Analysis of CPU Scheduling Algorithms

Operating Systems
CSD-222

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Introduction

This document is a report for the individual project "Simulation of various CPU scheduling algorithms and analysing the behaviour of each scheduler". CPU scheduling is a process which allows one process to use the CPU while the execution of another process is on hold(in waiting state) due to unavailability of any resource like I/O etc, thereby making full use of CPU. The aim of CPU scheduling is to make the system efficient, fast and fair.

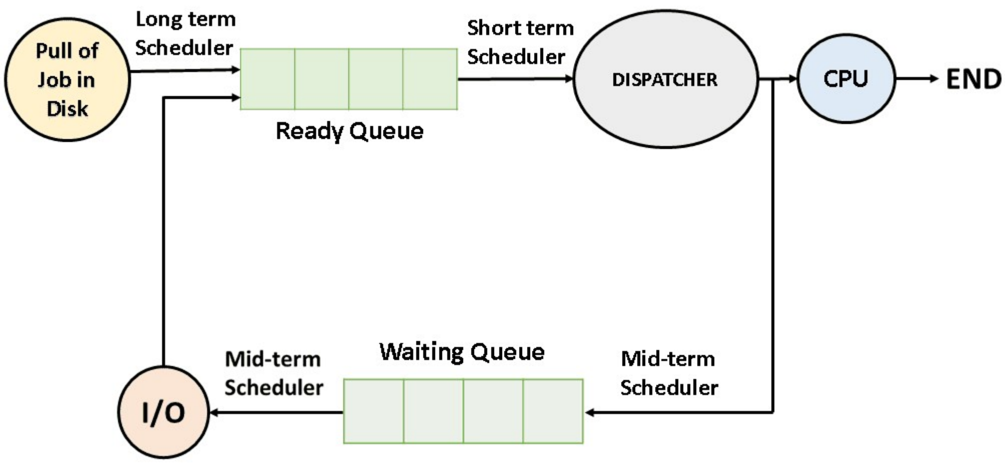


Figure 1.1: Cpu scheduling

The project is an attempt to differentiate the behaviour of each scheduler with the statistical approach. In this project we performed each CPU scheduling and compared them on the basis of their completion time,throughput,average job elapsed time and average job waiting time during the process. It also discusses the complexity of the written code as instructed.

Software requirement and specification

Python(3.7.6)

Python is an interpreted, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python's design philosophy emphasizes code readability with its notable use of significant whitespace.

Python-dateutil(2.8.1)

The dateutil module provides powerful extensions to the standard datetime module, available in Python.

matplotlib(3.2.2)

Matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python.

cycler(0.10.0)

A single entry Cycler object can be used to easily cycle over a single style.

numpy(1.19.0)

NumPy is the fundamental package for scientific computing in Python. It is a Python library that provides a multidimensional array object, various derived objects (such as masked arrays and matrices).

Kiwisolver(1.2.0)

Kiwisolver is an efficient C++ implementation of the Cassowary constraint solving algorithm. Kiwi is an implementation of the algorithm based on the seminal Cassowary paper.

pyparsing(2.4.7)

Pyparsing is a mature, powerful alternative to regular expressions for parsing text into tokens and retrieving or replacing those tokens.

six(1.15.0)

Six provides simple utilities for wrapping over differences between Python 2 and Python 3. It is intended to support codebases that work on both Python 2 and 3 without modification.

Usage

Install Python 3.7.6 and then install all packages mentioned in 'requirements.txt' in root folder by:

```
python -m pip install -r requirements.txt
```

After Installing all the packages run the main script with command:

```
python main.py
```

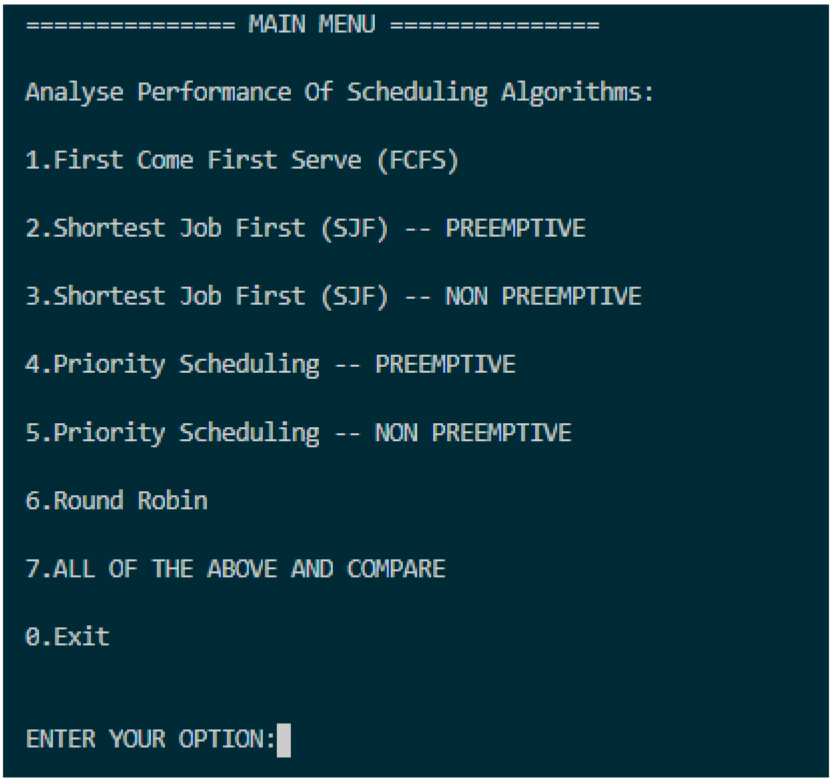


Figure 3.1: Main Menu

Contents

First Come First Serve (FCFS)

