

C950 WGUPS Algorithm Overview

Gabriel Sabella

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C950 Data Structures and Algorithms II

Introduction

The purpose of this assignment is to implement an algorithm that will deliver the required packages while accounting for their given constraints and remaining under the maximum allotted miles, which is 140.

A. Algorithm Identification

The algorithm I chose is a type of greedy algorithm called Nearest Neighbor . This algorithm loops over a list of possible destinations and selects the one that is closest. The selected destination now becomes the reference location, and is removed from the list of possible destinations. The algorithm continues to run until the list of possible destinations is empty.

B1. Logic Comments

The code determines the smallest value in distances by using the min() function in python. This returns the minimum value of an array for example. Min[10,2,15,3] would return 2. The pseudo code has been updated to reflect this.

```
PROCEDURE deliverAllPackages(truck):
    truckSpeed EQUALS 18
    distance_data EQUALS column in distances.csv AT INDEX OF
        truck.currentLocation
    WHILE there are undelivered packages:
        distanceIDs EQUALS []
        distances EQUALS []
        FOR package in trucksPackages:
            IF package is not None
                IF packageStatus is not 'Delivered':
                    APPEND packageDistanceID to distanceIDs
                    APPEND distance_data AT INDEX OF
                        packageDistanceID TO distances
                END IF
            END IF
        END FOR
        closestDistance EQUALS smallest value in distances
        closestDistance EQUALS min(distances)
        packageKey EQUALS INDEX OF closestDistance in distances
        minutesToClosestNeighbor EQUALS closestDistance DIVIDED
            BY truckSpeed AND MULTIPLIED BY 60
        UPDATE previousLocation TO currentLocation
        UPDATE currentLocation TO destination of packageToUpdate
        UPDATE currentTime TO currentTime PLUS
        minutesToClosestNeighbor
```

```

    UPDATE truckMileage TO truckMileage PLUS closestDistance
    deliveredPackage EQUALS package with matching packageKey
        in truckPackages
    UPDATE deliveredPackage TO 'Delivered'
    INSERT deliveredPackage INTO truckPackages
END WHILE
distanceBackToHub EQUALS distances_data at index of
currentLocation
UPDATE truckMileage TO currentMileage PLUS distanceBackToHub
minutesFromHub EQUALS (distanceBackToHub DIVIDED BY
truckSpeed AND MULTIPLIED BY 60)
UPDATE currentTime TO currentTime PLUS minutesFromHub
END PROCEDURE

```

B2. Development Environment

VSCode Version: Version: 1.73.0 (Universal)

Python Version: Python 3.9.7

Hardware: Macbook Air (M1, 2020) running macOS Monterey

The programming environment that I used for this application is Visual Studio Code. I downloaded a few extensions to improve the coding experience. Firstly, I added Code Runner, which makes it possible to compile Python within the VSCode. I also downloaded an extension called Python, which adds IntelliSense. These extensions made for faster coding and more informative error messages.

B3. Space-Time and Big-O

The overall program has a time complexity of $O(n^2)$. The comments within the code analyze each major function.

The delivery algorithm itself is $O(n^2)$ because it loops over a list of distances and then recursively calls itself.

The function that loads distance data into the packages also has a time complexity of $O(n^2)$, as does the function that loads the packages onto the truck. These functions both use nested for loops.

The function that prints all package data is $O(n)$ since it loops over all packages.

The function that prints a single package to the UI is $O(1)$ since it only searches the hash table for a single package.

The hash table has a space complexity of $O(n)$, with each of its functions having an $O(1)$ time complexity (Lysecky, Section 2.6).

B4. Scalability and Adaptability

My solution would have to be updated in order to accommodate more packages. I took the advice of one of my instructors to load the trucks manually, but this is not a scalable solution. I would need to write a function that loads the trucks programmatically based on time constraints and notes. This would be difficult given the range of special cases, like when a package is delayed on flight or can only be on a specific truck, but would be absolutely necessary to make my application scalable.

B5. Software Efficiency and Maintainability

This software has a good structure to build upon and is efficient when compared to similar applications that do not use a hash map. I refactored what was over 500 lines of code to be as minimalistic as I could make it. Having a solid skeleton like this would make this project intuitive to build upon while staying organized as the new features are implemented. The project structure can easily remain organized as utility functions are separated from the package and truck class files.

