9->P4->P5->P6-
>P7->P0->P5->P7->P9->P6->P5->P9->P7->P6->P9->P5->P7->P6->P5->P9->P7->P9->P5->P7-
>P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P7->P9->P7->P9-
>P7->P9->P7->P9->P7->P9->P9->P9->P9
Average Waiting Time: 1004.9
Average Compilation Time: 1247.4
CPU Utilization: 80.55956389289722
-----------------------------------RR(30)---------------------------------------
------------
P   AT  BT  CT  WT
0   110 7   1129    1122
1   17  54  895 841
2   45  59  165 106
3   16  156 343 187
4   65  160 1127    967
5   6   227 2039    1812
6   77  241 1553    1312
7   65  415 2294    1879
8   98  524 478 -46
9   115 582 2316    1734
Sequence of process  ->P0->P1->P2->P0->P3->P1->P2->P4->P5->P0->P1->P3->P6->P0-
>P4->P5->P7->P1->P6->P8->P9->P4->P5->P0->P7->P1->P6->P9->P4->P5->P0->P1->P7->P6-
>P0->P4->P5->P9->P7->P6->P9->P4->P5->P0->P6->P7->P9->P5->P7->P6->P5->P9->P7->P6-
>P9->P5->P7->P6->P5->P9->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9->P5->P7->P9-
>P7->P9->P7->P9->P7->P9->P7->P9->P7->P9->P9->P9
Average Waiting Time: 991.4
Average Compilation Time: 1233.9
CPU Utilization: 80.34686765540158
-----------------------------------RR(35)---------------------------------------
------------
P   AT  BT  CT  WT
0   110 7   1064    1057
1   17  54  895 841
2   45  59  190 131
3   16  156 418 262
4   65  160 1129    969
5   6   227 2054    1827
6   77  241 1463    1222
7   65  415 2274    1859
8   98  524 448 -76
9   115 582 2316    1734
```

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```
Sequence of process  ->P0->P1->P2->P0->P3->P1->P2->P4->P5->P0->P6->P1->P3->P7-
>P4->P5->P8->P0->P6->P9->P1->P4->P5->P7->P0->P6->P9->P1->P7->P4->P5->P0->P6->P9-
>P7->P0->P4->P5->P6->P9->P7->P5->P6->P9->P7->P5->P6->P9->P7->P5->P9->P7->P5->P9-
>P7->P5->P9->P7->P5->P9->P7->P5->P9->P7->P9->P7->P9->P7->P9->P7->P9->P9->P9
Average Waiting Time: 982.6
Average Compilation Time: 1225.1
CPU Utilization: 80.20569749408212
-----------------------------------RR(40)-------------------------------------
------------
P   AT  BT  CT  WT
0   110 7   1119    1112
1   17  54  745 691
2   45  59  215 156
3   16  156 463 307
4   65  160 1017    857
5   6   227 2079    1852
6   77  241 1593    1352
7   65  415 2304    1889
8   98  524 508 -16
9   115 582 2316    1734
Sequence of process  ->P0->P1->P2->P3->P0->P1->P2->P4->P5->P6->P0->P1->P3->P7-
>P4->P5->P8->P9->P6->P0->P1->P7->P4->P5->P9->P6->P0->P7->P4->P5->P9->P6->P0->P7-
>P5->P9->P6->P7->P5->P9->P6->P7->P5->P9->P6->P7->P5->P9->P7->P5->P9->P7->P5->P9-
>P7->P5->P9->P7->P9->P7->P9->P7->P9->P7->P9->P9
Average Waiting Time: 993.4
Average Compilation Time: 1235.9
CPU Utilization: 80.3786714135448

-------CPU utilization comparizon Table-----

Algorithm       CPU Utilization
FCFS            79.49510106805543
SJF             75.6089911134344
RR(Q=20)        80.08867723129978
RR(Q=25)        80.55956389289722
RR(Q=30)        80.34686765540158
RR(Q=35)        80.20569749408212
RR(Q=40)        80.3786714135448
```

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