Airport Project Report

Implementation by Circular Queue

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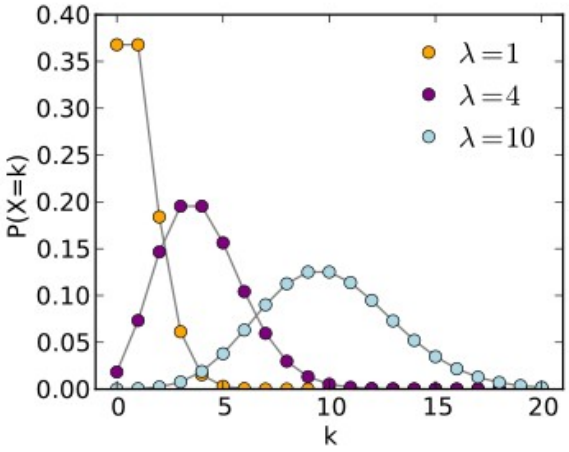
Introduction

The project was to simulate an airport with 5 runways, a queue of planes awaiting takeoff and a queue of planes awaiting landing. For each time sequence planes would arrive at the airport and add their ID to the landing queue. As each time sequence passes the planes waiting in the landing queue lose fuel by 1. In the process if a plane's fuel becomes 0 it is classified as an emergency and is given priority to land as quickly as possible. Also for each time sequence planes get ready for takeoff and add their ID to the takeoff queue. Both landing queues and takeoff queues can access the runway in similar manner except for the 5th runway. The 5th runway is given priority to takeoff except for an emergency landing. Each runway can be loaded 1 plane at a time. The loaded planes then exit the runway also one at a time. Therefore the runways rarely exceed their capacity. On the other hand, for the landing and takeoff queues, planes are added with probabilities following the Poisson and uniform distribution respectively. The Poisson distribution is as follows:



Probability mass function of the Poisson distribution

$$f(k;\lambda) = \Pr(X = k) = \frac{\lambda^k e^{-\lambda}}{k!},$$

When the Poisson distribution parameter lambda increases, so does the probability of many planes arriving at the landing queue. This results in catastrophic failure as emergencies increase. More on this issue is covered in the discussion section.

Implementation

The simulation consists of a group of circular queues: a landing queue, a takeoff queue, an emergency queue and 5 runway queues.

```
CircularQueue landing = Initialize(1000);
CircularQueue takeoff = Initialize(10);
CircularQueue emergency = Initialize(6);
CircularQueue runway[5];
runway[0] = Initialize(5);
runway[1] = Initialize(5);
runway[2] = Initialize(5);
runway[3] = Initialize(5);
runway[4] = Initialize(5);
```

In order to keep the takeoff queue at a reasonable size I initialized the queue at a size 10. The landing queue is given a large enough size since we are not in control of arriving planes. Also I wanted to simulate a catastrophic failure where planes arrive at a very high rate. Emergencies can only be taken care of 5 at a time due to the number of

runways. The reason for size 6 is to catch failures. This will be explained in detail later.

```
addLanding(landing);
PrintQueue(landing);
addTakeoff(takeoff);
PrintQueue(takeoff);

printf("average takeoff waiting time: ");
printWait(takeoff);
printf("average landing waiting time: ");
printWait(landing);
error = useFuel(landing, emergency);
printf("emergency: ");
PrintQueue(emergency);
error += landPlanes(runway, landing, emergency, takeoff);
if(error) {
    printf("\nToo many emergencies!\n");
    return 1;
}
for(int j=0;j<5;j++) {
    printf("runway%d: ", j);
    PrintQueue(runway[j]);
}
updateRunway(runway);
updateTime(landing, takeoff, runway);
```

The full implementation in the main function is shown above. First we add arriving planes to the landing queue and ready planes to the takeoff queue. Next fuel of waiting planes is decreased by 1. Here if a plane's fuel reaches zero it is transferred to the emergency queue. Finally, we move planes around in the landPlanes() function giving priority to the emergency planes. If however we fail to process all of the emergencies we exit the simulation with an error.

```
int landPlanes(CircularQueue runway[5], CircularQueue landing,
    for(int i=4; i>=0; i--) {
        if(!IsFull(runway[i])) {
            if(i==4) {
                if(!IsEmpty(E))
                    Insert(GetMin(E), runway[i]);
                else if(!IsEmpty(takeoff))
                    Insert(GetMin(takeoff), runway[i]);
                else if(IsEmpty(runway[i])&&!IsEmpty(landing))
                    Insert(GetMin(landing), runway[i]);
            }
            else if(!IsEmpty(E))
                Insert(GetMin(E), runway[i]);
            else if(!IsEmpty(takeoff))
                Insert(GetMin(takeoff), runway[i]);
            else if(!IsEmpty(landing))
                Insert(GetMin(landing), runway[i]);
        }
    }
    if(!IsEmpty(E))
        return 1;
    return 0;
}
```

