Technical Report: Final Project
EECE 2560: Fundamentals of Engineering Algorithms

Christopher Lam, Dante LoPriore, Jasime Sajna
Department of Electrical and Computer Engineering
Northeastern University
`lopriore.d, lam.chris, sajna.j`

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1 Project Scope

1.1 Finalized Project Scope

The aim of this project is to design and develop a user-friendly flight reservation system to simulate for customers how they would book, cancel, and view available seats across the offered flights of an airline. This system will explore how data can be dynamically stored and managed using databases, and how this dynamically stored data can be sorted using the linked list data structure. The expected outcomes include a functioning well documented web-based system, a final project report, and a powerpoint presentation.

1.2 Project Performance Requirements To Create Flight Reservation System

The project's objectives for the anticipated system are:

- To allow customers to book, cancel, and search for an available seat using an interactive local web-based flight reservation system, and also easily view available flights using their starting and destination locations.
- Provide the current booking trends and flight availability statistics to help the airline make profitable decisions based on the given data results.
- Preform features with fast response times and allow for many users to interact with the system without any changes in performance.

1.3 Project Code Implementation Objectives

The project's coding secure architecture objectives are:

- **Frond End:** The Front End component would be the team building a responsive web application using a GUI to visualize the flight reservation functions that are set for the users and admin.
- **Back End:** The Back End component would be the team building a the server side of the application that enables the transactions and processes made in a database using Flask and SQL.
- **Emphasis on Linked Lists, BFS, Sorting Algorithms:** The team's primary data structures to include are linked lists, sorting algorithms and breath first search algorithms. The team plan to use the sorting algorithms to create the navigation, searching. The team will use linked lists to represent the nodes as the seats reference the seats with pointer values. BFS algorthim is used to find optimal flight paths.

2 Project Plan

2.1 Brief Timeline

The project is divided into phases, each with specific deliverables:

- **Week 1 (October 7 - October 13)**: Define scope, establish team roles, outline skills/tools.
- **Week 2 (October 14 - October 20)**: Begin development on the bare logic of the system, set up project repository
- **Week 3 (October 21 - October 27)**: Coding, work on backend and frontend separately
- **Week 4 (October 28 - November 3)**: Finish backend, integrate the frontend. Start PowerPoint presentation.
- **Week 5 (November 4 - November 10)**: Finalize system, organize test scripts, continue documenting in report.
- **Week 6 (November 11 - November 17)**: Revise and finalize technical report and presentation.
- **Week 7 (November 18 - November 28)**: Final presentation, submit report.

2.2 Milestones

Key milestones include:

- Project Scope and Plan (October 7).
- GitHub Repository Setup and Initial Development (October 9).
- Showcase Backend Progress and Completion (October 28).
- Final System Testing and Report Draft (November 10).
- Final Presentation and Report Submission (November 28).

2.3 Schedule Overview

The team divided the tasks based on the team members strengths and expertise, which then enabled the team to organize a plan to successfully complete the project within a timely manner. Figure 1 is a gnatt chart that shows how the team agreed to take on certain sections of the project throughout the semester.

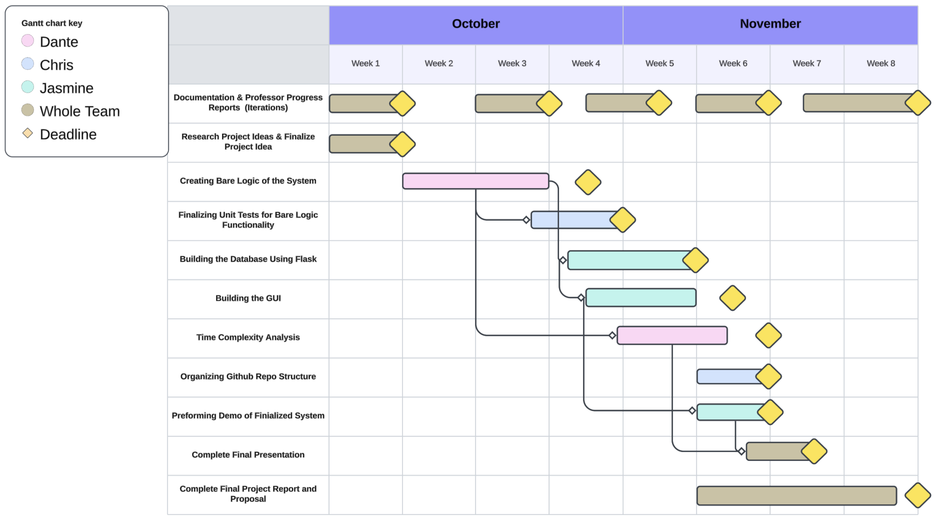


Figure 1: Gnatt Chart Schedule of Events

The team consistently meet after each Algorithms class to check-in with our progress on the desired tasks and determine if the team need to adjust the schedule of events to meet certain deadlines. Before any major project iterations and progress reports were due, the team typically meet a day before the due date on zoom or microsoft team to confirm the team's submission on describing the team's progress.

3 Team Roles

3.1 Primary Roles

- **Team Member 1**: **Chris Lam:** Testing Frontend and Backend Functionality, Time Complexity Analysis, Backend logic, UI
- **Team Member 2**: **Dante LoPriore:** Building and Testing Frontend, Creating Bare Logic, Testing Backend logic, UI
- **Team Member 3**: **Jasmine Sajna:** Testing and Creating Backend on Flask, backend logic, UI

3.2 Team Responsibilities

Each team member will focus on specific areas, but roles may adapt as the project progresses:

- **Frontend Development (Jasmine, Dante):** In this role, the group would build the user interface for the flight reservation system using a GUI. The GUI will allow the user to see the data visualization of the current navigation options to reserve and cancel an available flight.
- **Backend Development (Whole Team):** In this role, the group will be responsible for creating a reliable backend system that creates an universal database for users with different roles to schedule a flight, reserve an available seat, and display passengers info.
- **Technical Documentation (Whole Team):** As a collective group, it is each team member's responsibility to document their progress with their role and provide feedback to improve the project's projected goals.
- **System Testing (Chris):** Within this role, the team members would check in with the progress of the code functionality and validating that the system works for the front end to the back end, ensuring a variety of edge cases are accounted for.
- **Time Complexity Analysis (Whole Team):** Within this role, the team members would check if the algorithms and code functionality within the bare logic is an optimal solution. Also, this role helps improving code runtime and efficiency within a system.

4 Methodology

4.1 Data Entity Structure and Relationships for the Bare Logic

This section illustrates how the team structured the data entities within the bare logic of the flight reservation system. In Figure 1 displays the UML diagram to reflect the data relationships in the SQL database to model and represent the flight reservation system.

