Project Checkpoint 1

CSE6730 – Spring 2022 – Project Group 36

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1. Abstract

Modern airports are complex multimodal systems with intertwined relationships of passengers, facilities and airplanes. Significant efforts have been dedicated to optimizing the total flow inside an airport, which can be further broken down into passenger flow and airplane traffic. Most prior works have focused on either one of the two systems, namely passenger flow or traffic flow, to reduce the complexity of simulation and uncertainties. While some researchers have attempted to integrate simulated airport systems for a holistic evaluation of the airport total flow, their objectives are primarily focused on optimizing airport design. However, the relationship between the airport traffic flow and the passenger flow should not be simply decoupled when a feedback loop of self-excitation is evident. In this project, we aim to answer the following research questions, 1) what are the primary factors contributing to passenger congestion inside an airport terminal, 2) what are the top reasons for airport traffic congestion, and 3) what is the relationship between passenger congestion and airport traffic congestion? These questions are answered by simulating the passenger flow, airport traffic flow and the coupling variables between passenger congestion and airport congestion. It is hypothesized that a positive correlation between passenger congestion and airport congestion will be observed, and the system can suffer from instability without proper intervention. The project aims to provide further advice on proper intervention and setting standards to modulate system stability.

2. Description of the system

Airport terminal passenger flow system

The airport passenger flow system is the flow of passengers from entry of the airport to the terminal of the departure aircraft. It can be described using a series of sub-systems comprising check-in desk, Security Check, Immigration, Terminal Gate entry and Boarding. The check-in process is assumed to be of two types: 1) Online: Passengers who completed their check-in online take this queue. 2) Offline: Passengers who are yet to complete their check-in through offline mode take this queue. All other sub-systems are assumed to have a fixed number of queues with time taken at each queue taken as a probability distribution. The number of queues at each sub-system and the values of the probability distributions are decided based on studying the data recorded at existing airports.

Airport traffic flow system

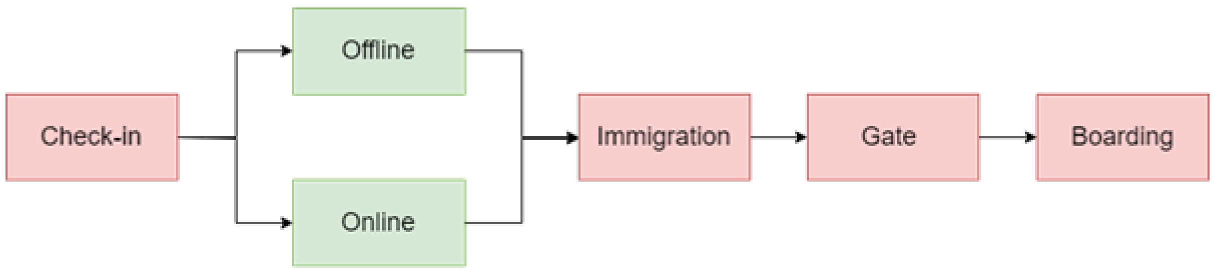
The system of interest is an airport with only one runway. The runway of an airport can either be active (being used by another aircraft) or accessible. If the runway is idle when an airplane arrives in the airport's airspace, the aircraft can use the runway for landing. If the runway is active, the air traffic controller ("ATC" - the simulator in this model) will place the aircraft in a queue until the runway is free to be used. Similarly, ATC will put the plane in a queue when the aircraft is about to takeoff. The system can be determined by three factors: flight schedule, passenger flow and runway. Boarding of passengers impacts when a flight is about to takeoff. Flight schedule impacts the operations of the runway. FIFO order is used to queue the airplanes (for landing and takeoff). ATC will help schedule and maintain the flying list. The events of an aircraft are scheduled based on the runway and the type of weather conditions.

The passenger flow system provides the number of passengers arriving and departing each airport. The simulation computes the circling time (for the aircraft when it enters the airspace), which is the time when an airplane is ready to land but is waiting for its line in the queue. Some input parameters such as the number of aircraft, simulation length in minutes, and airplane passenger capacity are predefined. All the variables are uniformly distributed.

3. Conceptual model of the system

Passenger flow model

The Airport passenger flow system is formulated using Discrete Event Simulation (DES) model. DES models the operation of a system as a discrete sequence of events in time which starts from a master event followed by sub-events. The master event is taken as the entry of passengers into the airport which triggers the subsequent sub-events. The flowchart below shows the sequence of the passenger flow model:



1. *Check-in:*

We set the initial conditions such that 'x' number of passengers enter the airport every 't' timesteps. In 'x' passengers a ± b fraction of passengers has completed the Online Check-in process. Those passengers will have less processing time than the passengers who check-in offline. Using this intuition, time steps taken by offline and online check-in process are set as $t_1 \pm z_1$ and $t_2 \pm z_2$ respectively.