B6. Self-Adjusting Data Structures

The main strength of the chaining hash table is how fast its data can be interacted with. Having a data structure that can update, remove, and insert data in linear time is a major upside. Another upside is that it is able to handle collisions gracefully. These strengths combined make for an excellent data structure in terms of scalability. A possible downside of this data structure is that there may be wasted space if it is initiated to be larger than necessary to account for future packages. For example, the hash table was implemented to be able to hold thousands of items, it is likely that the majority of its buckets will be empty at times. However, wasted storage is a minor downside given its speed advantages.

C. Original Code

See attached files

C1. Identification Information

See attached files

C2. Process and Flow Comments

See attached files

D. Data Structure

The self adjusting data structure that can be used with the algorithm discussed in part A is the chaining hash table.

D1. Explanation of Data Structure

The hash table used for this project is influenced by the chaining hash table structure described in our Zybooks curriculum (Lysecky, section 7). It implements an insertion function that uses a key-value pair to store and retrieve pieces of information. The hash table for this project has an initial size of forty. The key represents one of its forty ‘buckets’, the value is the object that will be stored in said bucket. For example, to insert package p into hashtable HT: HT.insert(p.ID, p). In this way, the unique package id (p.ID) indicates which bucket the item is stored in.

The hash table accounts for the relationship between the stored data points first by using the ID number. This ID acts as the key that can be used to retrieve the entire package object being stored or one of its specific attributes, such as its destination or deadline.

Any piece of information about any package can be accessed using this model. If one wanted to view the destination of a package with ID 13, they would use the hash table search function to retrieve the entire package (HT.search(13)). They now have access to this entire package object. They could then easily get the destination by adding “.destination” to the end of the search function, for example ht.search(13).destination. This can be accomplished in a similar manner for any of the package attributes, thus the hash table accounts for all relationships between the data points it is storing.