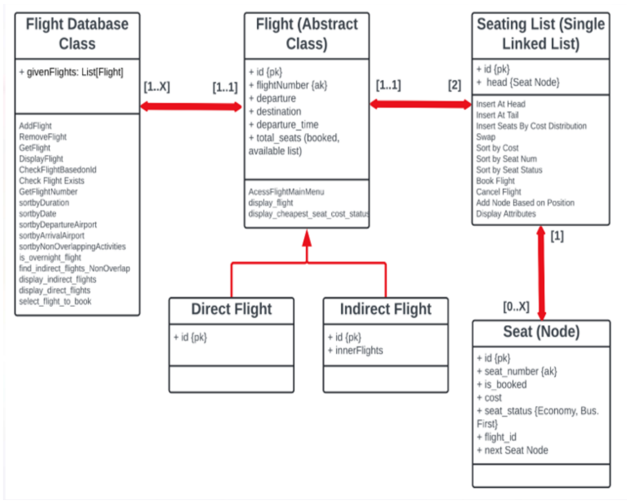


Figure 2: UML Diagram to Describe Data Entities in the Bare Logic

The UML diagram includes a flight database class that manages the multiple flights stored in the system, which practically stores a list of flight objects. This is where the interactive menu would be stored to navigate through each Flight's details, adding flights, deleting flights, filtering flights, and selecting the flights from the list. The framework builds off of how Flights and Seats interact with each other to organize the respective operations for each entity. The team found that each Flight will have a one-to-many relationship with the seats as a flight can have infinite seats, but only one seat can belong to a user on a single flight. Seats include the seat's status and cost based on whether the seat is first class, business class, or economy class. The relationship between the Flightdatabase and the Flight can be one too many as the flight database needs to have at least one Flight to operate the system, and the database can have as many flights as it wants. The relationship of the Flight to the flight database is referenced to the amount of single linked lists for each Flight, which are 2, one for booked flights and another for available flights. Thus, the LinkedLists and Flights relationship is deemed a composition relationship since the linked lists depend on whether the Flight exists in the Flightbase. Overall, the team is pleased with the results for the bare logic to serve as a foundation to help structure the backend structure.

4.2 Linked Lists Data Structure to Represent a Seating List For a Flight

Within this Flight reservation system, the seats are represented as nodes in a linked list and the linked list represents either the avaliable seating or booked seating for a given flight. The data visualization diagram to reflect this system using the linked list can be seen in Figure 3.

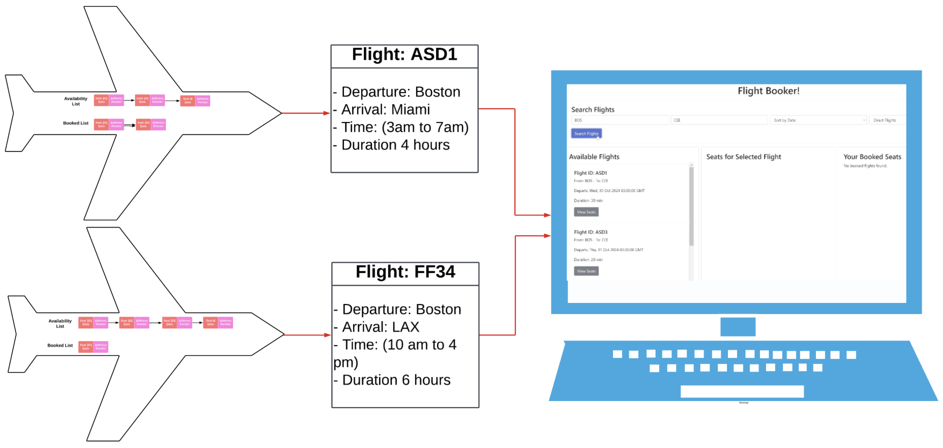


Figure 3: Flight Reservation System Structure Data Visualization

4.3 Indirect Flight Algorithm Methodology

The team considered using a BFS or breath first search sorting algorithm to help find the shortest indirect flight path from the user's inputted departure airport to the desired arrival location. The team used the same tree structure to search for the flights closest to the starting flight and then the path expands based on the given direction and threshold until it reaches the flight to the correct final destination. The team's approach to create the indirect flight path can be best described in a worked example seen using the known flight map seen in Figure 4. For the demonstration I wanted to go from NYC to LAX

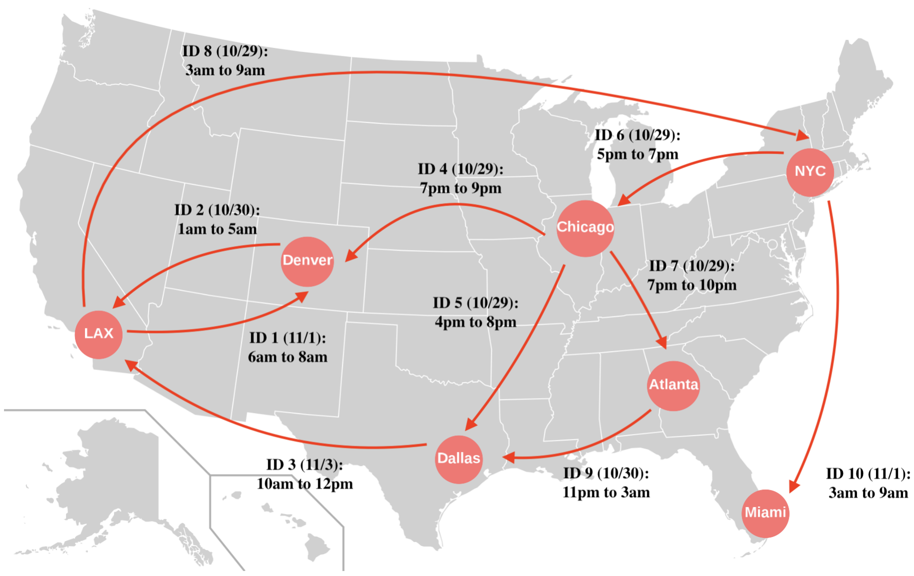


Figure 4: Example of Flight Map with System

4.3.1 Step 1: Initialize Known Variables

Before starting the algorithm, the team initialized a queue for the breath first search that contains the information for the current location, current path of flights represented as a list, the end of the last flight, and the date of the last flight.