2. *Immigration:*

We assume that the airport in our system is an international airport and hence an immigration control area is present after the check-in node. The time steps taken at this node is assumed as $t_3 \pm z_3$.

3. *Gate*

Passengers are queued at the Gate till the time step reaches a certain limit and then are sent for boarding.

4. *Boarding*

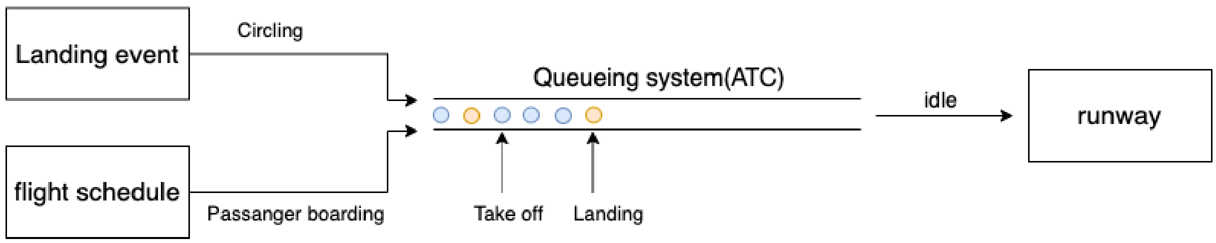
Boarding is assumed to take $t_4 \pm z_4$ time steps and will stop when both the situations described below happens:

- If the ratio of seats filled and total seats reach a certain limit.
- If the time steps cross the departure time of the aircraft and there is a considerable interval between subsequent passengers.

The number of counters or desks in each node will be decided and the passenger flow density will be studied by varying them.

Airplane traffic flow model

Airplane traffic flow model will be mainly stimulated by the queueing system. The model will firstly initialize a FIFO queue. When a flight needs to land or take off, the event will be added to the queue. Then, when the runway is idle, the first event of the queue will be taken out and handled. The flowchart below shows the sequence of the airplane traffic flow model:



1. Flight schedules and landing event
Initialize the flight schedule and landing event, every t_1 time period, there will be a plane ready to land, and every t_2 time period, there will be a plane scheduled to take off.
2. ATC queueing system.
The ATC system will be implemented by a FIFO queue. The queue receives two kinds of events, namely take-off event, and landing event:

- When the plane is hovering in the air and requesting to land, ATC receives the landing request and adds the landing event at the end of the queue.
- When the aircraft requests takeoff after the passenger has completed boarding, ATC will receive the takeoff request and add the takeoff event at the end of the queue.

3. Runway
When the runway is idle at time t, the event at the head of the queue will be fetched and processed. Depending on the type of event (takeoff and landing), it will occupy the runway for different durations t_3. After the t_3 duration, the runway will continue to fetch the next event, repeat until the queue is empty.

4. Platform of Development

We are using Python as the programming language to develop the above-mentioned models and visualize the results. Packages such as simpy will be used to facilitate discrete event simulation.

5. Literature Review

To maximize the passenger flow and reduce congestion, various design changes of key facilities and service optimization have been investigated through simulations. Casas et al. [1] illustrated a conceptual model of passenger flow in airport terminals via a micro-simulation at Barcelona International Airport. Specifically, the simulation model represents detailed passenger flow in complex facilities of an airport. This was made possible by parameterizing synthetic input data for elements necessary for passenger flow simulation with an objective to assist airport design and recurrent terminal optimization. Takakuwa and Oyama [2] examined the passenger processing time for departure through a simulation and identified key contributors to the passenger processing flow. Specifically, the paper presented an analysis of the boarding process of an international airport and segmented the airport based on facilities with their respective conditions. Passenger data were generated through a passenger flow generator and the simulation concluded that more counter staff and making use of first and business class kiosk can drastically reduce passengers missing flights. Gatersleben and van der Weij [3] conducted a simulation to examine passenger handling with a dynamic model. The specific goal of the paper was to identify the logistic bottleneck in passenger handling and provide insights into airport development decisions. Alodhaibi et al. [4] developed a simulation framework using Discrete-Event Simulation (DES) on ExtendSim V9.2 simulator software. Using the model, they evaluated the efficiency of the outbound operational processes including check-in, security screening, immigration, customs and boarding. The flight schedule was used as the input to identify potential bottlenecks in the system. Tesoriere et al. [5]