Listing 4.1: fcfs source code

```
import matplotlib.pyplot as plt

plt.style.use('fivethirtyeight')

## Finds waiting time for each process
def findWaitingTime(processes,  burst_time, waiting_time,
    ↪ arrival_time):
    service_time = [0] *len(processes)
    service_time[0] = 0
    waiting_time[0] = 0
    for i in range(1, len(processes)):

        service_time[i] = (service_time[i - 1] +  burst_time[i -
            ↪ 1])

        waiting_time[i] = service_time[i] - arrival_time[i]
        if (waiting_time[i] < 0):
            waiting_time[i] = 0


#Finds Turn Around Time for All processes
def findTurnAroundTime(processes, burst_time, waiting_time,
    ↪ turn_around_time):
    for i in range(len(processes)):
        turn_around_time[i] = burst_time[i] + waiting_time[i]


#Returns waiting,turn around, completion time for each process
def findavgTime(processes,  burst_time, arrival_time):

    waiting_time = [0] *len(processes)
    turn_around_time = [0] *len(processes)
    findWaitingTime(processes,  burst_time, waiting_time,
        ↪ arrival_time)
    findTurnAroundTime(processes,  burst_time, waiting_time,
        ↪ turn_around_time)

    total_wt = 0
    total_turn_around_time = 0
    compl_time = [0]*len(processes)
    for i in range(len(processes)):
```

```
        total_wt = total_wt + waiting_time[i]
        total_turn_around_time = total_turn_around_time +
            ↪ turn_around_time[i]
        # Calculate completion time

        compl_time[i] = turn_around_time[i] + arrival_time[i]

    return waiting_time , turn_around_time ,compl_time


def plot_graph(processes,waiting_time,compl_time,turn_around_time
    ↪ ):

    plt.plot(processes,waiting_time,label = "Waiting time")
    plt.plot(processes,compl_time,label = "Completion time")
    plt.plot(processes,turn_around_time,label = "Turnaround Time"
        ↪ )
    plt.text(4,2,'Throughput = %.5f' % (len(processes)/
        ↪ compl_time[len(processes)-1]))
    plt.title("First Come First Serve Algo")
    plt.xlabel("Processes")
    plt.ylabel("Time Units")
    plt.legend()
    plt.savefig('./output/FCFS_output.png')
    plt.show()



def print_details(processes,waiting_time,turn_around_time,
    ↪ compl_time,burst_time,arrival_time):

    print("Processes   Burst Time   Arrival Time     Waiting",
            "Time   Turn-Around Time  Completion Time \n")
    for i in range(len(processes)):
        print(" ", processes[i] , "\t\t", burst_time[i], "\t\t",
            ↪ arrival_time[i],
                "\t\t", waiting_time[i], "\t\t ", turn_around_time[
                    ↪ i], "\t\t ", compl_time[i])

    print("Average waiting time = %.5f "%(sum(waiting_time) /len(
        ↪ processes)))
    print("\nAverage turn around time = ", sum(turn_around_time)
```

```
    ↪ / len(processes))
    print('\nThroughput = ', len(processes)/ compl_time[len(
    ↪ processes)-1])


# driver function

def fcfs():

    processes = []
    burst_time = []
    arrival_time = []
    #breakpoint
    with open('./inputs/FCFS.txt','r') as  f:
        f.readline()
        for line in f.readlines():
            process , burst , arrival = (line.split(" "))
            processes.append(process)
            burst_time.append(int(burst))
            arrival_time.append(int(arrival))

    #returned waiting time and turn around time
    waiting_time , turn_around_time, compl_time = findavgTime(
    ↪ processes,  burst_time, arrival_time)

    #print details about data
    print_details(processes,waiting_time,turn_around_time,
    ↪ compl_time,burst_time,arrival_time)

    #plotting
    plot_graph(processes,waiting_time,compl_time,turn_around_time
    ↪ )
    plt.close(fig='all')

if __name__ =="__main__":
    fcfs()
```

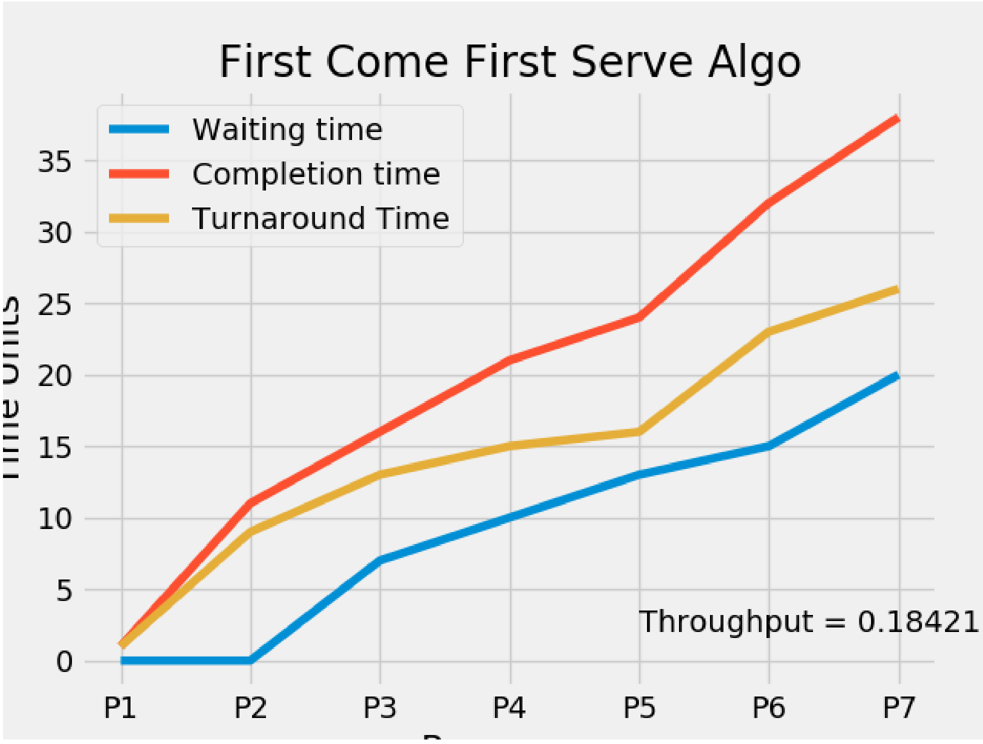


Figure 4.1: FCFS output values.

```
Processes    Burst Time    Arrival Time     Waiting Time    Turn-Around Time  Completion Time

  P1            1              0               0               1              1
  P2            9              2               0               9              11
  P3            6              3               7               13             16
  P4            5              6               10              15             21
  P5            3              8               13              16             24
  P6            8              9               15              23             32
  P7            6              12              20              26             38
Average waiting time = 9.28571

Average turn around time =  14.714285714285714

Throughput =  0.18421052631578946
press any button to continue.....
```

Figure 4.2: FCFS output values.

Shortest Job First(SJF)

