**CSCE 1101-01, 02, 05 Spring 2023 Term Project Report**

**Simulating Randomness in Airport Landing Queue: Estimating Average Waiting Time and analyzing**

**Efficiency**

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# Abstract:

Search algorithms play a crucial role in various computer science applications. In many cases, using high complexity search algorithms can be impractical due to limited computational resources. The A\* algorithm is a popular search algorithm that efficiently finds the shortest distance between two nodes. As a best-first search algorithm, A\* chooses the next best node while finding the optimal path to the destination. Additionally, A\* utilizes a heuristic function to guide its search path, making it a smarter algorithm. This paper presents a comprehensive overview of the fundamental components of the A\* algorithm, the problems it solves, and its functionality. We also evaluate the effectiveness and complexity of the algorithm, as well as some of its diverse applications in computer science and artificial intelligence.

*Keywords:* A\* Algorithm, optimizing pathfinding, search algorithm problems

# Introduction

Efficient airport operations are crucial for ensuring seamless air traffic flow and providing a safe and convenient travel experience for passengers. Among the key factors contributing to efficient airport management is the effective handling of landing queues, where airplanes patiently await their turn to touch down on a runway. Optimal queue management minimizes delays, optimizes resource utilization, and enhances overall airport performance.

The objective of this project is to develop a program that simulates the queueing operations of an airport, with a specific focus on estimating the average waiting time for airplanes in the landing queue before they can land. By conducting this simulation, valuable insights can be gained into the efficiency of the landing process, enabling the identification of potential areas for improvement and optimization.

By accurately estimating the average wait time in the landing queue, airport managers can assess the adequacy of their current systems and implement targeted measures to reduce congestion and enhance overall efficiency. Therefore, this simulation can serve as a valuable tool for airport authoritie***s.*** The program will replicate real-world scenarios, taking into account factors such as a single landing runway, random arrival times, and varying service times. The program will facilitate efficient management of the landing queue, allowing for seamless insertion and removal of airplanes as they await their turn to land.

Furthermore, the simulation will operate within a fixed simulation period, providing a comprehensive analysis of queue dynamics and enabling a meaningful evaluation of performance. The log of arrival and landing events will provide valuable information for analyzing the project's data. This data analysis will help identify any areas of congestion or problems and allow for the implementation of effective solutions to address them.

# Problem Definition

The problem we aim to address in this project is to simulate the waiting queues of airplanes in an airport and calculate the average wait time in the landing queue. We will focus on a specific scenario of an airport with a single landing runway. When airplanes arrive near the airport, they are required to join a landing queue. Each plane has a random arrival time, denoted as Tarrival, which represents the time at which it arrives near the airport. Once in the landing queue, a plane may have to wait for a certain duration, Twait, until the runway becomes free and ready to receive it.

After a plane land on the beginning of the runway, the runway remains occupied for a fixed service time, Tlanding, until the plane successfully docks. During this service time, no other planes can land. To conduct the simulation, we will utilize a Double-ended Queue (DEQ) data structure. A DEQ allows for efficient insertion and removal of elements at both ends, which suits the requirements of our landing queue simulation. The program will be designed to run for a fixed simulation period, denoted as Tmax. We will consider the time unit as one minute for simplicity. Additionally, we will assume a random arrival time, Tarrival, for each plane, with a fixed average inter-arrival time, ΔT. Moreover, no plane will leave the queue until it successfully lands on the runway.

To enhance the simulation, the program will generate a log of the arrival and landing events, capturing the time of each event and the corresponding plane's information. This log will provide valuable insights into the sequence of events and can be used for analysis and further optimization. By varying parameters such as the inter-arrival time ΔT or the landing service time Tlanding, we can explore different scenarios, such as simulating peak and slack times of the day or assessing the impact of changes in landing duration. The C++ Random Number Generator (RNG) will be utilized to generate the time of arrival for each plane and determine whether it will land or not based on certain criteria.

Through this simulation project, we aim to gain a deeper understanding of the dynamics of landing queues at airports and provide insights into optimizing queue management for improved efficiency and passenger experience.

# Methodology

The program represents a simulation of the queueing operations at an airport, specifically focusing on estimating the average waiting time for airplanes in the landing queue. The simulation is implemented using classes such as Runway, Plane, DEQ (Double-ended Queue), and Airport.

The Runway class encapsulates the runway's properties and behavior. It tracks the landing time and provides methods to set and retrieve the landing time. The Occupied function checks if the runway is currently occupied and determines if a plane can land based on the arrival time and current time.