E. Hash Table

See attached project

F. Look-Up Function

See attached project

G. Interface

See attached project

G1. First Status Check

Selecting 'all' and searching for package statuses at 9:15.

```
gabrielsabella@Gabriels-MacBook-Air:~/C958Revision3 % python3 main.py
Hello, welcome to WGUUPS Tracking System. Please enter a time to search by.
Enter hour: 9
Enter minute: 15
Searching for packages at 9:15
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: all
You have chosen to view all packages. Select the hour (military time) and minute to view package info.
You have requested to view all packages at 09:15
Package ID: 1 Delivery Address: 195 W Oakland Ave Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 21 Status: is en-route to 195 W Oakland Ave, and will be delivered at 09:35:24
Package ID: 2 Delivery Address: 2530 S 500 E Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 44 Status: has not yet left the hub, , will be delivered to 2530 S 500 E at 11:03:18
Package ID: 3 Delivery Address: 233 Canyon Rd Deadline: EOD City: Salt Lake City Zip Code: 84103 Weight: 2 Status: was delivered to 233 Canyon Rd at 09:58:24
Package ID: 4 Delivery Address: 380 W 2880 S Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 4 Status: is en-route to 380 W 2880 S, and will be delivered at 09:31:42
Package ID: 5 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 5 Status: is en-route to 410 S State St, and will be delivered at 09:47:06
Package ID: 6 Delivery Address: 3060 Lester St Deadline: 10:30 AM City: West Valley City Zip Code: 84119 Weight: 88 Status: is en-route to 3060 Lester St, and will be delivered at 09:17:24
Package ID: 7 Delivery Address: 1330 2100 S Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 8 Status: has not yet left the hub, , will be delivered to 1330 2100 S at 12:06:09
Package ID: 8 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 1 Status: has not yet left the hub, , will be delivered to 410 S State St at 11:59:24
Package ID: 9 Delivery Address: 380 W 2880 S Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 2 Status: has not yet left the hub, , will be delivered to 410 S State St at 11:51:42
Package ID: 10 Delivery Address: 600 E 900 South Deadline: EOD City: Salt Lake City Zip Code: 84085 Weight: 1 Status: has not yet left the hub, , will be delivered to 600 E 900 South at 11:45:42
Package ID: 11 Delivery Address: 2600 Taylorsville Blvd Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 1 Status: has not yet left the hub, , will be delivered to 2600 Taylorsville Blvd at 12:51:18
Package ID: 12 Delivery Address: 3575 W Valley Central Station bus Loop Deadline: EOD City: West Valley City Zip Code: 84119 Weight: 1 Status: has not yet left the hub, , will be delivered to 3575 W Valley Central Station bus Loop at 12:51:18
...
Package ID: 13 Delivery Address: 2010 W 500 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84104 Weight: 2 Status: is en-route to 2010 W 500 S, and will be delivered at 09:17:48
Package ID: 14 Delivery Address: 4300 S 1300 E Deadline: 10:30 AM City: Millcreek Zip Code: 84117 Weight: 88 Status: was delivered to 4300 S 1300 E at 09:06:18
Package ID: 15 Delivery Address: 4588 S 2300 E Deadline: 10:30 AM City: Holladay Zip Code: 84117 Weight: 88 Status: was delivered to 4588 S 2300 E at 08:13:00
Package ID: 16 Delivery Address: 3148 S 1100 W Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 8 Status: has not yet left the hub, , will be delivered to 3148 S 1100 W at 11:15:42
Package ID: 17 Delivery Address: 1488 4800 S Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 2 Status: has not yet left the hub, , will be delivered to 1488 4800 S, and will be delivered at 10:36:00
Package ID: 18 Delivery Address: 177 W Price Ave Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 37 Status: was delivered to 177 W Price Ave at 08:31:24
Package ID: 19 Delivery Address: 3595 Main St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 37 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 20 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 3 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 21 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 3 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 22 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 3 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 23 Delivery Address: 5100 South 2700 West Deadline: EOD City: Salt Lake City Zip Code: 84117 Weight: 5 Status: has not yet left the hub, , will be delivered to 5100 South 2700 West at 12:50:00
Package ID: 24 Delivery Address: 5025 State St Deadline: EOD City: Murray Zip Code: 84107 Weight: 7 Status: has not yet left the hub, , will be delivered to 5025 State St at 10:33:00
Package ID: 25 Delivery Address: 5383 South 900 East #104 Deadline: 10:30 AM City: Salt Lake City Zip Code: 84117 Weight: 7 Status: was delivered to 5383 South 900 East #104 at 09:13:00
Package ID: 26 Delivery Address: 5383 South 900 East #104 Deadline: EOD City: Salt Lake City Zip Code: 84117 Weight: 25 Status: was delivered to 5383 South 900 East #104 at 09:13:00
Package ID: 27 Delivery Address: 1600 Dalton Ave Deadline: 10:30 AM City: Salt Lake City Zip Code: 84104 Weight: 1 Status: has not yet left the hub, , will be delivered to 1600 Dalton Ave at 11:31:00
Package ID: 28 Delivery Address: 3060 Lester St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 7 Status: has not yet left the hub, , will be delivered to 3060 Lester St at 11:07:00
Package ID: 29 Delivery Address: 1330 2100 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84106 Weight: 2 Status: was delivered to 1330 2100 S at 08:44:06
Package ID: 30 Delivery Address: 306 State St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84103 Weight: 1 Status: was delivered to 306 State St at 09:03:48
Package ID: 31 Delivery Address: 3365 S 900 W Deadline: 10:30 AM City: Salt Lake City Zip Code: 84119 Weight: 1 Status: is en-route to 3365 S 900 W, and will be delivered at 10:12:24
Package ID: 32 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 2 Status: has not yet left the hub, , will be delivered to 3595 Main St at 08:30:18
Package ID: 33 Delivery Address: 4588 S 2300 E Deadline: 10:30 AM City: Holladay Zip Code: 84117 Weight: 2 Status: was delivered to 4588 S 2300 E at 08:13:00
Package ID: 34 Delivery Address: 4588 S 2300 E Deadline: 10:30 AM City: Holladay Zip Code: 84117 Weight: 2 Status: was delivered to 4588 S 2300 E at 08:13:00
Package ID: 35 Delivery Address: 1040 Dalton Ave S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 88 Status: has not yet left the hub, , will be delivered to 1040 Dalton Ave S at 11:31:00
Package ID: 36 Delivery Address: 2300 Parkway Blvd Deadline: EOD City: West Valley City Zip Code: 84119 Weight: 88 Status: is en-route to 2300 Parkway Blvd, and will be delivered at 10:22:42
Package ID: 37 Delivery Address: 410 S State St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84111 Weight: 2 Status: was delivered to 410 S State St at 09:47:06
Package ID: 38 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 9 Status: was delivered to 410 S State St at 09:47:06
Package ID: 39 Delivery Address: 2010 W 500 S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 9 Status: was delivered to 2010 W 500 S at 09:17:48
Package ID: 40 Delivery Address: 380 W 2880 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 45 Status: is en-route to 380 W 2880 S, and will be delivered at 09:31:42
Truck 1 Mileage: 34.2
Truck 2 Mileage: 38.3
Truck 3 Mileage: 38.3
Total Final Mileage: 122.8
gabrielsabella@Gabriels-MacBook-Air:~/C958Revision3 %
```