4.3.2 Step 2: Create Dictionary Of All Departing Flights Each Airport

The Indirect Flight algorithm starts by creating a dictionary of all the departing flights for each airport. The sample dictionary shows how when we start doing the algorithm

- Key: NYC - Items: Chicago, Miami
- Key: Chicago - Items: Denver, Atlanta, Dallas
- Key: Atlanta - Items: Dallas
- Key: Dallas - Items: LAX
- Key: Denver - Items: LAX
- Key: LAX - Items: Denver, NYC

4.3.3 Step 3: Check if Destination is Reached

The breath first search is supposed to check for all known paths. My approach to this is to dequeue the flight from the BFS queue to extract and get the current flight to preform the BFS algorithm on. Start by doing a check where the current location should be the destination the user wants to reach. If this condition is true, extract all the flight numbers from the flight path or journey it took to reach this destination. Please, note that this will only work in causes where the flight path contains more than two flights.

4.3.4 Step 4: Start by Searching Known Paths

We start searching the known paths by extracting the key from the departure map dictionary to see what flights depart from the current location. In this process, cycles can not occur as current location is put into a set that tells the system to skip over the flight if that location was already used.

If this location is the first flight in the path, then create a path with its first element starting with the current flight and enqueue the next arrival location in the queue

If the fligth path contains any flights check to see if you can create a new path with the current flight added. The constraints to this are the following:

- Non-overlapping Time Intervals - The next flights start fly time is directly after the last flight's end time to ensure no conflicting events at the same tome
- Indirect Flight Path duration has limit of 2 days from original source
- Overnight Flights Are Considered
- Can't Visit Same Airport More Than Once

When all the constraints are meet, then you can enqueue the next location to be added to the bfs queue and also include the flight in the known flight path of indirect flights

4.3.5 Step 5: Do Steps 3 and 4 until the BFS searching has been done

The while loop will do steps 3 and 4 and iterate over all possible permutations of the flight path could be reached for an indirect flight path from the source to destination.

5 Algorithm Design for System's Basic Logic

The current pseudcode list in this section shows all the methods that make up the flight reservation system. The bare logic of the simple system are the sorting and navigation of traverse through seats, and allowing the user to dynamically enter a seat that is available or booked. The bare logic files can be seen in this github link to the branch of the working python file `https://github.com/sajna-j/flight-reservation/blob/bare-logic-in-python`.

5.1 General Booking System Helper Functions

5.1.1 insertHead Method

Algorithm 1 insertHead:

Input: An integer representing seat , *data*
Output (Changed State): A linked list with a new node inserted at the head of the list

```
Begin Algorithm: insertHead
$newNode \leftarrow SeatNode(data)$
if $head == NULL$ then
    $head \leftarrow newNode$
    $return;$
end
$newNode.next \leftarrow this.head$
$this.head \leftarrow newNode$
End Algorithm: insertHead
```

Frequency Count Analysis:
SeatNode creation: 1 operation
conditional check: 1 operation
assignment of newNode at head: 1 operation
Shifting of node at head back: 1 operation
Frequency Count: F(n) = 4
Time Complexity: O(1)
Purpose: To insert a node at the head of the list

5.1.2 insertAtEnd Method

Algorithm 2 insertAtEnd

Input: An integer representing seat , *data*
Output (Changed State): A linked list with a new node inserted at the tail of the list

```
Begin Algorithm: insertAtEnd
$newNode \leftarrow SeatNode(data)$
if $head == NULL$ then
    $head \leftarrow newNode$
    $return;$
else
    $temp \leftarrow head$
    while $temp.next! = NULL$ do
        $temp \leftarrow temp.next$
    end
    $temp.next \leftarrow newNode$
end
End Algorithm: insertAtEnd
```

Frequency Count Analysis:
newNode creation: 1 operation
conditional check: 1 operation
assignment of newNode: 1 operation

shifting head to temp: 1 operation
while loop: n iterations
shifting temp: n iterations

Frequency Count: F(n) = 2n + 4
Time Complexity: O(n)
Purpose: To insert a node at the tail of the list

5.1.3 deleteNodeAtPosition Method

Algorithm 3 deleteNodeAtPosition

```
Input: An integer value to represent the positionIndex
Output (Changed State): Get a linked list with a node deleted at a given index position.
Begin Algorithm: deleteNodeAtPosition
$count \leftarrow 0$
if $head == NULL$ then
    print $The * list * is * empty$
    $return$
end
if $positionIndex == 0$ then
    $temp = head$
    $head \leftarrow temp.next$
    $return$
end
$currNode = head$
while $(currNode.next$ not equal $nullptr)$ and $(positionIndex - 1$ not equal $count)$ do
    $count+ = 1$
    $currNode \leftarrow currNode.next$
end
$tempNode \leftarrow currNode.next$
print $DeletingSeat : tempNode.data, Address : currNode.next$
$currNode.next \leftarrow tempNode.next$
delete $tempNode$
End Algorithm: deleteNodeAtPosition
```

Frequency Count Analysis:
user input of position: 1 operation
count initialization: 1 operation
check head isn't NULL: 1 comparison
check if user wants to remove the first head: 1 comparison
assign head to currNode: 1 operation
while loop iterations: n operations
while loop comparisons: 2*n comparisons
inside the while loop operations: 2*n operations
assign currNode.next to tempNode: 1 operation
print seat being deleted and the address: 1 operation
assign tempNode.next to currNode.next: 1 operation
delete tempNode: 1 operation

Frequency Count: F(n) = $5n + 9$
Time Complexity: O(n)

Purpose: To remove the seat node in a single linked list at a given position index. Iterate over each node of the list and keep a count for each pass of the node in the linked list to keep track of the index to remove the node. When the list reaches the index that the user wants to delete then delete the node and redirect the node's pointers accordingly.

5.1.4 addNodeAtPosition Method

```
Algorithm 4 addNodeAtPosition
Input: An integer value or index to add the node positionIndex, the integer values representing the data in the node data
Output (Changed State): The linked list with the added seat based on the user's index
Begin Algorithm: addNodeAtPosition

Initialize SeatNode* newNode = new SeatNode(data)
Set count ← 0

if (head is equal to NULLpointer) then
    print − > throw error how list is empty
    terminate program
end
if (positionIndex is equal to 0) then
    newNode− >next = head
    head = newNode
    terminate program
end
Intialize SeatNode* currNode = head
while ((currNode− >next not equal to nullptr) and (positionIndex - 1 not equal to count)) do
    increment count by 1
    currNode = currNode− >next
end
print− > "Add Seat:" + newNode− >data + ", Address: " + currNode-¿next
newNode− >next = currNode− >next
currNode− >next = newNode

End Algorithm: addNodeAtPosition
```

Frequency Count Analysis:

initialize the new node that is going to be added on to the linked list: 1 operation
set a count to keep track the nodes in the linked list: 1 operation
check if the linked list is empty using if comparison: 1 operation
if condition is true throw an error how the operation can be preformed: 1 operation
if condition is true end the program: 1 operation
check if the new node should be placed at the start of the linked list using if comparison: 1 operation
if condition is true reassign the pointers to make the next item in the list for the new node to be the start of the list: 1 operation
if condition is true make the start of the list be the new node: 1 operation
if condition is true end the program: 1 operation
iterate each element in the list via while loop until the current position is found to place the new node: 2n operations
increment the count of the current place of the current node in list by 1: 1 operation
reassign the pointers of the current node to be the next item in the list: 1 operations
print the what the new node being placed into the list: 1 operations

reasssign the pointers of the next element of the new node to be the next element of the current node : 1 comparison

reasssign the pointers of the next element of the current node to be the new node : 1 comparison

Frequency Count: F(n) = 2n + 15

Time Complexity: O(n)

Purpose: To add the seat node in a single linked list at a given position index. Iterate over each node of the list and keep a count for each pass of the node in the linked list to keep track of the index to add the node. When the list reaches the index that the user wants to add then add the node and redirect the node's pointers accordingly.