The Airport class is responsible for managing the landing queue and simulating the airport operations. It utilizes the DEQ template class to store the planes in the landing queue. The AddToQueue function adds planes to the queue, and the planeArrives function adds a plane to the queue when it arrives at the airport. The planeLands function handles the process of a plane landing, considering the runway's occupancy and inter-arrival time. To decide wether the plane will land or not, there is two main factors. First, the runway should not be busy meaninging that it has no plane being served. The second factor is the randomness from our random number function approach we used that we would discuss later. The Crowded function checks if the landing queue is crowded and accordingly it will affect our data analysis that will be presented later in this paper.

The Plane class represents an airplane and maintains information about each plane's waiting time, arrival time, and ID. It provides functions to calculate the average wait time and average arrival time.

In the main function, the simulation is executed by creating an Airport object and an array of Plane objects. The planes are added to the queue, and the simulation proceeds by iterating through each time unit. The planeLands function is called to check if a plane can land, and the corresponding output is displayed based on the return value. The simulation continues until the maximum time is reached, and the average wait time and average arrival time are printed at the end.

The approach in this code involves the utilization of various classes and their interactions to simulate the queueing operations at an airport. The code implements the logic for managing the landing queue, tracking arrival and waiting times, and determining whether a plane can land based on the runway's occupancy and inter-arrival time. The simulation allows for the analysis of data through a generated log of arrival and landing events.

# Specification of used Algorithms

Psudo code

# Data Specifications

|  |  |  |
| --- | --- | --- |
| Time | Status | Runway status |
| 0:01 | No planes currently | No |
| 0:02 | No planes currently | No |
| 0:03 | No planes currently | No |
| 0:04 | No planes currently | No |
| 0:05 | No planes currently | No |
| 0:06 | No planes currently | No |
| 0:07 | No planes currently | No |
| 0:08 | Plane 1 has arrived in the airspace & Plane 1 has landed and waited 0 minutes in the air | Yes |
| 0:09 | No planes currently | Yes |
| 0:10 | No planes currently | Yes |
| 0:11 | No planes currently | Yes |
| 0:12 | Plane 2 has arrived in the airspace | Yes |
| 0:13 | Occupied | Yes |
| 0:14 | Occupied | Yes |
| 0:15 | Occupied | Yes |
| 0:16 | Occupied | Yes |
| 0:17 | Occupied | Yes then plane 1 left after service |
| 0:18 | Plane 2 has landed and waited 6 minutes in the air | Yes |
| 0:19 | No planes currently | Yes |
| 0:20 | No planes currently | Yes |
| 0:21 | Plane 3 has arrived in the airspace | Yes |
| 0:22 | Occupied | Yes |
| 0:23 | Occupied | Yes |
| 0:24 | Occupied | Yes |
| 0:25 | Occupied | Yes |
| 0:26 | Occupied | Yes |
| 0:27 | Occupied | Yes then plane 2 left after service |
| 0:28 | Plane 3 has landed and waited 7 minutes in the air | Yes |
| 0:29 | No planes currently | Yes |
| 0:30 | No planes currently | Yes |
| 0:31 | No planes currently | Yes |
| 0:32 | No planes currently | Yes |
| 0:33 | No planes currently | Yes |
| 0:34 | No planes currently | Yes |
| 0:35 | No planes currently | Yes |
| 0:36 | No planes currently | Yes |
| 0:37 | No planes currently | Yes |
| 0:38 | No planes currently | Yes then plane 3 left after service |
| 0:39 | No planes currently | No |
| 0:40 | No planes currently | No |
| 0:41 | Plane 4 has arrived in the airspace & Plane 4 has landed and waited 0 minutes in the air | Yes |
| 0:42 | No planes currently | Yes |
| 0:43 | Plane 5 has arrived in the airspace | Yes |
| 0:44 | Plane 6 has arrived in the airspace | Yes |
| 0:45 | Occupied | Yes |
| 0:46 | Occupied | Yes |
| 0:47 | Occupied | Yes |
| 0:48 | Occupied | Yes |
| 0:49 | Plane 7 has arrived in the airspace | But now time ended and plane 3 didn’t yet finished service |

Results: -

The average wait time for the 4 planes which landed is: 13 miuntes

Number of planes didn’t land: 3

# Conclusions

In conclusion, this project successfully simulated airport queueing operations and estimated the average waiting time for airplanes in the landing queue. Valuable insights were gained regarding the efficiency of the landing process and areas for improvement. The developed code and classes effectively modeled the airport system, with the DEQ template class handling queueing operations. The accurate estimation of average wait time is valuable for airport management decisions. The project emphasizes the importance of efficient queue management for minimizing delays and optimizing resource utilization. Overall, the project serves as a valuable tool for analyzing and improving airport queueing systems.

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# References