Airport Simulation Design

CSE 6730 Project 2

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***Abstract*—This report describes the airport simulator design. The model is implemented by a queue system and simulates 100 airports and up to 160000 airplanes. Besides, the model includes 3 features as gas condition, weather condition and multiple runways. Testing result and analysis are mentioned as well.**

Keywords—simulation, airport, queue system, M/M/C queue

I. INTRODUCTION

This project simulates air traffic at 100 airports and models airplanes' arrival and departure. The simulator is implemented with a queue system using concept of M/M/C queue [1] to ensure planes are not arriving and taking off at the same time on a same runway. Each airport has 3 runways and plane's event will be affected by weather condition and gas condition.

During the simulation, our model would monitor the passengers delivered number for every flight by printing them. And at the end of simulation, the system will output the total number of arriving and departing passengers for each airport. Besides, the total amount circling time for each airport will be calculated as well.

II. SIMULATION MODEL

The airport simulation model is implemented with the model of airport, airplane, airport event and airport simulator. Classes of event and event handler is provided for basic operation.

A. Event Class and Event handler Interface

Event class is the most basic event model. It has attributes of event type, event ID and event time. Also, it can call event handler interface to handle event. To ensure the simulator time is constituent with system time, the event class has a function to check event time.

B. Airplane Class

Airplane class is designed for airplane model. It has attributes of airplane name, minimum properties of speed, maximum passengers capacity and current passengers. Current passengers is a random number between 1 and maximum passenger capacity. SetNumPassengers function is used for set random passengers to airplane every time it departs. Several get and set functions are implemented to get access to these attributes.

C. AirportEvent Class

AirportEvent class is implemented for airport event model. It is inherited from event class.

D. Airport Class

Airport class is developed for airport model, which simulates traffic in each airport. It is inherited from event handler interface.

The airport needs to handle four types of AirportEvents: plane_arrivals, plane_landed, plane_takeoff and plane_departs.

1) Plane Arrival

When a plane arrives, the number of planes in the air increases by one. Then I add the plane into arrivingQueue. ArrivingQueue ensures the first arrived plane landed first. If one of the two arriving runway is free, we release one plane from arrivingQueue and schedule landed event for this plane after m_runwayTimeToLand. Besides, I record the time when plane arrives the airspace of airport and the time when plane is ready to land for circling time calculation. The number of arriving Passengers is recorded as well.

2) Plane Landed

When a plane landed, the number of planes in the air decreases by one. Then I schedule takeoff event for current plane after m_requiredTimeOnGround. If one of the arriving runway is free and there are more planes waiting in the arrivingQueue, I release airplane from queue and schedule landed event.

3) Plane Takeoff

When a plane takeoff, I add the plane to departureQueue. Then I check if take off runway is free. If the takeoff runway is free, I release plane from departureQueue and schedule departs event after m_runwayTimeToTakeoff.

4) Plane Departs

When a plane departs, I schedule arriving event for it after flight time. The flight time is calculated by distance between two airports/flight speed. Thus I create a matrix to record the actual distance between five airports. Then I check if there are more planes waiting in departureQueue and schedule departs events.

III. FEATURES

There are 3 additional features of this airport simulation model, which simulate more possible situations in real life to make the model more realistic and useful.

A. Multiple Runways

In this model, every airport has three runways, two of them are only used for landing and the other one is only used for takeoff. Compared to single runway, this change will definitely increase the passenger flow volume and decrease the circling time, which make each airport work more efficiently.

B. Weather Condition

In the real life, weather condition is one of the most important element that will affect flights' schedule. Therefore, in this model, the weather is set for 2 possible conditions: good and bad. The good weather or bad weather's probability can be changed manually. If the weather is good, the landing and taking off event will be processed normally. Otherwise, for the security of passengers, the planes which are going to land or take off must wait until the weather condition becomes good.

C. Gas Condition

In the real life, when there are several planes wait to land, the order of landing is not only decided by arriving time. The air-traffic controller will change the order based on the fuel left of each plane. So in this model, each plane's residual amount of fuel will be monitored and if the value is less than warning value, this plane will be scheduled to land first no matter when it arrives.