5.2 Book A Seat Function

5.2.1 bookSeat Method

Algorithm 5 bookSeat

```
Input: A single LinkedList, availableSeatList
Output: To add a seat node to the book seat list and remove the booked seat from the available seating list.
Begin Algorithm: bookSeat

$input(intuserSeatInput)$
$indexCount = 0$

while $(currentAvailable.next\ not\ equal\ nullptr) AND (currAvailableSeatNode.data\ not\ equal\ userSeatInput)$ do
    $indexCount \leftarrow indexCount + 1$
    $currAvailableSeatNode \leftarrow currAvailableSeatNode.next$
end
if $userSeatInput == currAvailableSeatNode.data$ then
    $insertAtEnd(userSeatInput)$
    $print\ seats$
    $availableSeatList.deleteNodeAtPosition(indexCount)$
    $return$
else
    $print\ UnabletoBook!$
end
End Algorithm: bookSeat
```

Frequency Count Analysis:
user input of seat: 1 operation
indexCount initialization: 1 operation
while loop iterations: n operations
while loop conditional checks: 2*n comparisons
indexCount increment: n operations
shift next SeatNode: n operations
if condition check: 1 comparison
insertion at end (O(n)): n operations
print seats (O(n)): n operations
deleteNodeAtPosition: n operations

Frequency Count: F(n) = 8n + 3

Time Complexity: O(n)

Purpose: To allow the user to book a seat based on the given a hand selected availability list. Make sure that the seat node exist in the list in the available list to be able to book the seat node to be stored in the booked list.

5.3 Cancel A Seat Function

5.3.1 cancelASeat Method

Algorithm 6 cancelASeat

```
Input: LinkedList, availableSeatList
Output: To remove the selected booked seat from the booked seat list and add the canceled seat back to the available seating list
Begin Algorithm: cancelASeat

$input(intuserSeatInput)$
$indexCount \leftarrow 0$

if $head == NULL$ then
    print− >Can't be booked
    $return$
end
$currBookedSeatNode \leftarrow head$

while $((currentAvailable.next\ not\ equal\ nullptr)\ AND\ (currAvailableSeatNode.data\ not\ equal\ userSeatInput))$ do
    $indexCount \leftarrow indexCount + 1$
    $currBookedSeatNode \leftarrow currBookedSeatNode.next$
end
if $currBookedSeatNode.data == userSeatInput$ then
    $currAvailSeatNode \leftarrow availableSeatList.head$
    $indexCountAvail = 0$
    $deleteNodeAtPosition(indexCount)$

    while (currentAvailable.next not equal nullptr) AND (userSeatInput > currAvailSeatNode.data) do
        $currAvailSeatNode \leftarrow currAvailSeatNode.next$
        $indexCountAvail \leftarrow indexCountAvail + 1$
    end
    $availableSeatList.addNodeAtPosition(indexCountAvail, userSeatInput)$
else
    print − > uncancellable seat!
end
End Algorithm: cancelASeat
```

Frequency Count Analysis (Worst Case):
user input of seat: 1 operation
indexCount initialization: 1 operation
check head isn't NULL: 1 comparison
assign head to current booked node: 1 operation
while loop iterations: n operations
while loop comparisons: 2*n comparisons
inside while loop operations: 2*n operations
if block userinput comparison: 1 comparison
assign availableSeats head to current Node: 1 operation
indexCountAvail assignment: 1 operation
deleteNodeAtPosition(indexCount) (O(n)): n operations

while loop iterations: n operations
while loop comparisons: 2n comparisons
while loop operations: 2 operations
addNodeAtPosition (O(n)): n operations

Frequency Count: F(n) = 10n + 9

Time Complexity: O(n)

Purpose: To allow the user to cancel a seat from the booked list. Make sure that the seat node exist in the booked list to be able to cancel the seat node and then add the canceled seat back into the available seat in a sorted order.

5.4 FlightDatabase Filtering Direct and Indirect Flights Functions

5.4.1 Find Indirect Flights NonOverlap Method (BFS Algorithm)

Frequency Count Analysis:

initialize known indirect flight variable: 1
initialize known departure map dictionary variable: 1
iterate through each flight in flight list : n
check if the departure location is in the dictionary if condition : 1
if condition is true assign the empty list to new departure map dictionary : 1
if condition is false assign the flight to new departure map dictionary based on departure key: 1
initialize a queue to store the known flight path: 1
iterate over a queue via a while loop : n
set variables for the queue : 1
check the if condition for the current location is the destination : 1
get a list of the known flight number iterating through for loop of known flights : n
check if the flight is located in the indirect flight list: 1 comparison
add the flight number to the knownIndirectFlights: 1 comparison
if condition to check if the current flight in departure mapping: 1 comparison
iterate through each flight in the departure map based on the current location: n^2 comparison
initialize a visited key: 1
check if a visited key in the visited set and add the key: 2
check if a current flight path exists: 1
assign and create flight path : 1
append the current flightpath to the queue : 1
initialize variables to check known constraints to define an in: 5
assign and create flight path and append the current flightpath to the queue : 2
return indirect flight list : 1

Frequency Count: F(n) = n^2+7n+22

Time Complexity: O(n^2)

Purpose: This function allocates the correct list for indirect flights based on a given source and destination airport that the user inputted. The BFS algorithm gets the all the valid indirect flight paths without excessive layovers and no overlapping flights. The BFS algorithm starts by creating a dictionary to represent a departure mapping system that stores the flights based on their departure locations to allow the search algo to pull from if needed. The queue is initialize to investigate all known possible flight paths in the BFS tree to reach from the departure location to the arrival location. The a valid indirect flight can be consider on to the ongoing list if the flight meets the requirements of being within a max layover of two days, prevents revisted already past flights using a set, check if the time of the next flight is valid and going to the correct path to the destination.