5.1 SJF(Preemptive)

Listing 5.1: SJF Preemptive Source code

```
import matplotlib.pyplot as plt;

plt.style.use('fivethirtyeight')

def findWaitingTime(processes, n, wt):
        rt = [0] * n
        for i in range(n):
                rt[i] = processes[i][1]
        complete = 0
        t = 0
        minm = 999999999
        short = 0
        check = False

        while (complete != n):
                for j in range(n):
                        if ((processes[j][2] <= t) and
                                (rt[j] < minm) and rt[j] > 0):
                                minm = rt[j]
                                short = j
                                check = True
                if (check == False):
                        t += 1
                        continue

                rt[short] -= 1
                minm = rt[short]
                if (minm == 0):
                        minm = 999999999
                if (rt[short] == 0):

                        complete += 1
                        check = False
                        fint = t + 1
                        wt[short] = (fint - processes[short][1] -
                            ↪ processes[short][2])

                        if (wt[short] < 0):
```

```
                        wt[short] = 0
                t += 1


def findTurnAroundTime(processes, n, wt, tat):

        for i in range(n):
                tat[i] = processes[i][1] + wt[i]



def findavgTime(processes, n):
        wt = [0] * n
        tat = [0] * n
        findWaitingTime(processes, n, wt)
        findTurnAroundTime(processes, n, wt, tat)
        compl_time = []
        for i in range(n):
                        compl_time.append(tat[i]+processes[i][2])
        return wt, tat,compl_time


def print_data(processes,w_time,tat_time,compl_time,n):

        print("Processes\t\tBurst Time\t\tWaiting",
                                "Time\t\tTurn-Around Time\t\tArrival Time\t\tCompletion Time" )
        for i in range(n):

                print(" ", processes[i][0], "\t\t\t",
                                processes[i][1], "\t\t\t",
                                w_time[i], "\t\t\t", tat_time[i],'\t\t\t\t',processes[i][2],'\t\t\t',compl_time[i])

        print("\nAverage waiting time = %.5f "%(sum(w_time) /n) )
        print("Average turn around time = ", sum(tat_time) / n)
        print("Throughput  =  ",n/max(compl_time))
```

```python
def  plot_graph(processes,waiting_time,compl_time,turn_around_time):

        plt.plot(processes,waiting_time,label = "Waiting time")
        plt.plot(processes,compl_time,label = "Completion time")
        plt.plot(processes,turn_around_time,label = "Turnaround Time")
        plt.text(4,2,'Throughput = %.5f'  % (len(processes)/compl_time[len(processes)-1]))
        plt.title("SJF PREEMPTIVE")
        plt.xlabel("Processes")
        plt.ylabel("Time Units")
        plt.legend()
        plt.savefig('./output/SJF_P_output.png')
        plt.show()



def sjf_p():
        process_data = []
        #change dis
        with open('./inputs/SJF_P.txt','r') as  f:
                f.readline()
                for line in f.readlines():
                        temporary = []
                        process , burst , arrival = (line.split(" "))
                        temporary.extend([process, int(burst), int(arrival)])
                        process_data.append(temporary)
        n = len(process_data)
        w_time,tat_time,compl_time =  findavgTime(process_data, n)
        print_data(process_data, w_time, tat_time,compl_time,n)
        plot_graph([p[0] for p in process_data],w_time,compl_time,tat_time)
        plt.close(fig='all')

# Driver code
if __name__ =="__main__":
        sjf_p()
```

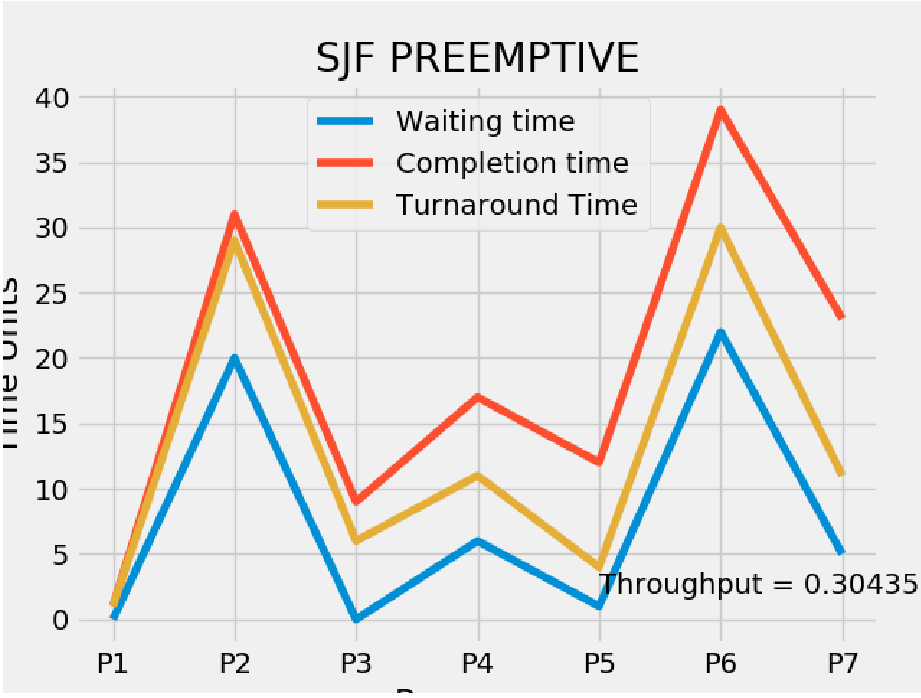


Figure 5.1: SJF(Preemptive) output values.

Processes	Burst Time	Waiting Time	Turn-Around Time	Arrival Time	Completion Time
P1	1	0	1	0	1
P2	9	20	29	2	31
P3	6	0	6	3	9
P4	5	6	11	6	17
P5	3	1	4	8	12
P6	8	22	30	9	39
P7	6	5	11	12	23

```
Average waiting time = 7.71429
Average turn around time =  13.142857142857142
Throughput  =   0.1794871794871795
press any button to continue.....
```

Figure 5.2: SJF(Preemptive) output values.