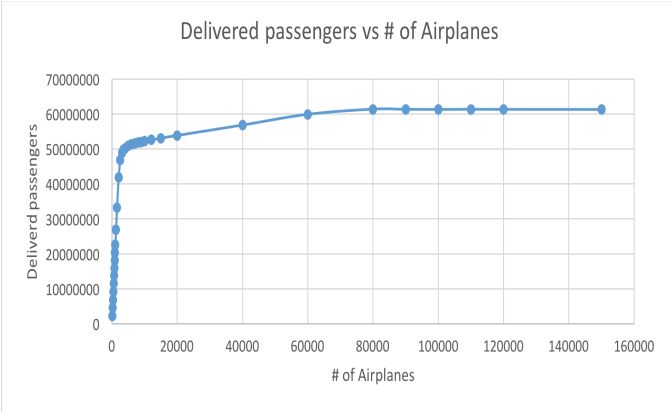
IV. SIMULATION RESULTS AND ANALYSIS

We run our simulation model several times with different airportEvent settings. The result is consistent with same input. All the 100 airports' physical location data is from [2]. And the airplanes' parameters like speed is from [3].

A. Delivered Passengers

We test the simulation model with different number of planes flying in 100 airports. The simulation time is 1000 seconds and does not have weather influence. The total number of arriving passengers is recorded. Testing result is shown below.

Figure 1. Delivered Passengers vs Number of airplanes



As the figure 1 shown, we find several interesting results:

a. When the number of airplanes is less than 3000, the delivery efficiency increases linearly with high rate.

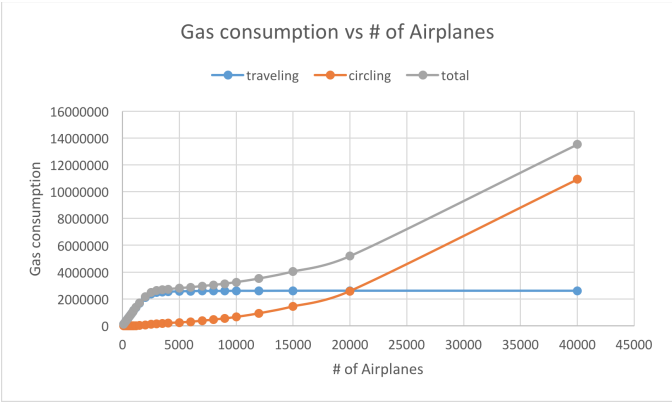
b. After that, the linear delivery's efficiency drops massively.

c. When the number of airplanes reach 80000, the delivery passengers is about steady of 60000000.

B. Gas Consumption

The testing condition is same as A. We test with different number of airplanes and record the traveling, circling and total gas consumption. Testing result is shown below.

Figure 2. Gas consumption vs Number of airplanes



As the figure 2 shown, we find several interesting results:

a. When airplanes less than 3000, the gas consumption is mainly from traveling part;

b. After that, the traveling part increases slower and circling part increases faster due to the decrease of delivery efficiency, and the total gas consumption follows the trend of circling part;

c. The traveling part would eventually stagnate and total gas consumption would change exactly as circling part which is increase in a linear way.

C. Weather

We test the simulation model with 2000 airplanes flying in 100 airports. The traveling gas consumption per mile is the double of circling gas consumption. The simulation time is

1000 seconds. We record the delivered passengers number, traveling gas consumption and circling gas consumption with different bad weather probability. The testing results are shown below.

Figure 3. Delivered passengers vs Bad weather probability

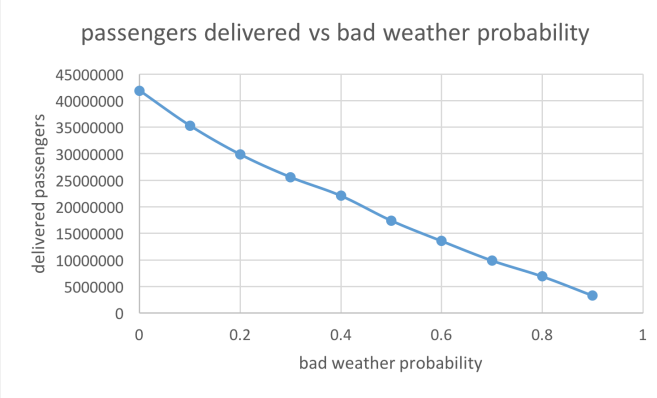
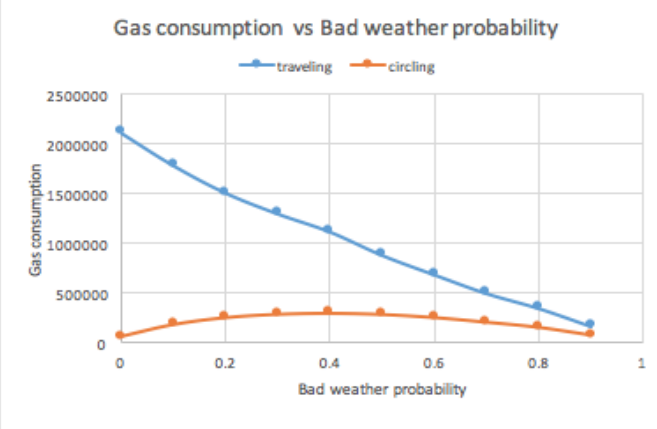


