CIS*3130 Final Report

Course: Systems Modeling and Simulation

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Problem Formulation

For my simulation I wanted to process a series of airport operations. I chose to do an airport since it is a very complex system with a lot of moving parts that I thought would be interesting to try and recreate. When looking into a problem to solve for an airport, I decided to investigate optimization. I wanted to analyze the slowest parts of the airport and see if there were ways to speed up the overall process. The overall question I went into this project was, how can an airport be optimized?

Since an airport is mostly a closed system, I believe it is very feasible to be simulated. While a real airport is very complex, we can look at the main operations on a more basic level. It is very technologically feasible to do this using modern simulation software. There is not a huge urgency to solve this problem as airport are already very well optimized, but I believe it to be an interesting problem, nonetheless.

Setting of Objectives and Overall Plan

The questions that I would like to answer are:

- What is the slowest operation in an airport?
- Can we perform multiple procedures simultaneously to speed up the process?
- Should we prioritize the runway for incoming or outgoing flights?

A simulation would be able to answer these questions correctly. With a proper model all the processes can be compared, and the total time taken compared for optimal strategies. The scenarios I would like to investigate involve a single runway to bottleneck the system, passenger boarding, inspection and refuel, and a baggage loading system. I will do a very general overview with data requirements gathered from the internet. The data I will gather has to do with airport processes as well as times for certain events.

Model Conceptualization

Entities and Attributes:

- Aircraft – Takes off and lands on runway, is loaded with passengers and baggage, must be refueled and inspected
    - Seating capacity – Number of seats on aircraft
    - Take-off time – Length of time to take-off
    - Landing time - Length of time to land
    - Arrival interval – How often new aircraft arrive
    - Inspection and refuel time – Length of time to inspect and refuel
- Passengers – Load onto aircraft
    - Speed – How fast passengers get to their seat

- Luggage – Loaded into truck, gets taken to aircraft, then loaded on aircraft
    - Weight – How much a piece of luggage weighs (affects truck)
    - Distance – How long it takes to load a piece of luggage on truck
- Truck
    - Truck time – How long it takes truck to get to airplane and back
    - Max truck weight – Amount of luggage the truck can hold for one trip

Resources:

- Runway – Aircraft need to wait for the runway to be free. Used for taking off and landing

Variables:

- Number of aircraft to process – Total aircraft to be simulated
- Number of runways – Total runways that can be used
- Check-in time – How long it takes passengers to check-in
- Passenger Sorting - process passengers randomly or in a specific order

State:

- Aircraft at airport – Current number of aircraft at airport
- Runway status- Queue of aircraft waiting to use runway
- Aircraft status- What aircraft is currently doing ex. Loading, waiting for runway etc.