5.2 SJF(Non-Preemptive)

Listing 5.2: SJF Preemptive Source code

```
import matplotlib.pyplot as plt

plt.style.use('fivethirtyeight')
```

```python
def schedulingProcess(  process_data):
        start_time = []
        exit_time = []
        s_time = 0
        process_data.sort(key=lambda x: x[1])
        '''
        Sort processes according to the Arrival Time
        '''
        for i in range(len(process_data)):
                ready_queue = []
                temp = []
                normal_queue = []

                for j in range(len(process_data)):
                        if (process_data[j][1] <= s_time) and (
                           ↪ process_data[j][3] == 0):
                                temp.extend([process_data[j][0],
                                   ↪ process_data[j][1],
                                   ↪ process_data[j][2]])
                                ready_queue.append(temp)
                                temp = []
                        elif process_data[j][3] == 0:
                                temp.extend([process_data[j][0],
                                   ↪ process_data[j][1],
                                   ↪ process_data[j][2]])
                                normal_queue.append(temp)
                                temp = []

                if len(ready_queue) != 0:
                        ready_queue.sort(key=lambda x: x[2])
                        '''
                        Sort the processes according to the Burst
                           ↪  Time
                        '''
                        start_time.append(s_time)
                        s_time = s_time + ready_queue[0][2]
                        e_time = s_time
                        exit_time.append(e_time)
                        for k in range(len(process_data)):
                                if process_data[k][0] ==
                                   ↪ ready_queue[0][0]:
                                        break
                        process_data[k][3] = 1
```

```
                    process_data[k].append(e_time)

                elif len(ready_queue) == 0:
                    if s_time < normal_queue[0][1]:
                        s_time = normal_queue[0][1]
                    start_time.append(s_time)
                    s_time = s_time + normal_queue[0][2]
                    e_time = s_time
                    exit_time.append(e_time)
                    for k in range(len(process_data)):
                        if process_data[k][0] ==
                            ↪ normal_queue[0][0]:
                            break
                    process_data[k][3] = 1
                    process_data[k].append(e_time)

        calculateTurnaroundTime( process_data)
        calculateWaitingTime( process_data)

        waiting_time = [p[6] for p in process_data]
        turn_around_time = [p[5] for p in process_data]
        compl_time = [p[4] for p in process_data]
        return waiting_time,turn_around_time,compl_time


def calculateTurnaroundTime( process_data):
        total_turnaround_time = 0
        for i in range(len(process_data)):
            turnaround_time = process_data[i][4] -
                ↪ process_data[i][1]
            '''
            turnaround_time = completion_time - arrival_time
            '''
            total_turnaround_time = total_turnaround_time +
                ↪ turnaround_time
            process_data[i].append(turnaround_time)


def calculateWaitingTime( process_data):
        total_waiting_time = 0
        for i in range(len(process_data)):
            waiting_time = process_data[i][5] - process_data[
                ↪ i][2]
```

```
            '''
            waiting_time = turnaround_time - burst_time
            '''
            total_waiting_time = total_waiting_time +
               ↪ waiting_time
            process_data[i].append(waiting_time)



def printData( process_data):
        average_turnaround_time  = sum(p[5] for p in process_data
           ↪ )/len(process_data)
        average_waiting_time = sum(p[6] for p in process_data)/
           ↪ len(process_data)
        process_data.sort(key=lambda x: x[0])
        '''
        Sort processes according to the Process ID
        '''
        print("\nProcess_ID\t\t\tArrival_Time\t\t\tBurst_Time\t\t
           ↪ \tCompleted\t\t\tCompletion_Time\t\t\
           ↪ tTurnaround_Time\t\t\tWaiting_Time")

        for i in range(len(process_data)):
                for j in range(len(process_data[i])):

                        print(process_data[i][j], end="
                           ↪                          ")
                print()

        print(f'Average Turnaround Time: {average_turnaround_time
           ↪ }')

        print(f'Average Waiting Time: {average_waiting_time}')

        print("Throughput  =  ",len(process_data)/max([p[4] for p
           ↪  in process_data]))




def plot_graph( process_data):
        plt.plot([p[0] for p in process_data],[po[4] for po in
```

```
    ↪ process_data],label = 'Completion␣Time')
plt.plot([p[0] for p in process_data],[po[5] for po in
    ↪ process_data],label = 'Turnaround␣Time')
plt.plot([p[0] for p in process_data],[po[6] for po in
    ↪ process_data],label = 'Waiting␣TIme')
plt.title("Shortest␣Job␣First␣Algo␣-␣Non␣Preemptive")
plt.xlabel("Processes")
plt.ylabel("Time␣Units")
plt.legend()
plt.savefig('./output/SJF_NP_output.png')
plt.show()



def sjf_np():

        process_data = []
        #change dis
        with open('./inputs/SJF_NP.txt','r') as  f:
                f.readline()
                for line in f.readlines():
                        temporary = []
                        process , burst , arrival = (line.split("
                            ↪ ␣"))
                        temporary.extend([process, int(arrival),
                            ↪ int(burst), 0])
                        process_data.append(temporary)
        schedulingProcess(process_data)

        printData( process_data)

        plot_graph(process_data)
        plt.close(fig='all')


if __name__ == '__main__':
        sjf_np()
```

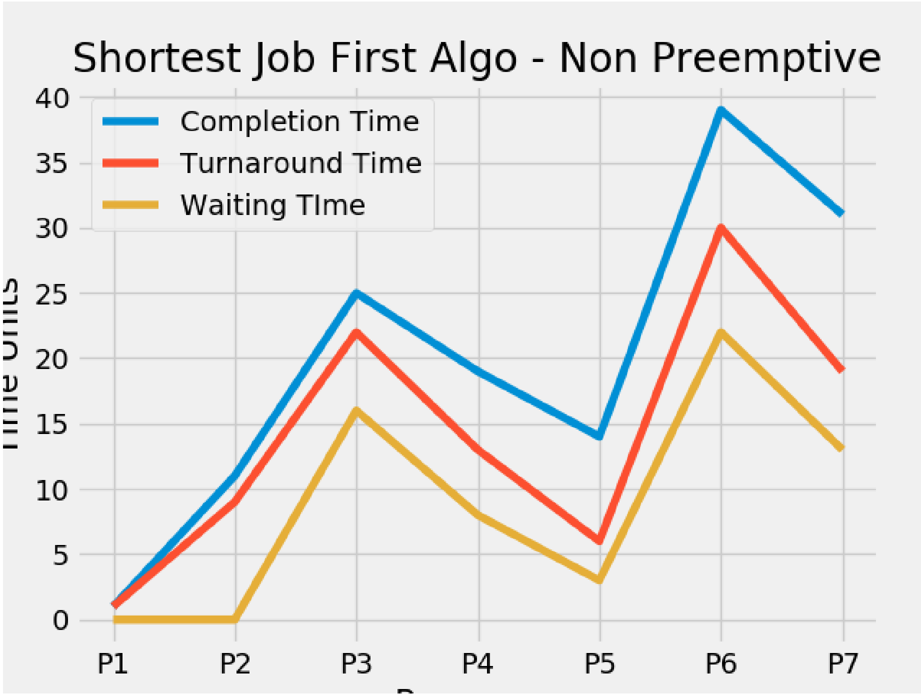


Figure 5.3: SJF(Preemptive) output values.

Process_ID	Arrival_Time	Burst_Time	Completed	Completion_Time	Turnaround_Time	Waiting_Time
P1	0	1	1	1	1	0
P2	2	9	1	11	9	0
P3	3	6	1	25	22	16
P4	6	5	1	19	13	8
P5	8	3	1	14	6	3
P6	9	8	1	39	30	22
P7	12	6	1	31	19	13

```
Average Turnaround Time: 14.285714285714286
Average Waiting Time: 8.857142857142858
Throughput  =   0.1794871794871795
press any button to continue.....
```

Figure 5.4: SJF(Preemptive) output values.