Algorithm 7 Indirect Flights BFS NonOverlap Method :

Input: The string value of the desired airport departure location, *source*, The string value of the desired airport arrival location, *dest*

Output: A list of correct indirect flights based on the set arrival and departure airports.

Begin Algorithm: Indirect Flights BFS NonOverlap Method

```
Initalize $knownIndirectFlights$ = []
Initalize $departureMap$ = empty dictionary
for (flight in self.givenFlights) do
    if (flight.departureLocation not in departureMap) then
        Assign departureMap[flight.departureLocation] = empty list
    end
    departureMap[flight.departureLocation].append(flight)
end
queue = deque([(source, emptylist, NULL pointer, NULL pointer)]) Initalize visitedSet = set()
while (queue is not NULL) do
    Set currentLocation, flightPath, lastEndTime, lastDate = queue.popleft()
    if (currentLocation == dest) then
        flightNumbers = [flight.flightNumber for flight in flightPath] if (flightNumbers not in knownIndirectFlights)
        then
            knownIndirectFlights.append(flightNumbers)
        end
        continue
    end
    if (currentLocation in departureMap) then
        for (nextFlight in departureMap[currentLocation]) do
            Set visitKey = (nextFlight.flightNumber, nextFlight.timeInterval, nextFlight.date)
            if (visitKey in visitedSet) then
                continue
            end
            visitedSet.add(visitKey)

            if (flightPath does not exist) then
                Set newFlightPath = [nextFlight]
                queue.append((nextFlight.arrivalLocation, newFlightPath, nextFlight.timeInterval[1],
                nextFlight.date))
            else
                Set lastFlight = flightPath[-1]
                Set lastEndTime = lastFlight.timeInterval[1]
                Set nextStartTime = nextFlight.timeInterval[0]

                Assign isOvernight = self.isOvernight$_flight(lastEndTime, nextStartTime)$
                $Assigndif ferenceDatesTimes = (nextFlight.date - lastFlight.date).days$

                if ((lastEndTime <= nextStartTime or isOvernight) and (lastFlight.date <= nextFlight.date) and (dif-
                ferenceDatesTimes <=2)) then
                    newFlightpath = flightPath + [nextFlight] queue.append((nextFlight.arrivalLocation, newFlight-
                    Path, nextFlight.timeInterval[1], nextFlight.date))
                end
            end
        end
    end
end
return knownIndirectFlights
End Algorithm: Indirect Flights BFS NonOverlap Method
```

5.5 Sorting Flights and Seats

5.5.1 Bubble Sorting Indirect/Direct Flights by Date/Duration

Algorithm 8 sortByDate, sortByDuration:

```
Input: Flights, a list of Indirect or Direct Flight objects, data
Output (Changed State): a sorted list of Direct or Indirect Flights
Begin Algorithm: sortByDateDuration

i ← 0
j ← 0
for i=0 to n=length(Flights) do
    for j=0 to n=length(Flights) do
        if Flights[i].duration/date == Flights[j].duration/date then
            temp ← $Flights[i]$
            Flights[i] ← $Flights[j]$
            Flights[j] ← $Flights[temp]$
        end
    end
end
return Flights
End Algorithm: sortByDateDuration
```

Frequency Count Analysis (Worst Case):

index initialization: 2 assignments
outer for loop incrementation: n operations
inner for loop incrementations: n*n operations
swapping assignments: 3*n*n operations
return Flights: 1 operation

Frequency Count: F(n) = $4n^2 + n + 3$
Time Complexity: O(n) = n^2
Purpose: To bubble-sort a given list of flights (Direct or Indirect) by their departure time or their total duration.

5.5.2 Bubble Sorting Seat Nodes by Cost/Status/ID

Algorithm 9 sortBySeatCost, sortBySeatStatus, sortBySeatID:

```
Input:Head of Singly Linked Seats data
Output (Changed State):
Begin Algorithm: sortBySeatCost/Status/ID

if $head == NULL$ then
    throw Error for no node in list
end
swappingNodeFlag ← $True$
while $swappingNodeFlag$ do
    swappingNodeFlg ← $False$
    curNode ← $head$
    while $(curNode! = NULL)AND(curNode.next! = NULL)$ do
        if $curNode.cost/status/ID > curNode.next.cost/status/ID$ then
            swap(curNode, curNode.next)
            swappingNodeFlag ← $True$
        end
        curNode ← $curNode.next$
    end
end
End Algorithm: sortBySeatCost/Status/ID
```

Frequency Count Analysis (Worst Case):

first if-statement: 1 comparison
initialize swappingNodeFlag: 1 assignment
outer while loop condition check: n comparisons
change swap flag, and curNode: 2 assignments
inner while loop conditional checks: 2*n*n
checking cost/status/ID: 2*n*n
swap, and reassign swap flag: 4*n*n assignments
shift curNode: n operations

Frequency Count: F(n) = $8n^2 + 2n + 4$
Time Complexity: O(n) = n^2
Purpose: To bubble-sort a flight's singly linked seat nodes by either cost, status, or ID number of the seat.

5.6 Data Collection and Preprocessing

5.6.1 Actual Flights and Seats

To ensure users have access to a list of flights with seats to begin with, all flights and seats are initialized when the application is started by instantiating a single custom FlightDatabase object populated with Flights in the flight_objects.py script. By default when these flights are made, the seats of each are initialized as well.

In the constructor of each flight, a number of seats is provided and the first 20 percent of seats are made as First Class, second 20 percent are Business, and remaining 60 are Economy. The cost of each is made pseudorandomly using python's random module. Each seat is made by inserting a SeatNode into the available singly linked seating list (from the head) of the FlightDatabase.

To ensure users have a wide variety of flight cases available, the flight_objects.py script creates flights that cover the following cases:

- Overnight flights
- Indirect Flights (Limit of 2 days)
- Flights with the same SRC/DEST but different depart times

5.6.2 Enabling UI Data Collection with a Backend

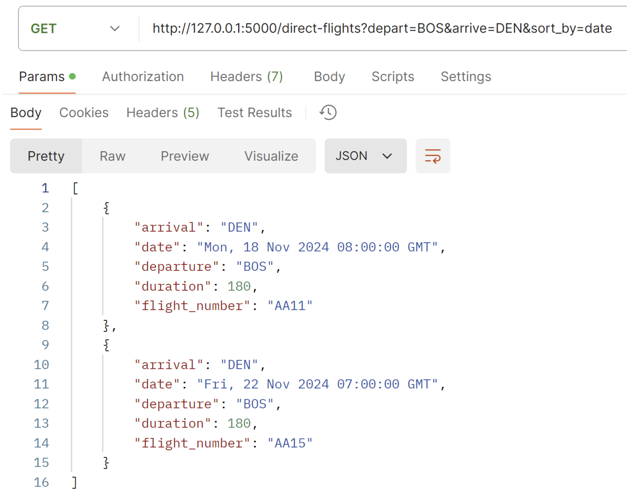
To create a working website for users, the Flask backend needed to work with the bare logic algorithms and produce JSON lists and objects for the HTML and CSS frontend to properly display the results.