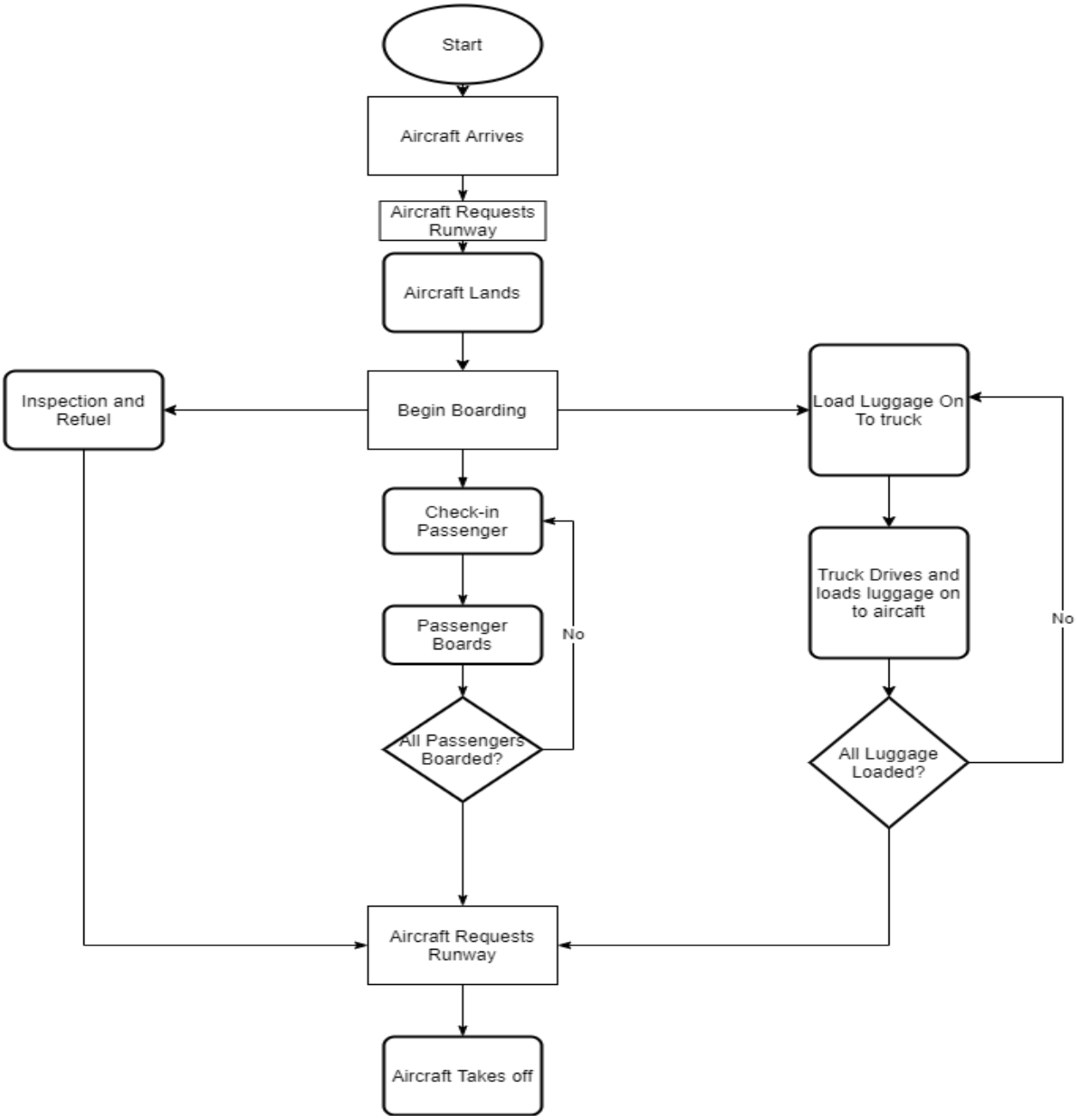
Event:

- Arrival of aircraft
- Aircraft landing
- Aircraft taking off

Activity:

- Aircraft landing
- Aircraft Taking off
- Aircraft inspection and refueling
- Loading luggage
- Loading passengers

Flow Diagram



Data Collection

Variables and Sources

- **Time taken to land** - Approximately 10 minutes for plane to touch down from 30000 feet. We can leave the runway open for longer, so we can say touchdown is 5 minutes (300 seconds)

Odukoya, J., Burchell, A., & Highskyflying. (2020, May 19). How Long Does It Take for A Plane to Descend And Land? (Rule Of Three). Retrieved December 17, 2020, from https://www.highskyflying.com/how-long-does-it-take-for-a-plane-to-descend-and-land-rule-of-three/

- **Time taken to takeoff -** Approximately 30-35 seconds for take-off. We will assume that they need the runway for a longer period, so we will designate 180 seconds.

  Cox, J. (2013, January 14). Ask the Captain: Does every takeoff take the same amount of time? Retrieved December 17, 2020, from https://www.usatoday.com/story/travel/columnist/cox/2013/01/13/ask-the-captain-takeoff-take-same-amount-of-time/1831525/

- **Time taken to refuel -** 15 to 20 minutes. Assume 20 minutes (1200 seconds) to account for the quick inspection as well

  How is an aircraft refueled? Here are the facts. (n.d.). Retrieved December 17, 2020, from https://www.finavia.fi/en/newsroom/2016/how-aircraft-refueled-here-are-facts

- **Time taken to board passengers -** 140 passengers in 30 to 40 minutes. Assume 35 min, 35/140 = 0.25 minutes per passenger, therefore we will designate around 15 sec/passenger.

  Mouawad, J. (2011, October 31). Most Annoying Airline Delays Might Just Be in the Boarding. Retrieved December 17, 2020, from https://www.nytimes.com/2011/11/01/business/airlines-are-trying-to-cut-boarding-times-on-planes.html

- **Luggage distance -** Most of the time luggage is supposed to arrive around the same time as the passengers, so can tweak the distance values to get an accurate idea.

  Nice, K. (2020, July 30). How Baggage Handling Works. Retrieved December 17, 2020, from https://science.howstuffworks.com/transport/flight/modern/baggage-handling.htm

- **Luggage weight:** Max weight of 50 pounds. Will assume minimum is half at 25 pounds

  Airline Luggage Restrictions. (n.d.). Retrieved December 17, 2020, from https://www.luggagepros.com/pages/carry-on

- **Truck Max Weight:** Around 40 000 pounds per trip

Baggage Tractors. (n.d.). Retrieved December 17, 2020, from https://airportequipmentgroup.com/equipment/baggage-tractors/

Model Translation

The model was implement using Python with SimPy. See implementation section for more information.