Result

This is the output of the first 5 time sequences when lambda is set to 2. There is at most 4 planes added to the landing queue each time sequence which is smaller than the number of runways. Therefore we do not run into any problems in this setting. When emergencies emerge we process them into the 5th runway. When there are multiple emergencies other runways are used also used. The average landing waiting time is 0 which means that planes are immediately able to land.

```
pineapple@pineapple-desktop:~/Git/Data-Structures/AirPort$ ./airport
-----------------------------------------------------
3 more planes await landing! : ID:2 Fuel:2,     ID:4 Fuel:3,    ID:6 Fuel:1
3 more planes await takeoff! : ID:1 Fuel:50,    ID:3 Fuel:50,   ID:5 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 0
emergency: ID:6 Fuel:0
runway0: ID:2 Fuel:1
runway1: ID:3 Fuel:50
runway2: ID:5 Fuel:50
runway3: ID:1 Fuel:50
runway4: ID:6 Fuel:0

-----------------------------------------------------
1 more planes await landing! : ID:4 Fuel:2,     ID:8 Fuel:2
3 more planes await takeoff! : ID:7 Fuel:50,    ID:9 Fuel:50,   ID:11 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 0
emergency:
runway0: ID:8 Fuel:1
runway1: ID:4 Fuel:1
runway2: ID:9 Fuel:50
runway3: ID:11 Fuel:50
runway4: ID:7 Fuel:50

-----------------------------------------------------
2 more planes await landing! : ID:10 Fuel:2,    ID:12 Fuel:3
1 more planes await takeoff! : ID:13 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 0
emergency:
runway0:
runway1:
runway2: ID:12 Fuel:2
runway3: ID:10 Fuel:1
runway4: ID:13 Fuel:50

-----------------------------------------------------
4 more planes await landing! : ID:14 Fuel:5,    ID:16 Fuel:4,   ID:18 Fuel:2,   ID:20 Fuel:1
1 more planes await takeoff! : ID:15 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 0
emergency: ID:20 Fuel:0
runway0: ID:16 Fuel:3
runway1: ID:18 Fuel:1
runway2: ID:14 Fuel:4
runway3: ID:15 Fuel:50
runway4: ID:20 Fuel:0

-----------------------------------------------------
3 more planes await landing! : ID:22 Fuel:2,    ID:24 Fuel:2,   ID:26 Fuel:4
2 more planes await takeoff! : ID:17 Fuel:50,   ID:19 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 0
emergency:
runway0: ID:24 Fuel:1
runway1: ID:26 Fuel:3
runway2: ID:22 Fuel:1
runway3: ID:19 Fuel:50
runway4: ID:17 Fuel:50

-----------------------------------------------------
```