To ensure JSON conversions of our flightbooking system, methods were added to each class to create a JSON-able representation of the instance. For the SinglyLinkedSeatingList, a function $as\_list()$ is made to iterate through each node from the head, and create a Python List object representation. For Seats, a function $as\_dict()$ is made in which a key-value object is made that contains the seats number, status, and cost. Each flight's $as\_dict()$ function presents a key-value object containing the number, departure location, arrival location, date, and duration. Indirect Flight objects have an $as\_list()$ function in which all inner Flights are shown using their dictionary representations (from $as\_dict()$) in the order of the path searched to create them.

The following endpoints were defined in the Flask backend script with their own functions for each, working with the FlightDatabase instance and applying the as_dict and as_list methods for the results of each sort and filter.

- GET flight by ID
- GET direct and indirect flights for src dest
- GET flights sorted by depart time, duration
- GET seats of a flight sorted by cost, status, id
- GET a single seat of a flight
- GET all booked seats
- POST a flight's seat as booked
- POST a flight's seat as cancelled

We verified these results were working and accessible through HTTP requests to the Flask Backend with Postman.

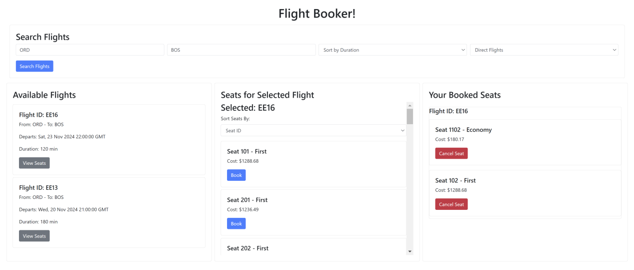


```
[
    {
        "arrival": "DEN",
        "date": "Mon, 18 Nov 2024 08:00:00 GMT",
        "departure": "BOS",
        "duration": 180,
        "flight_number": "AA11"
    },
    {
        "arrival": "DEN",
        "date": "Fri, 22 Nov 2024 07:00:00 GMT",
        "departure": "BOS",
        "duration": 180,
        "flight_number": "AA15"
    }
]
```

Figure 5: Sample Backend Return of List of JSON Objects from a GET flights request.

5.6.3 Frontend UI

The frontend was built with HTML and CSS using a Boostrap Grid template [2] to organize a main search bar for filtering flights, and three main windows to view flights, seats, and booked seats. The layout is designed in scrollable sections, while JavaScript is used to handle interactions for buttons and the backend endpoints and dynamically display all options.


Flight Booker!

Search Flights

ORD | BOS | Sort by Duration | Direct Flights

Search Flights

Available Flights

Flight ID: EE16
From: ORD - To: BOS
Departs: Sat, 23 Nov 2024 22:00:00 GMT
Duration: 120 min
View Seats

Flight ID: EE13
From: ORD - To: BOS
Departs: Wed, 20 Nov 2024 21:00:00 GMT
Duration: 180 min
View Seats

Seats for Selected Flight
Selected: EE16
Sort Seats By:
Seat ID

Seat 101 - First
Cost: $1288.68
Book

Seat 201 - First
Cost: $1236.49
Book

Seat 202 - First

Your Booked Seats
Flight ID: EE16

Seat 1102 - Economy
Cost: $180.17
Cancel Seat

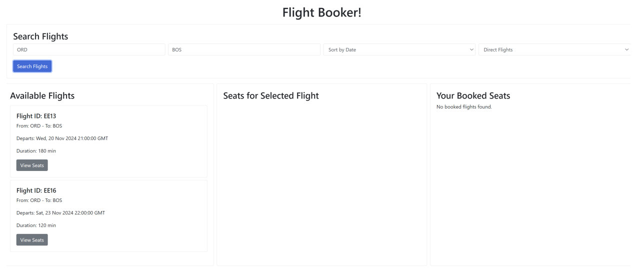
Seat 102 - First
Cost: $1288.68
Cancel Seat

Figure 6: Final UI Visual

6 Results

Present the results, including key performance metrics and visualizations (e.g., tables, charts) that illustrate the effectiveness of the algorithms.

The working results of filtering and sorting direct flights can be seen in the images below. Whereby the search output correctly shows all Direct Flight options from ORD to BOS in the left side window, sorted by departure date.


Flight Booker!

Search Flights

ORD | BOS | Sort by Date | Direct Flights

Search Flights

Available Flights

Flight ID: EE13
From: ORD - To: BOS
Departs: Wed, 20 Nov 2024 21:00:00 GMT
Duration: 180 min
View Seats

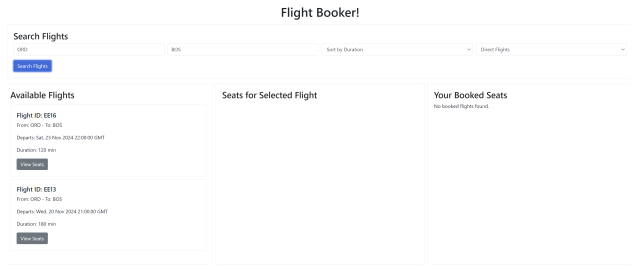
Flight ID: EE16
From: ORD - To: BOS
Departs: Sat, 23 Nov 2024 22:00:00 GMT
Duration: 120 min
View Seats

Seats for Selected Flight

Your Booked Seats
No booked flights found.

Figure 7: Direct Flights from ORD to LAX sorted by departure date

When changing the sort feature to sort by duration, the bubble sort algorithm correctly swaps the two flights shown above from ORD to LAX as seen below.


Flight Booker!

Search Flights

ORD | BOS | Sort by Duration | Direct Flights

Search Flights

Available Flights

Flight ID: EE16
From: ORD - To: BOS
Departs: Sat, 23 Nov 2024 22:00:00 GMT
Duration: 120 min
View Seats

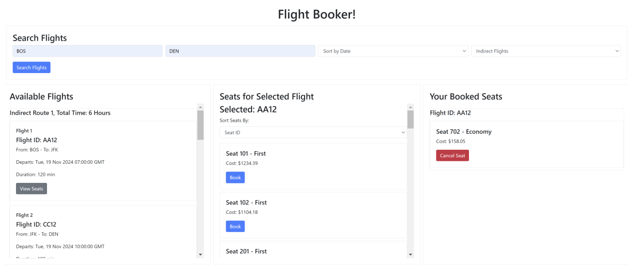
Flight ID: EE13
From: ORD - To: BOS
Departs: Wed, 20 Nov 2024 21:00:00 GMT
Duration: 180 min
View Seats

Seats for Selected Flight

Your Booked Seats
No booked flights found.