Priorty Scheduling

6.1 Priorty(Preemptive)

Listing 6.1: SJF Preemptive Source code

```
import matplotlib.pyplot as plt

plt.style.use('fivethirtyeight')


def schedulingProcess( process_data):
        start_time = []
        exit_time = []
        s_time = 0
        sequence_of_process = []
        process_data.sort(key=lambda x: x[1])
        '''
        Sort processes according to the Arrival Time
        '''
        while 1:
                ready_queue = []
                normal_queue = []
                temp = []
                for i in range(len(process_data)):
                        if process_data[i][1] <= s_time and
                           ↪ process_data[i][4] == 0:
                                temp.extend([process_data[i][0],
                                   ↪ process_data[i][1],
                                   ↪ process_data[i][2],
                                   ↪ process_data[i][3],
                                                                process_data
                                                                   ↪ [
                                                                   ↪ i
                                                                   ↪ ][5]])
                                                                   ↪
                                ready_queue.append(temp)
                                temp = []
                        elif process_data[i][4] == 0:
                                temp.extend([process_data[i][0],
                                   ↪ process_data[i][1],
                                   ↪ process_data[i][2],
                                   ↪ process_data[i][4],
                                                                process_data
```

```
                                                  ↪ [
                                                  ↪ i
                                                  ↪ ][5]])
                                                  ↪
                    normal_queue.append(temp)
                    temp = []
    if len(ready_queue) == 0 and len(normal_queue) ==
        ↪ 0:
            break
    if len(ready_queue) != 0:
            ready_queue.sort(key=lambda x: x[3],
                ↪ reverse=True)
            start_time.append(s_time)
            s_time = s_time + 1
            e_time = s_time
            exit_time.append(e_time)
            sequence_of_process.append(ready_queue
                ↪ [0][0])
            for k in range(len(process_data)):
                    if process_data[k][0] ==
                        ↪ ready_queue[0][0]:
                            break
            process_data[k][2] = process_data[k][2] -
                ↪ 1
            if process_data[k][2] == 0:       #if
                ↪ burst time is zero, it means
                ↪ process is completed
                    process_data[k][4] = 1
                    process_data[k].append(e_time)
    if len(ready_queue) == 0:
            normal_queue.sort(key=lambda x: x[1])
            if s_time < normal_queue[0][1]:
                    s_time = normal_queue[0][1]
            start_time.append(s_time)
            s_time = s_time + 1
            e_time = s_time
            exit_time.append(e_time)
            sequence_of_process.append(normal_queue
                ↪ [0][0])
            for k in range(len(process_data)):
                    if process_data[k][0] ==
                        ↪ normal_queue[0][0]:
                            break
```

```python
                    process_data[k][2] = process_data[k][2] -
                      ↪  1
                    if process_data[k][2] == 0:        #if
                      ↪ burst time is zero, it means
                      ↪ process is completed
                        process_data[k][4] = 1
                        process_data[k].append(e_time)
        calculateTurnaroundTime( process_data)
        calculateWaitingTime( process_data)
        twt = [p[8] for p in process_data]
        tat = [p[7] for p in process_data]
        ctime = [p[6] for p in process_data]
        return twt,tat,ctime,sequence_of_process

def calculateTurnaroundTime( process_data):
        total_turnaround_time = 0
        for i in range(len(process_data)):
                turnaround_time = process_data[i][6] -
                  ↪ process_data[i][5]

                total_turnaround_time = total_turnaround_time +
                  ↪ turnaround_time
                process_data[i].append(turnaround_time)



def calculateWaitingTime( process_data):
        total_waiting_time = 0
        for i in range(len(process_data)):
                waiting_time = process_data[i][6] - process_data[
                  ↪ i][1]
                '''
                waiting_time = turnaround_time - burst_time
                '''
                total_waiting_time = total_waiting_time +
                  ↪ waiting_time
                process_data[i].append(waiting_time)


def plot_graph(process_data):
        processes = [p[0] for p in process_data]
        twt = [p[8] for p in process_data]
        tat = [p[7] for p in process_data]
```

```python
        ctime = [p[6] for p in process_data]

        plt.plot(processes,twt,label='Waiting Time')
        plt.plot(processes, tat, label = 'TurnAround Time')
        plt.plot(processes, ctime, label = 'Completion Time')

        plt.legend(loc='best')
        plt.savefig('./output/PRIORITY_P_output.png')
        plt.show()
        plt.close(fig='all')

def printData( process_data,sequence_of_process):
        process_data.sort(key=lambda x: x[0])
        '''
        Sort processes according to the Process ID
        '''
        print("Process_ID  Arrival_Time  Rem_Burst_Time   
            ↪ Priority        Completed  Orig_Burst_Time 
            ↪ Completion_Time  Turnaround_Time  Waiting_Time")
        for i in range(len(process_data)):
                for j in range(len(process_data[i])):
                        print(process_data[i][j], end='\t\t')
                print()
        print('\nAverage Turnaround Time: ',sum(p[7] for p in
            ↪ process_data)/len(process_data))
        print('Average Waiting Time: ',sum(p[8] for p in
            ↪ process_data)/len(process_data))
        print("Throughput: ",len(process_data)/max([p[6] for p in
            ↪  process_data]))
        print(f'Sequence of Process: {sequence_of_process}')



def priority_p():
        process_data = []
        with open('./inputs/PRIORITY_P.txt', 'r') as f:
                f.readline()
                for line in f.readlines():
                        temporary = []
                        process , burst , arrival,priority = (
                            ↪ line.split(" "))
                        temporary.extend([process, int(arrival),
                            ↪ int(burst),int(priority), 0,int(
```

```
                    ↪ burst)])
                process_data.append(temporary)

        sequence_of_process = schedulingProcess( process_data)
        printData(process_data,sequence_of_process)
        plot_graph(process_data)

if __name__ == "__main__":
        priority_p()
```

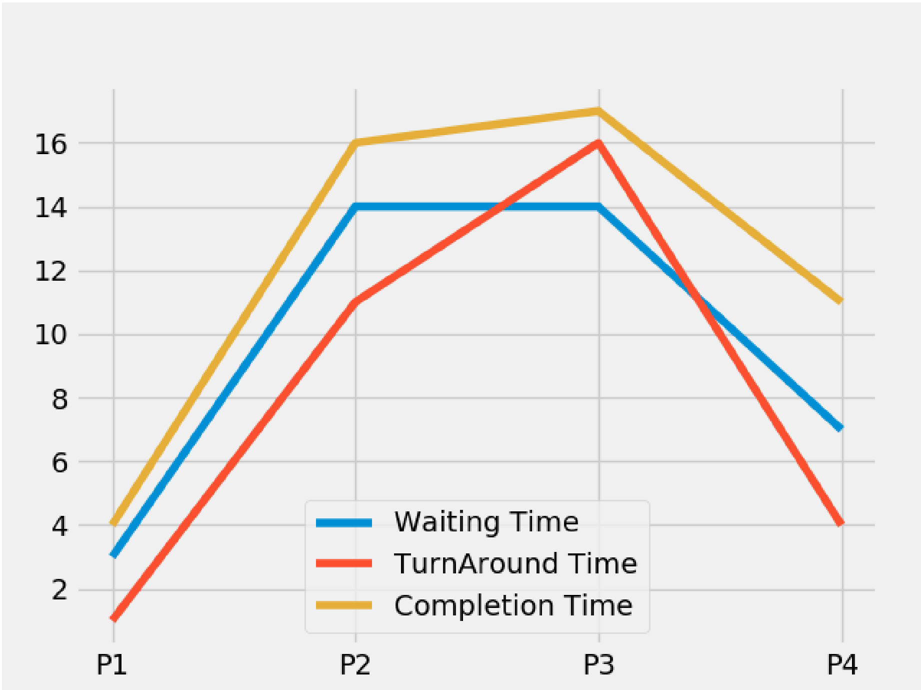
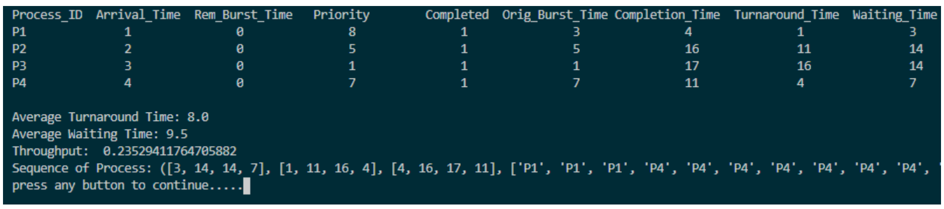


Figure 6.1: SJF(Preemptive) output values.