Verification and Validation

The implementation took me quite a while. Initially there was some other functionality that I could not seem to integrate using SimPy. After modifying the original plan, I managed to get all the functionality in and have it simulating successfully. In order to verify I used a series of print statements including the times to ensure everything was executing in the correct order. I began simulating with just one aircraft, then slowly continued to increase the value to ensure that it was working as expected. I compared the outcome to my sources listed in the Data Collection section.

Checking the variables and ensuring that they all lined up was a difficult process as well. There was a lot of trial and error to find values that accurately represented my research, and still made sense in my simulation. For example, having the passengers waiting for 2 hours on the aircraft did not make sense, so I needed to investigate why this was happening. However, it can be difficult to validate certain parts of my system as this is not a traditional airport. There are certain things missing from it, such as constraints on the number of terminals where people can board, travel time of the aircraft to the terminal and runway etc. When I compared it to the values from my research I had to account for this and attempt to make the best choice when picking values.

Experimental Design

Alternative Scenarios to Simulate

- Different runway priorities. First come first serve, take-off gets priority, landing gets priority
- Different aircraft size
- Running different processes concurrently

Number of Simulation Runs

I plan on running this simulation a total of 50 times to get the averages for each one. It takes me about 5 minutes to run with 1000 aircraft processed in each simulation 50 times. I

initialize the variable changes in “source” functions that initialize all the variables and loop through all the different aircraft processes.

Implementation

My implementation used Python 3.8.6 with the SimPy library. My application begins by setting a global random seed and a value for the number of aircraft each airport will process. I then initialize the environment and the runway resource for the first simulation. Next all the variables are set for the specific simulation and the random values for the luggage and passengers are determined. The aircraft process then begins, the first operation is requesting the runway and waiting for the landing process. The landing process is a timeout (the simulation waits) for a specified length of time determined by the initial variables.

Once it has landed, it begins the loading process. The loading process involves the inspection and refuel, the luggage loading, and passenger loading. These are run either simultaneously or individually depending on a variable that is set. The inspection and refuel process is a timeout for a set amount of time determined by a variable.

The luggage loading takes each baggage’s weight and adds it to a total, this total is the current truck weight. The program then times out for the distance attribute on the bag. If the truck is full, the simulation times out for the truck to deliver the luggage and return.

The passenger loading process first checks a passenger in, which is a timeout for a set amount of time determined in a variable. It then allows the passenger on to board. Once all passengers have been checked in, it waits for the passengers to all be seated.

Once the loading has been completed, the application requests the runway for takeoff. Once the aircraft has taken off, its journey is complete. The simulation will continue until all aircraft have taken off. It then marks the final simulation time.

Variable Values

The following is the values I use for simulation one, this is the basis for all other simulation values. All the other simulations I run will list the differences that they have from the original simulation.

NOTE: The luggage distance, luggage weight, and passenger speed values are generated as follows:

distance = random.uniform(minDistance, maxDistance)

weight = random.uniform(minWeight, maxWeight)

speed = random.uniform(minSpeed, maxSpeed)

Variable values for simulation one:

- NEW_AIRCRAFT = 1000 #Total number of airplanes to process
- aircraftInterval = 100 #how often new aircraft arrive
- aircraftSize = 100 #how many passengers on aircraft
- landingTime = 300 #how long it takes for aircraft to land
- takeoffTime = 180 #how long it takes for aircraft to takeoff
- inspectionAndRefuelTime = 1200 #how long it takes for aircraft to be inspected and refu eled
- passengerCheckInTime = 15 #How long it takes for a passenger to check in
- maxDistance = 10 #maximum luggage distance (time taken to load)
- minDistance = 5 #minimum luggage distance (time taken to load)
- maxWeight = 50 #maximum luggage weight
- minWeight = 25 #minimum luggage weight
- maxSpeed = 20 #maximum passenger speed (time taken to seat)
- minSpeed = 120 #minimum passenger speed (time taken to seat)
- truckTime = random.uniform(120, 180) #time it takes for truck to deliver luggage
- maxTruckWeight = 40000 #weight the truck can hold
- randomizePassengers = True #randomize passenger seating order
- loadSeparately = False #run the inspection, luggage, and passenger loading separately
- priorityRunway = -1 #-1 for no priorities, 0 for landing priority, 2 for takeoff priority

Simulation Two Values Differing from Simulation One:

- aircraftSize = 200 #how many passengers on aircraft

Simulation Three Values Differing from Simulation One:

- priorityRunway = 0 #-1 for no priorities, 0 for landing priority, 2 for takeoff priority

Simulation Four Values Differing from Simulation One:

- priorityRunway = 2 #-1 for no priorities, 0 for landing priority, 2 for takeoff priority

Simulation Five Values Differing from Simulation One:

- loadSeparately = True #run the inspection, luggage, and passenger loading separately

Simulation Six Values Differing from Simulation One:

- landingTime = 100 #how long it takes for aircraft to land
- takeoffTime = 50 #how long it takes for aircraft to takeoff

Simulation Seven Values Differing from Simulation One:

- passengerCheckInTime = 5 #How long it takes for a passenger to check in
- maxDistance = 5 #maximum luggage distance (time taken to load)
- minDistance = 2 #minimum luggage distance (time taken to load)
- maxSpeed = 5 #maximum passenger speed (time taken to seat)

- minSpeed = 50 #minimum passenger speed (time taken to seat)

Simulation Eight Values Differing from Simulation One:

- landingTime = 100 #how long it takes for aircraft to land
- takeoffTime = 50 #how long it takes for aircraft to takeoff
- priorityRunway = 0 #-1 for no priorities, 0 for landing priority, 2 for takeoff priority

Simulation Nine Values Differing from Simulation One:

- landingTime = 100 #how long it takes for aircraft to land
- takeoffTime = 50 #how long it takes for aircraft to takeoff
- priorityRunway = 2 #-1 for no priorities, 0 for landing priority, 2 for takeoff priority

Simulation Ten Values Differing from Simulation One:

- landingTime = 100 #how long it takes for aircraft to land
- takeoffTime = 50 #how long it takes for aircraft to takeoff
- loadSeparately = True #run the inspection, luggage, and passenger loading separately

Results

After running the simulation 50 times with 1000 aircraft, these are the averages I received. These times are the total simulation time, so from the first aircraft requesting the runway, to the last one taking off.

Simulation One Time: 480002.44932141213
Simulation Two Time: 480008.9701465394
Simulation Three Time: 480005.46891020524
Simulation Four Time: 480873.84562151134
Simulation Five Time: 480006.54390566977
Simulation Six Time: 150200.2205005648
Simulation Seven Time: 480001.0849953714
Simulation Eight Time: 150232.07408755223
Simulation Nine Time: 151259.86845059865
Simulation Ten Time: 150372.03300882282

These results show two vastly different sets of times. On one hand we have simulations 1, 2, 3, 4, 5 and 7 all around the 480000 mark. While simulation 6, 8, 9 and 10 are all around the 150000 mark. Since in simulations 6, 8, 9 and 10 I reduced the landing time and takeoff time, it tells me that these values are bottlenecking the simulation.

Simulation 4 was the largest out of all the simulations and simulation 9 was the largest among the 150000-mark simulations. Since both prioritized the runway for takeoffs, we can say that this fact is slowing it down. In a real-world scenario, an airport would likely have a capacity

and need to prioritize takeoffs more, but it shows that overall, it slows down. Allowing the runway to operate in a first in first out manner seems to be slightly more efficient than prioritizing landings as well.

Simulations ten and five involve separating the loading processes. While they take slightly longer, it isn't a very large difference. This tells us that these processes are not what takes up the most time in this simulation. However, if other processes sped up, the rate at which each aircraft is processed gets greatly sped up when performing all the loading operations at the same time.

Conclusion

Overall, I believe I learned quite a bit about simulations from this assignment. Simulations can take quite a lot of planning to make, especially if it is for a customer. It is very important to have everything planned out before you meet them, as the data is a crucial component. I also learned that to simulate something like an airport, there are a ton of variables involved. Even though it is a relatively closed system, there are many moving pieces that all effect it and missing any one of these key pieces can result in a vastly different outcome. I also learned a lot about the implementation of simulations. I've found that after I implemented it, I think about the whole problem differently and notice some mistakes I made during the initial planning of this project. SimPy is a great library, but it does have limitations so keeping those in mind will be helpful for the future.

If I could go back, I believe I would choose a topic that has fewer components to it than an airport. Being able to model an entire system seems much more useful than modeling only a few components of a much larger system. The results I got would not accurately affect an actual airport's operations due to the number of other components that I missed. While I spent a lot of time and had difficulty with this simulation, there is still a lot of other pieces that I did not consider in the original plan. However, I did enjoy implementing the actual solution. Thank you for an awesome semester Professor Bruce!