Figure 8: Direct Flights from ORD to LAX sorted by duration

We can view the Indirect Flights by simply changing the flight type. The following showcase filters from BOS to DEN.



Flight Booker!

Search Flights

BOS | DEN | Sort by Date | Indirect Flights

Available Flights

Indirect Route 1, Total Time: 6 Hours

Flight 1
Flight ID: AA12
From: BOS - To: JFK
Departs: Tue, 19 Nov 2024 07:00:00 GMT
Duration: 120 min

Flight 2
Flight ID: CC12
From: JFK - To: DEN
Departs: Tue, 19 Nov 2024 10:00:00 GMT

Seats for Selected Flight

Selected: AA12

Sort Seats By: Seat ID

Seat 101 - First
Cost: $1234.39

Seat 102 - First
Cost: $1104.18

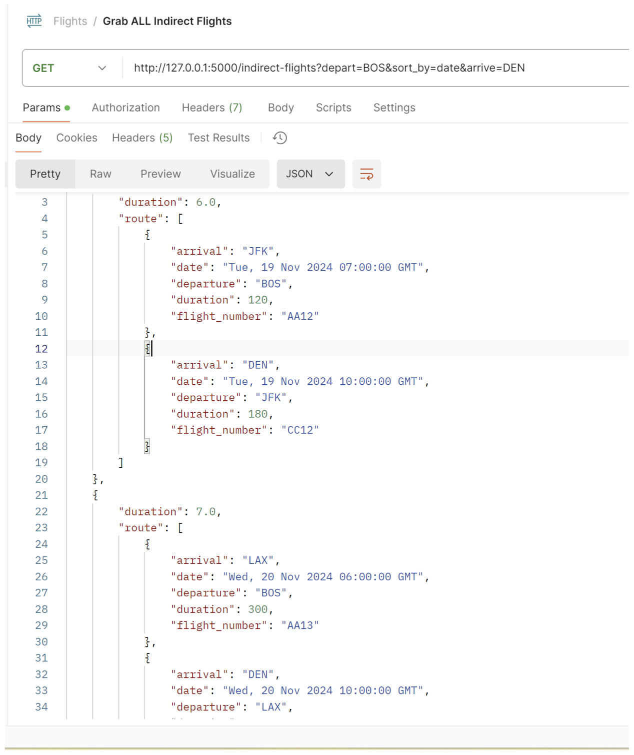
Seat 201 - First

Your Booked Seats

Flight ID: AA12

Seat 702 - Economy
Cost: $158.05

Figure 9: View Indirect Flights and Seats from BOS to DEN



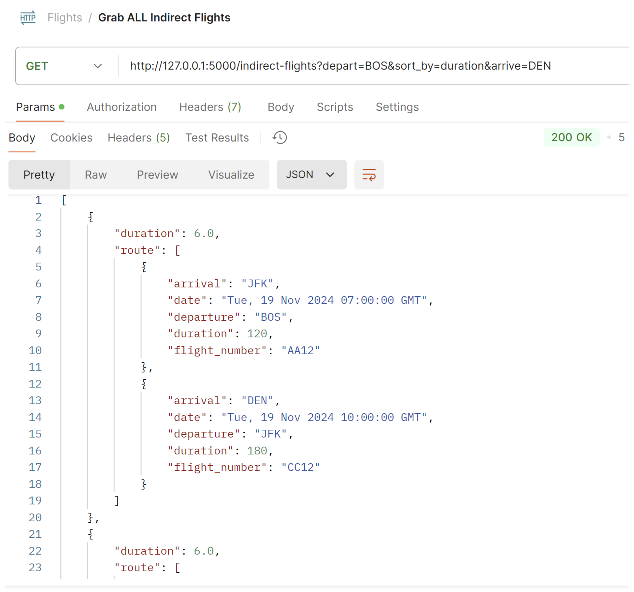
Flights / Grab ALL Indirect Flights

GET http://127.0.0.1:5000/indirect-flights?depart=BOS&sort_by=date&arrive=DEN

```
        "duration": 6.0,
        "route": [
            {
                "arrival": "JFK",
                "date": "Tue, 19 Nov 2024 07:00:00 GMT",
                "departure": "BOS",
                "duration": 120,
                "flight_number": "AA12"
            },
            {
                "arrival": "DEN",
                "date": "Tue, 19 Nov 2024 10:00:00 GMT",
                "departure": "JFK",
                "duration": 180,
                "flight_number": "CC12"
            }
        ]
    },
    {
        "duration": 7.0,
        "route": [
            {
                "arrival": "LAX",
                "date": "Wed, 20 Nov 2024 06:00:00 GMT",
                "departure": "BOS",
                "duration": 300,
                "flight_number": "AA13"
            },
            {
                "arrival": "DEN",
                "date": "Wed, 20 Nov 2024 10:00:00 GMT",
                "departure": "LAX",
```

Figure 10: Sort Indirect Flights by Date

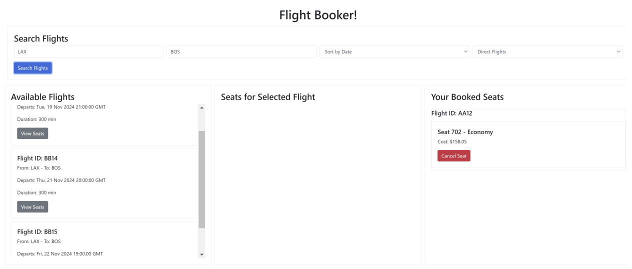
The working results of filtering and sorting indirect flights can be seen in the image above. Whereby the indirect flights view accurately shows all the indirect routes within 2 days from BOS to DEN using the BFS search algorithm detailed above, bubble-sorted by departure time. We can similarly sort using the duration correctly as seen below, where now the second route shown is 6 hours.



http://127.0.0.1:5000/indirect-flights?depart=BOS&sort_by=duration&arrive=DEN

```
[
    {
        "duration": 6.0,
        "route": [
            {
                "arrival": "JFK",
                "date": "Tue, 19 Nov 2024 07:00:00 GMT",
                "departure": "BOS",
                "duration": 120,
                "flight_number": "AA12"
            },
            {
                "arrival": "DEN",
                "date": "Tue, 19 Nov 2024 10:00:00 GMT",
                "departure": "JFK",
                "duration": 180,
                "flight_number": "CC12"
            }
        ]
    },
    {
        "duration": 6.0,
        "route": [
```