Process_ID	Arrival_Time	Rem_Burst_Time	Priority	Completed	Orig_Burst_Time	Completion_Time	Turnaround_Time	Waiting_Time
P1	1	0	8	1	3	4	1	3
P2	2	0	5	1	5	16	11	14
P3	3	0	1	1	1	17	16	14
P4	4	0	7	1	7	11	4	7

```
Average Turnaround Time: 8.0
Average Waiting Time: 9.5
Throughput:  0.23529411764705882
Sequence of Process: ([3, 14, 14, 7], [1, 11, 16, 4], [4, 16, 17, 11], ['P1', 'P1', 'P1', 'P4', 'P4', 'P4', 'P4', 'P4', 'P4', 'P4',
press any button to continue.....
```

Figure 6.2: SJF(Preemptive) output values.

6.2 Priorty(Non-Preemptive)

Listing 6.2: SJF Preemptive Source code

```
import matplotlib.pyplot as plt;

plt.style.use('fivethirtyeight')


def get_wt_time( wt, proc, totalprocess):

        service = [0] * totalprocess

        service[0] = 0
        wt[0] = 0

        for i in range(1, totalprocess):
                service[i] = proc[i - 1][1] + service[i - 1]
                wt[i] = service[i] - proc[i][0] + 1

                if(wt[i] < 0) :
                        wt[i] = 0

def get_tat_time(tat, wt, proc, totalprocess):

        for i in range(totalprocess):
                tat[i] = proc[i][1] + wt[i]

def findgc(proc, totalprocess):

        wt = [0] * totalprocess
        tat = [0] * totalprocess
        wavg = 0
        tavg = 0
        get_wt_time(wt,proc, totalprocess)
        get_tat_time(tat, wt, proc, totalprocess)
        stime = [0] * totalprocess
        ctime = [0] * totalprocess
        stime[0] = 1
        ctime[0] = stime[0] + tat[0]
        for i in range(1, totalprocess):
                stime[i] = ctime[i - 1]
                ctime[i] = stime[i] + tat[i] - wt[i]
```

```python
    for i in range(totalprocess):
        wavg += wt[i]
        tavg += tat[i]

    return wt, tat,ctime


def print_details(processes,proc,arrival_time,ctime,tat,wt):

    print("Process_no\tStart_time\tComplete_time",
                              "\tTurn_Around_Time\tWaiting_Time\t\tPriority")

    for i in range(len(processes)):
        print(proc[i][3], "\t\t", arrival_time[i],
                                              "\t\t", end = " ")
        print(ctime[i], "\t\t", tat[i], "\t\t\t", wt[i], '\t\t\t',proc[i][2])

    print("Average waiting time is : ", end = " ")
    print(sum(wt) / len(processes))
    print("average turnaround time : " , end = " ")
    print(sum(tat) / len(processes))


def plot_graph(processes,wt,tat,ctime):

    plt.plot(processes, wt,label='Waiting Time')
    plt.plot(processes, tat, label = 'TurnAround Time')
    plt.plot(processes, ctime, label = 'Completion Time')

    plt.legend(loc='best')
    plt.savefig('./output/PRIORITY_NP_output.png')
    plt.show()
    plt.close(fig='all')


# Driver code
def priority_np():
```

```
    processes = []
    burst_time = []
    arrival_time = []
    priority = []
    with open('./inputs/PRIORITY_NP.txt', 'r') as f:
        f.readline()
        for line in f.readlines():
            process, burst, arrival, prior = (line.
               ↪ split())
            processes.append(process)
            burst_time.append(int(burst))
            arrival_time.append(int(arrival))
            priority.append(int(prior))


    totalprocess = len(processes)
    proc = []
    for i in range(totalprocess):
        l = []
        for j in range(4):
            l.append(0)
        proc.append(l)


    for i in range(totalprocess):
        proc[i][0] = arrival_time[i]
        proc[i][1] = burst_time[i]
        proc[i][2] = priority[i]
        proc[i][3] = processes[i]

    proc = sorted (proc, key = lambda x:x[2])
    proc = sorted (proc)
    wt, tat,ctime = findgc(proc,totalprocess)
    print_details(processes,proc,arrival_time,ctime,tat,wt)
    plot_graph(processes,wt,tat,ctime)
    plt.close(fig='all')



if __name__ =="__main__":
    priority_np()
```

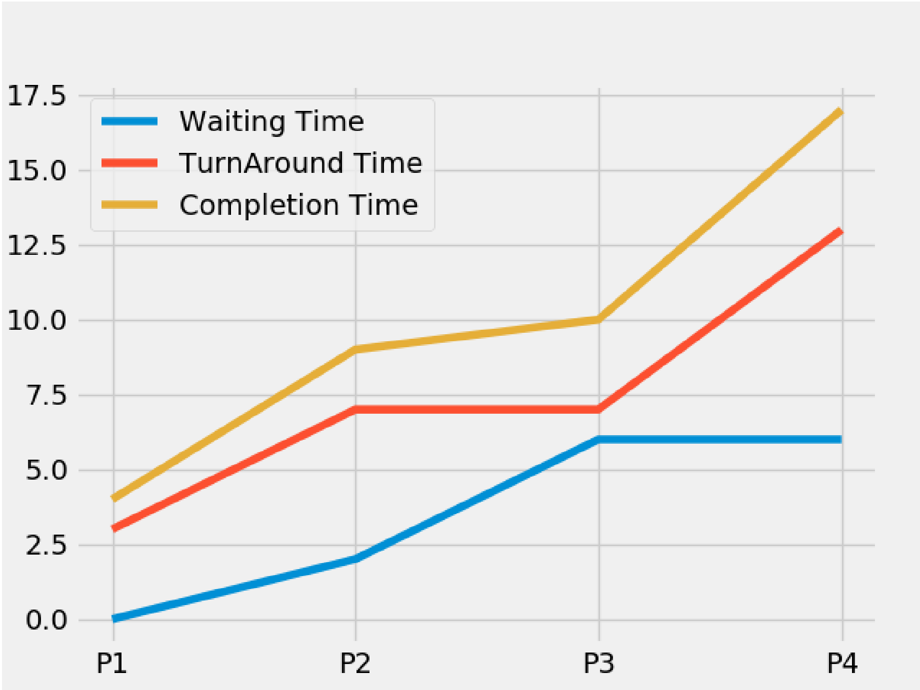


Figure 6.3: SJF(Preemptive) output values.

```
Process_no      Start_time      Complete_time     Turn_Around_Time        Waiting_Time            Priority
P1               1               4                3                        0                       2
P2               2               9                7                        2                       5
P3               3               10               7                        6                       1
P4               4               17               13                       6                       7
Average waiting time is :  3.5
average turnaround time :  7.5
press any button to continue.....
```

Figure 6.4: SJF(Preemptive) output values.