Figure 4. Gas consumption vs Bad weather probability



From figure 3 and 4, we find several interesting results:

a. As bad weather probability increase, the number of passengers delivered decreases constantly. The reason is airplanes are not able to land or takeoff due to bad weather, thus decreasing the number of delivered passengers.

b. As bad weather probability increase, traveling gas consumption decrease. It is also due to the number of flying airplanes decreases.

c. As bad weather probability increase, circling gas consumption firstly increases because more planes are waiting to land due to bad weather, and then circling gas consumption decrease because airplanes can't depart.

D. Multiple Runway

To show the working mechanism of the multiple runway, we first test the situation when 3 planes arrive at the same airport at the same time. The below figure is the simulation result. It can show that due to the 2 runways for landing, plane 1 and plane2 land to the LAX at the same time on different runways. But when plane3 arrives, it has to wait until plane 1 finishing landing. And for taking off, because there is only one runway, plane 1, plane 2 and plane 3 take off in order.

Figure 5. Multiple runways simulation result

```
5.0: plane1 arrived at LAX
5.0: plane1 start landing at the first landing runway of LAX
5.0: plane2 arrived at LAX
5.0: plane2 start landing at the second landing runway of LAX
5.0: plane3 arrived at LAX
5.5: plane1 lands at LAX
5.5: plane3 start landing at the first landing runway of LAX
5.5: plane2 lands at LAX
6.0: plane3 lands at LAX
7.5: plane1 takeoff from the first takeoff runway ofLAX
7.8: plane1 departs from LAX
7.8: plane2 takeoff from the first takeoff runway of LAX
8.1: plane2 departs from LAX
8.1: plane3 takeoff from the first takeoff runway of LAX
8.4: plane3 departs from LAX
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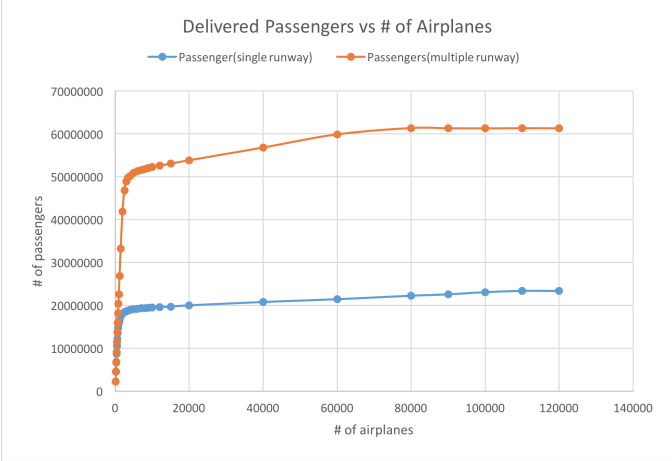
The figure below shows the comparison of delivered passengers with the single runway and multiple runways. From the figure we can observe that when airplane number is less than about 700, the difference of delivered passengers is not obvious, while when the airplane number increases, the number of delivered passengers of multiple runways are triple of single runway. This is because when the airplanes number is small, the multiple runway resource is not fully used. And with the increasing of airplanes number, all 3 runways are scheduled with planes.

Figure 5. Delivered Passengers vs number of Airplanes



References

[1] "M/M/c queue." *Wikipedia*. Wikimedia Foundation, n.d. Web. 12 Feb. 2017.

[2] https://datahub.io/dataset/global-airports

[3] http://ardupilot.org/plane/docs/parameters.html