Figure 11: Sorted by Duration Indirect Flights



Departs: Tue, 19 Nov 2024 21:00:00 GMT
Duration: 300 min

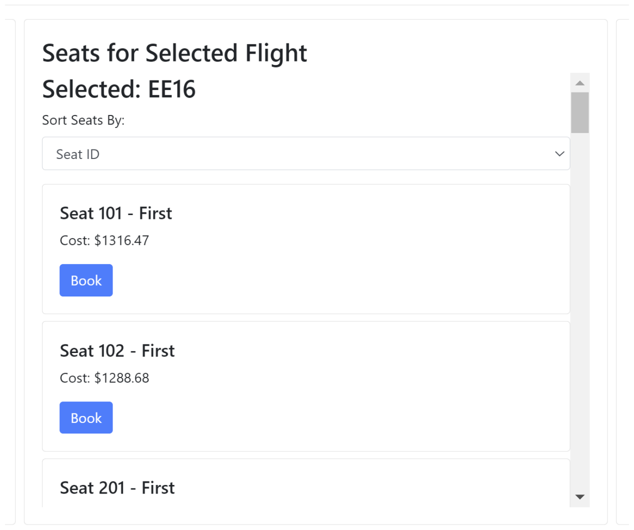
Flight ID: BB14
From: LAX - To: BOS
Departs: Thu, 21 Nov 2024 20:00:00 GMT
Duration: 300 min

Flight ID: BB15
From: LAX - To: BOS
Departs: Fri, 22 Nov 2024 19:00:00 GMT

Flight ID: AA12
Seat 702 - Economy
Cost: $158.05

Figure 12: View Direct Flights from LAX to BOS

The available seats of any Flight can be observed when clicking the ”View Seat Button”, populating the center window as seen below. Users are then given the options to sort these seats at the top of this center window by status, cost, or ID.


Seats for Selected Flight

Selected: EE16

Sort Seats By: Seat ID

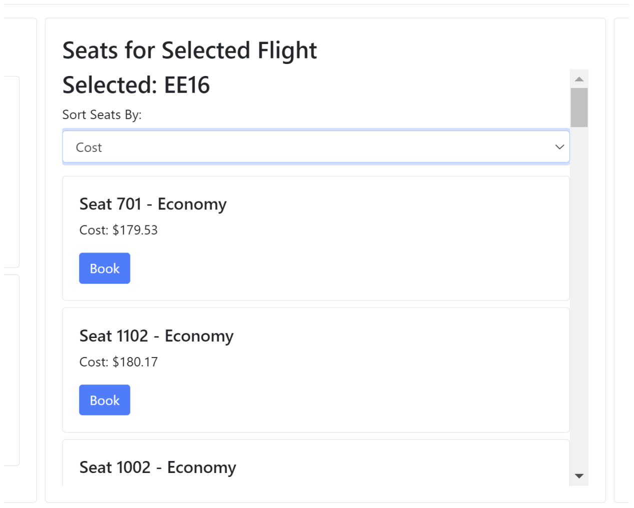
Seat 101 - First
Cost: $1316.47

Seat 102 - First
Cost: $1288.68

Seat 201 - First

Figure 13: Viewing Seats, sorted by ID by default

The Bubble Sort for the singly linked seat nodes working can be seen below where the seats are reorganized by cost, bringing the Economy Seats upwards.


Seats for Selected Flight

Selected: EE16

Sort Seats By: Cost

Seat 701 - Economy
Cost: $179.53

Seat 1102 - Economy
Cost: $180.17

Seat 1002 - Economy

Seats sorted by Cost

Users can accordingly book any seat from this window, thereby removing it from the available seats list and now visible in their singly linked booked seating list window on the right.

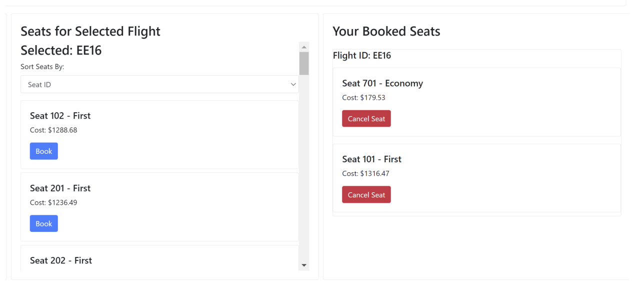


Figure 14: Booked Seats

Similarly, users can cancel any of these seat nodes, bringing them back to the available seating list window, as seen below.

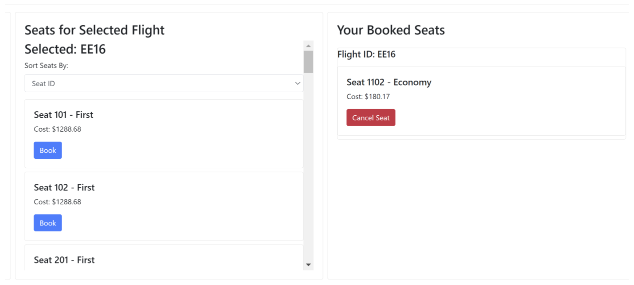


Figure 15: Canceling a Seat, Pushing back to Available List

7 Discussion

The designed Flight Booker accurately handles singly linked lists, lists, dictionaries, breadth first search, and bubble sort. While bubble sort uses O(n^2) time, this sorting was strategically chosen as typically faster sorts like quick sort and merge sort rely on recursive behavior. To simulate large websites with large structures for many flights and seats, recursive behavior can be risky with this many objects since it relies on having space in the stack.
While our final UI behavior is as we had initially expected and outlined, we initially expected our backend to be built with Django. With Django, we had planned for an Admin view and the creation of User groups and resources, but had discovered this to be more complex to design and had moved to using Flask to explicitly define only the endpoints necessary.

8 Conclusion

For building our Flight Booker, we were able to correctly implement a variety of algorithms principles–Singly Linked List construction and methods, Breadth First Search for finding indirect flights, bubble sort of seats and flights, and JSON dictionary objects to enable our backend. Some limitations with our project we resolved with the UI displaying all booked seats of a flight in the right side scroll window, thereby meaning that other users viewing the system would have access to cancel any booked seat. One way to improve this would be to implement a User class that holds the booked seating list and add an endpoint for a User to ”sign-in” to this. Another limitation of the project is that all flights available to the customer are manually populated and crafted, rather than representing real flights. One way to improve this would be to use the Aviation Stack free public API to grab real flights.

9 References

[1] https://www.scaler.com/topics/breadth-first-search-python/
[2] https://startbootstrap.com/templates
[3] https://stackpath.bootstrapcdn.com/bootstrap/4.5.2/css/bootstrap.min.css
[4] https://www.w3schools.com/bootstrap/bootstrap$_{t}emplates.asp$
[5] https://aviationstack.com/