Round Robin

Listing 7.1: Round Robin Source Code

```
import matplotlib.pyplot as plt
from statistics import mean

plt.style.use('fivethirtyeight')



def findWaitingTime(processes, n, burst_time, waiting_time,
    ↪ quantum):
    rem_burst_time = [0] * n

    for i in range(n):
        rem_burst_time[i] = burst_time[i]
    t = 0
    while(1):
        done = True
        for i in range(n):
            if (rem_burst_time[i] > 0) :
                done = False

                if (rem_burst_time[i] > quantum) :
                    t += quantum
                    rem_burst_time[i] -= quantum
                else:
                    t = t + rem_burst_time[i]
                    waiting_time[i] = t - burst_time[i]
                    rem_burst_time[i] = 0
        if (done == True):
            break


def findTurnAroundTime(processes, n, burst_time, waiting_time,
    ↪ tat):
    for i in range(n):
        tat[i] = burst_time[i] + waiting_time[i]



def findavgTime(processes, n, burst_time,arrival_time, quantum):
    waiting_time = [0] * n
    tat = [0] * n
```

```
    compl_time = [0]*len(processes)

    findWaitingTime(processes, n, burst_time,  waiting_time,
        ↪ quantum)

    findTurnAroundTime(processes, n, burst_time, waiting_time,
        ↪ tat)
    total_waiting_time = 0
    total_tat = 0
    for i in range(n):
        total_waiting_time = total_waiting_time + waiting_time[i]
        total_tat = total_tat + tat[i]
        compl_time[i] = arrival_time[i] + tat[i]
    return waiting_time, tat ,compl_time



def plot_graph_normal(processes,waiting_time,compl_time,
    ↪ turn_around_time,ax1):

    ax1.plot(processes,waiting_time,label = "waiting_time")
    ax1.plot(processes,compl_time,label = "Completion_time")
    ax1.plot(processes,turn_around_time,label = "Turnaround_Time"
        ↪ )

    ax1.legend()
   # plt.savefig('../output/ROUND_ROBIN_output.png')


def plot_graph_quantum(processes, burst_time, arrival_time,ax2):
    throughput_quantum = []
    avg_waiting_quantum = []
    avg_turnaround_quantum = []
    avg_completion_quantum =[]
    for n in range(1,10):
        waiting_time,turn_around_time,compl_time =  findavgTime(
            ↪ processes, len(processes), burst_time, arrival_time
            ↪ , n)
        throughput_quantum.append(len(processes)/ compl_time[len(
            ↪ processes)-1])
        avg_turnaround_quantum.append(mean(turn_around_time))
        avg_completion_quantum.append(mean(compl_time))
        avg_waiting_quantum.append(mean(waiting_time))
```

```
    rang = list(range(1,10))
    ax2.plot(rang,throughput_quantum,label="Throughput")
    ax2.plot(rang,avg_waiting_quantum,label="Average waiting_time
        ")
    ax2.plot(rang,avg_completion_quantum,label="Average 
        Completion Time")
    ax2.plot(rang,avg_turnaround_quantum,label="Average Turn 
        Around Time")

    ax2.legend()



def print_details(processes,burst_time,waiting_time,compl_time,
    tat):
    print("Processes    Burst Time     Waiting  Time    Turn-
        Around Time    Completion Time")
    for i in range(len(processes)):
            print(" ", processes[i]  , "\t\t", burst_time[i], "\t\t
                ", waiting_time[i], "\t\t", tat[i],"\t\t",
                compl_time[i])
    print("\nAverage waiting_time = %.5f "%(sum(waiting_time) /
        len(processes)) )
    print("Average turn around time = %.5f "% (sum(tat) / len(
        processes)))
    print('Throughput = ', len(processes)/ max(compl_time))
    print('Average Job elapsed time = ',sum(tat)/len(processes))



def round_robin():
    f, (ax1, ax2) = plt.subplots(1, 2, sharey=True)
    processes = []
    burst_time = []
    arrival_time = []
    #breakpoint
    with open('./inputs/ROUND_ROBIN.txt','r') as  f:
        f.readline()
        for line in f.readlines():
            process , burst , arrival = (line.split(" "))
            processes.append(process)
            burst_time.append(int(burst))
```

```
            arrival_time.append(int(arrival))

    # Time quantum
    quantum = 2;
    waiting_time,turn_around_time,compl_time =  findavgTime(
        ↪ processes, len(processes), burst_time, arrival_time,
        ↪ quantum)
    print_details(processes,burst_time,waiting_time,compl_time,
        ↪ turn_around_time)
    plot_graph_normal(processes,waiting_time,compl_time,
        ↪ turn_around_time,ax1)
    plot_graph_quantum(processes, burst_time, arrival_time,ax2)
    plt.savefig("./output/ROUND_ROBIN.png")
    plt.show()
    plt.close(fig='all')

# Driver code
if __name__ =="__main__":
    round_robin()
```

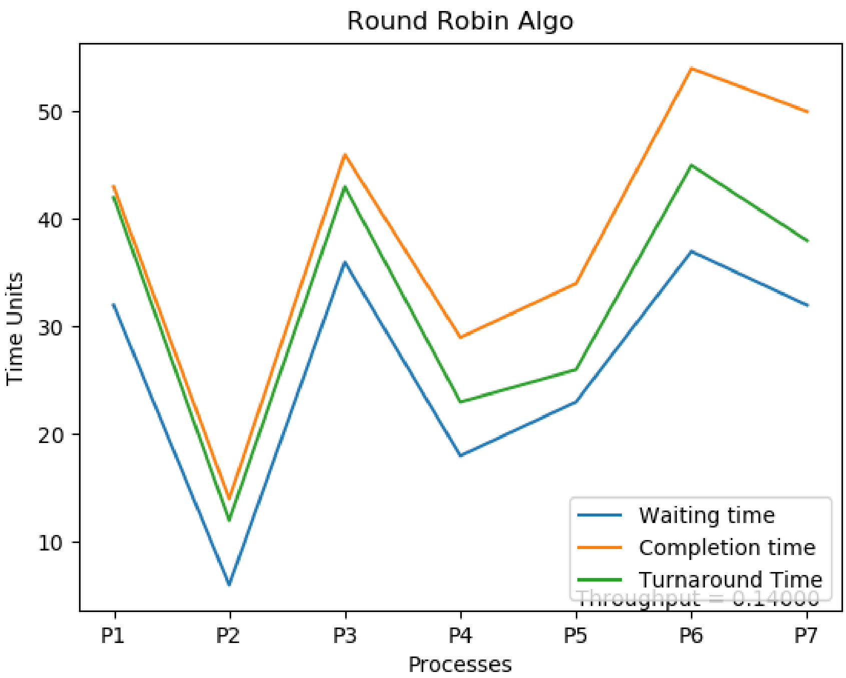


Figure 7.1: FCFS output values.