This is not the case however when lambda is set to 4(next page). Now up to 9 planes are added at each time sequence. This results in the landing queue to increase substantially. As you can see the average landing waiting time is increased to around 5 time sequences before too many emergencies emerge and the system terminates.

```
-------------------------------------------------------
7 more planes await landing! : ID:512 Fuel:1,   ID:520 Fuel:2,  ID:522 Fuel:1,  ID:528 Fuel:3,  ID:526 Fuel:2,
3,      ID:548 Fuel:2,  ID:544 Fuel:4,  ID:554 Fuel:5,  ID:568 Fuel:7,  ID:584 Fuel:8,  ID:540 Fuel:3,  ID:580
70 Fuel:5,      ID:600 Fuel:9,  ID:550 Fuel:4,  ID:552 Fuel:4,  ID:598 Fuel:12, ID:594 Fuel:7,  ID:574 Fuel:8,
10,     ID:582 Fuel:6,  ID:588 Fuel:9,  ID:590 Fuel:11, ID:566 Fuel:5,  ID:572 Fuel:8,  ID:604 Fuel:10, ID:606
18 Fuel:13
0 more planes await takeoff! :
average takeoff waiting time: 0
average landing waiting time: 5
emergency: ID:512 Fuel:0,       ID:522 Fuel:0,  ID:532 Fuel:0,  ID:530 Fuel:0
runway0: ID:520 Fuel:1
runway1: ID:530 Fuel:0
runway2: ID:532 Fuel:0
runway3: ID:522 Fuel:0
runway4: ID:512 Fuel:0

-------------------------------------------------------
6 more planes await landing! : ID:526 Fuel:1,   ID:528 Fuel:2,  ID:548 Fuel:1,  ID:536 Fuel:1,  ID:538 Fuel:2,
3,      ID:570 Fuel:4,  ID:550 Fuel:3,  ID:554 Fuel:4,  ID:568 Fuel:6,  ID:584 Fuel:7,  ID:560 Fuel:4,  ID:580
16 Fuel:12,     ID:600 Fuel:8,  ID:614 Fuel:11, ID:552 Fuel:3,  ID:598 Fuel:11, ID:594 Fuel:6,  ID:574 Fuel:7,
9,      ID:582 Fuel:5,  ID:588 Fuel:8,  ID:590 Fuel:10, ID:618 Fuel:12, ID:572 Fuel:7,  ID:604 Fuel:9,  ID:606
28 Fuel:10,     ID:630 Fuel:14
1 more planes await takeoff! : ID:231 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 5
emergency: ID:526 Fuel:0,       ID:548 Fuel:0,  ID:536 Fuel:0
runway0: ID:528 Fuel:1
runway1: ID:231 Fuel:50
runway2: ID:548 Fuel:0
runway3: ID:536 Fuel:0
runway4: ID:526 Fuel:0

-------------------------------------------------------
7 more planes await landing! : ID:538 Fuel:1,   ID:540 Fuel:1,  ID:544 Fuel:2,  ID:560 Fuel:3,  ID:542 Fuel:2,
5,      ID:570 Fuel:3,  ID:552 Fuel:2,  ID:554 Fuel:3,  ID:568 Fuel:5,  ID:578 Fuel:6,  ID:596 Fuel:6,  ID:580
16 Fuel:11,     ID:600 Fuel:7,  ID:614 Fuel:10, ID:628 Fuel:9,  ID:598 Fuel:10, ID:594 Fuel:5,  ID:574 Fuel:6,
8,      ID:582 Fuel:4,  ID:588 Fuel:7,  ID:590 Fuel:9,  ID:618 Fuel:11, ID:572 Fuel:6,  ID:604 Fuel:8,  ID:606
36 Fuel:14,     ID:638 Fuel:14, ID:640 Fuel:14, ID:642 Fuel:14, ID:644 Fuel:10
1 more planes await takeoff! : ID:233 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 4
emergency: ID:538 Fuel:0,       ID:540 Fuel:0,  ID:556 Fuel:0
runway0: ID:542 Fuel:1
runway1: ID:233 Fuel:50
runway2: ID:556 Fuel:0
runway3: ID:540 Fuel:0
runway4: ID:538 Fuel:0

-------------------------------------------------------
3 more planes await landing! : ID:544 Fuel:1,   ID:560 Fuel:2,  ID:550 Fuel:1,  ID:562 Fuel:1,  ID:558 Fuel:4,
11,     ID:570 Fuel:2,  ID:614 Fuel:9,  ID:554 Fuel:2,  ID:568 Fuel:4,  ID:578 Fuel:5,  ID:596 Fuel:5,  ID:580
16 Fuel:10,     ID:600 Fuel:6,  ID:638 Fuel:13, ID:628 Fuel:8,  ID:598 Fuel:9,  ID:594 Fuel:4,  ID:574 Fuel:5,
7,      ID:582 Fuel:3,  ID:642 Fuel:13, ID:590 Fuel:8,  ID:618 Fuel:10, ID:644 Fuel:9,  ID:604 Fuel:7,  ID:606
36 Fuel:13,     ID:646 Fuel:10, ID:648 Fuel:12, ID:650 Fuel:10
1 more planes await takeoff! : ID:235 Fuel:50
average takeoff waiting time: 0
average landing waiting time: 5
emergency: ID:544 Fuel:0,       ID:550 Fuel:0,  ID:562 Fuel:0,  ID:552 Fuel:0,  ID:546 Fuel:0,  ID:564 Fuel:0

Too many emergencies!
pineapple@pineapple-desktop:~/Git/Data-Structures/AirPort$
```

Discussion

My simulation works fine when lambda is set to a small number and the frequency of arriving planes is low. However a catastrophic failure occurs when lambda is increased. The landing queue grows substantially overtime and the waiting planes exhaust fuel causing many emergencies. Since the runways can only process 5 planes at a time more than 6 emergencies results in a plane crash. This is why the emergency queue size is set to 6. When the queue is full then we know that we have failed and the system is terminated.

A better implementation would be to have more planes land in one time sequence. Currently the runways are not well utilized. Although the size of a runway is 5 since only 1 plane can enter a runway at each time sequence the plane immediately exits the queue after that sequence is over. In reality planes are landed much faster than takeoffs especially for a busy airport. If more planes were to land in one time sequence then more planes would be on the runway and less planes would be in the landing queue.