carried out a case study regarding the movement of users inside the departures area of Fontanarossa-Catania airport. Evaluation of social forces acting has been carried out through the definition of nodes and arcs using UCINET 6 software. This work acts as a fundamental for the definition of the areas and the flows, which can provide useful details for the subsequent implementation through micro-simulation tools of the pedestrian outflow. Ju et al. [6] developed a simulation to measure the performance of an improved infrastructure design and to establish any benefits that may result from making changes to the system. Through optimization algorithms, the authors analyzed the optimum resource allocation of airport waiting rooms to increase their capacities and improve their service level. Guizzi et al. [7] developed a simulation model to analyze the passenger flow in the terminal airport from entrance to boarding based on Discrete Event theory. The method was tested in Naples International Airport and was found to be adaptable to the configuration and operational characteristics of a wide range of airport terminals. Qiang et al. [8] adopted a free boarding strategy when conducting passengers to board the airplanes. A simulation framework based on cellular automation is developed to mimic the dynamics of passenger flow in the free boarding process. In the model, each seat in the cabin is assigned a positive value to characterize how desirable it appears to the overall passengers. A logit-based discrete choice principle is applied to formulate the seat choice behaviors of passengers.

The increase in airplane traffic has created problems in almost all international airports. In order to handle the problems and to reduce waiting times, airport surface operations have to become more efficient. Previous airplane traffic models have a significant weakness that their usage of a constant taxiing speed. Studies at the airport of Duesseldorf have shown that a constant speed does not exist: taxiing speed can differ and even speed drops can be seen. Considering this changing speed, Mazur et al. [9] used Cellular automata models (CA) to simulate this non-linear traffic with interactions. In the model, the main steps of the Nagel-Schreckenberg-Model for road traffic (acceleration, deceleration, and randomization) are adopted and new rules for airplanes are supplemented. By comparing simulated taxiing times with real-world data at peak hours, simulating new taxiing routes on the actual layout of an airport and simulating new airport layouts in advance becomes possible. Nonetheless, the model does not consider the ground facility traffic influence, like Follow-Me-Cars, busses, etc. Andreatta et al. [10] presented a new aggregate mathematical model for air traffic flow management (ATFM). The model extends previous approaches and consider three important issues: (i) the model explicitly incorporates uncertainty in the airport capacities; (ii) it also considers the trade-off between airport arrivals and departures, which is a crucial issue in any hub airport; and (iii) it accounts for the interactions between different hubs. The model can capture connections between departures and arrivals at a specific airport, assume that the decision maker has the authority to decide which specific flight should be delayed. However, despite benefits that can be obtained because of modeling uncertainty, a drawback of the model is scalability to the problem, which may lead to very high model complexity.

Some statistical modeling approaches have also been proposed to learn traffic control rules in an airport setting. Tolstaya et al. studied [11] optimal planning for Air traffic control. Air traffic controllers (ATC) must follow a complex set of regulations, including requirements on the spacing between airplanes, weather restrictions, and airport-specific departure and arrival protocols. Additionally, experienced ATCs often formulate strategies that balance various demands from the complex interplay between these factors. One way to reduce the load on the human operators is to tackle the problem by an Autonomous ATC. It can be done by a system that concisely describes air traffic control rules, assists human operators, and supports dense autonomous air traffic around commercial airports. The proposed method learns air traffic control rules from real data as a cost function via maximum entropy inverse reinforcement learning. This cost function is used as a penalty for a search-based motion planning method that discretizes both the control and the state space. The used methodology showed that the approach could learn to imitate the airport arrival routes and separation rules of dense commercial air traffic. Another study on flight schedules with stochastics modeling limited flight delays during operations [12]. The strategy for addressing this problem considers the uncertainty of day-of-operations delays and adjusts flight schedules to accommodate them in the planning stage. Here, a stochastic programming model was used to account for uncertain future delays by adding buffers to flight turnaround times in a controlled manner. The model was studied for its scalability and effectiveness in reducing delays through an extensive simulation study of five different flight networks using real-world data.

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6. Current State of the project

Simplifying Assumptions

To initiate the modeling process, a few simplifying assumptions were made to the passenger and airplane traffic systems. The following are examples of variables assumed to be constant or independent for the first iteration of simulation:

- Passenger flow model
  - The number of passengers entering the airport at a given time is assumed to be independent of the flight schedule.
  - The processing time for any passenger going through immigration/security is assumed constant.
- Airplane traffic flow model
  - The departure time is only dependent on traffic queue, but independent of boarding status.

These relaxation assumptions will reduce the difficulty in modeling of the individual systems, but also provide a clear framework for increasing complexity for the investigation of queuing system integration, which aims to investigate the interactive nature of airplane traffic congestion and passenger flow congestion

Division of Labor

The division of labor is assigned such that all members of the team will have a focus, while being able to contribute to the overall project integration equally. The simulation workload is divided into passenger flow system, airport traffic system and system integration. Mugundhan and Xiaoliang will focus on the construction of passenger flow system, while Saran and Hui will dedicate their effort on airport traffic system. All four members of the team will work together to integrate the above two system with a queuing system simulation.

7. Project Git Repository

https://github.gatech.edu/xyan72/CSE6730_Group36.git