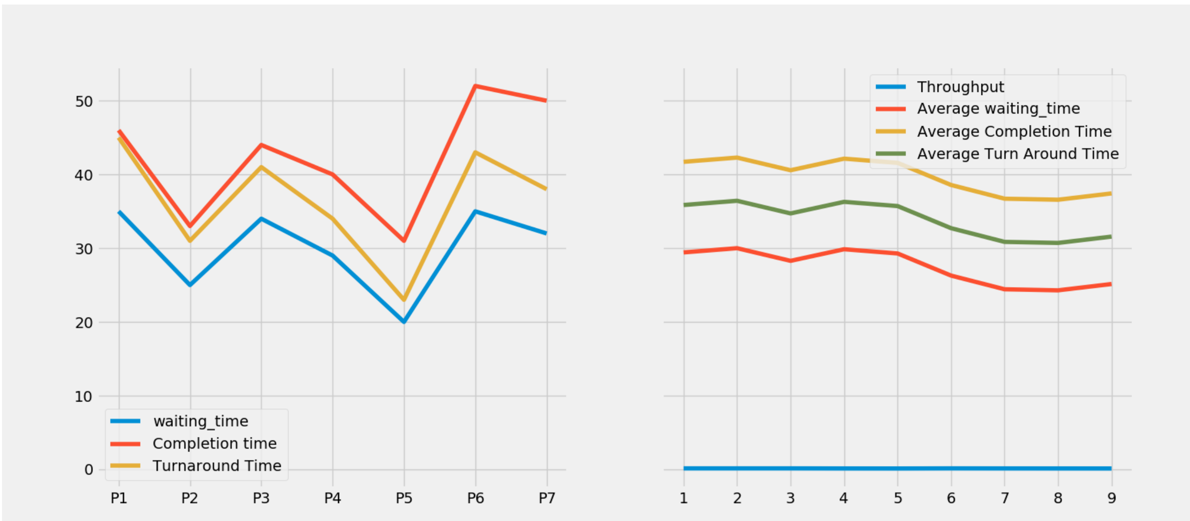


Figure 7.2: FCFS output values.

```
Processes    Burst Time    Waiting  Time    Turn-Around Time    Completion Time
  P1           10            35               45                  46
  P2           6             25               31                  33
  P3           7             34               41                  44
  P4           5             29               34                  40
  P5           3             20               23                  31
  P6           8             35               43                  52
  P7           6             32               38                  50

Average waiting_time = 30.00000
Average turn around time = 36.42857
Throughput =  0.1346153846153846
Average Job elapsed time =  36.42857142857143
press any button to continue.....
```

Figure 7.3: FCFS output values.

Conclusion

From the given project work we have concluded that the difference between the turn around time,average waiting time,average elapsed time and completion time for same input of different cpu scheduling is as follows:-

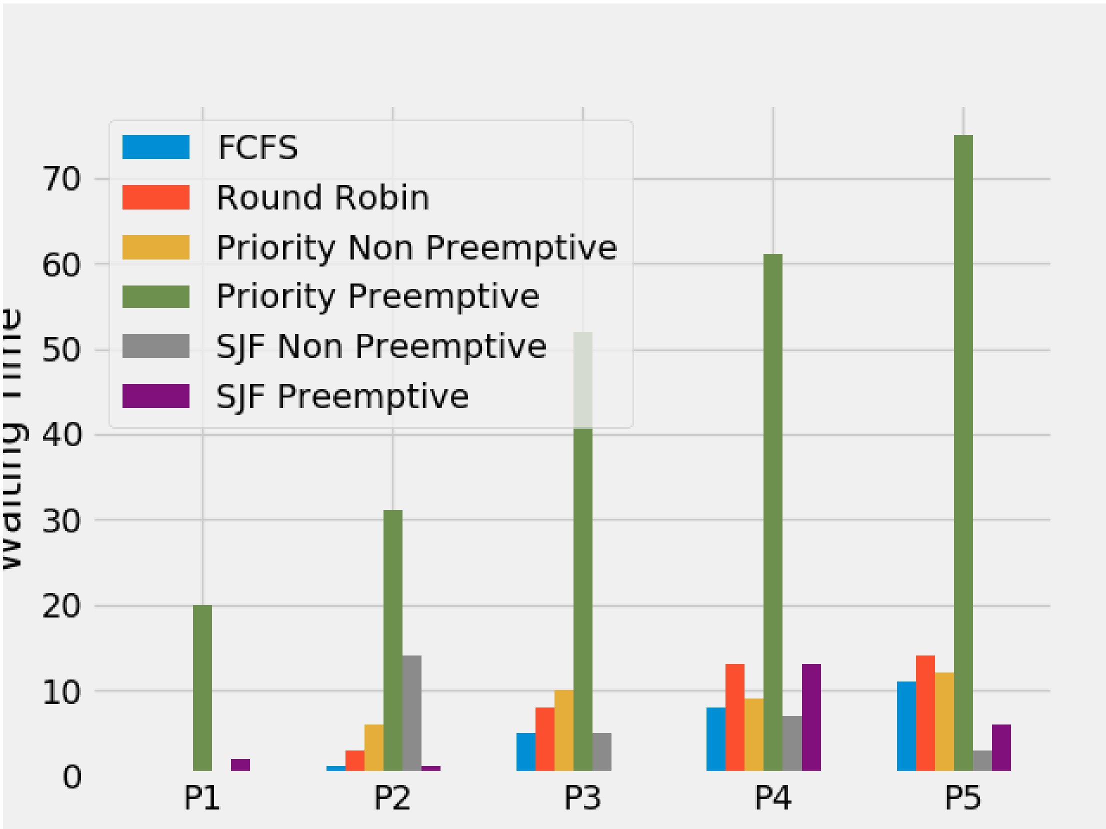


Figure 8.1: comparison between CPU scheduling.

from the above graph we came to know that every algorithm works better on the significant problem as the fcfs is better for a small burst time.The sjf is better if the process comes to processor simultaneously and round robin, is better to adjust the average waiting time desired and the priorty works better where the relative important of each process may be precisely defined.

References

The source code of the project can be found at:-
https://github.com/cannibalcheeseburger/cpu-scheduling-simluation.git
And the other references we used for this project are given:-

- A. Dusseau, R. H. dan A. C., Operating Systems: Three Easy Pieces, Arpaci-Dusseau Books, 2014.
- Operating System Principles – Galvin
- Tanenbaum, Modern Operating Systems, Pearson Education, Inc., 2008.
- http://www.cs.uic.edu/~jbell/CourseNotes/OperatingSystems/5_CPU_Scheduling.html
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