G2. Second Status Check

Selecting 'all' and searching for package statuses at 10:24.

```
gabrielsabella@Gabriels-MacBook-Air:~/revision3 % python3 main.py
Hello, welcome to WGUUPS Tracking System. Please enter a time to search by.
Enter hour: 10
Enter minute: 24
Searching for packages at 10:24
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: all
You have chosen to view all packages. Select the hour (military time) and minute to view package info.
You have requested to view all packages at 10:24
Package ID: 1 Delivery Address: 195 W Oakland Ave Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 21 Status: was delivered to 195 W Oakland Ave at 09:35:24
Package ID: 2 Delivery Address: 2530 S 500 E Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 44 Status: has not yet left the hub, , will be delivered to 2530 S 500 E at 11:03:18
Package ID: 3 Delivery Address: 233 Canyon Rd Deadline: EOD City: Salt Lake City Zip Code: 84103 Weight: 2 Status: was delivered to 233 Canyon Rd at 09:58:24
Package ID: 4 Delivery Address: 380 W 2880 S Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 4 Status: was delivered to 380 W 2880 S at 09:31:42
Package ID: 5 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 5 Status: was delivered to 410 S State St at 09:47:06
Package ID: 6 Delivery Address: 3060 Lester St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 7 Status: has not yet left the hub, , will be delivered to 3060 Lester St at 10:17:24
Package ID: 7 Delivery Address: 1330 2100 S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 8 Status: has not yet left the hub, , will be delivered to 1330 2100 S at 12:06:00
Package ID: 8 Delivery Address: 306 State St Deadline: EOD City: Salt Lake City Zip Code: 84103 Weight: 9 Status: was delivered to 306 State St at 09:03:48
Package ID: 9 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 8 Status: has not yet left the hub, , will be delivered to 410 S State St at 11:51:42
Package ID: 10 Delivery Address: 600 E 900 South Deadline: EOD City: Salt Lake City Zip Code: 84085 Weight: 1 Status: has not yet left the hub, , will be delivered to 600 E 900 South at 11:45:42
Package ID: 11 Delivery Address: 2600 Taylorsville Blvd Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 1 Status: has not yet left the hub, , will be delivered to 2600 Taylorsville Blvd at 12:51:18
...
Package ID: 12 Delivery Address: 3575 W Valley Central Station bus Loop Deadline: EOD City: West Valley City Zip Code: 84119 Weight: 1 Status: has not yet left the hub, , will be delivered to 3575 W Valley Central Station bus Loop at 12:51:18
Package ID: 13 Delivery Address: 2010 W 500 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84104 Weight: 2 Status: was delivered to 2010 W 500 S at 09:17:48
Package ID: 14 Delivery Address: 4300 S 1300 E Deadline: 10:30 AM City: Millcreek Zip Code: 84117 Weight: 88 Status: was delivered to 4300 S 1300 E at 09:06:18
Package ID: 15 Delivery Address: 4588 S 2300 E Deadline: 9:00 AM City: Holladay Zip Code: 84117 Weight: 4 Status: was delivered to 4588 S 2300 E at 08:13:00
Package ID: 16 Delivery Address: 3148 S 1100 W Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 8 Status: has not yet left the hub, , will be delivered to 3148 S 1100 W at 11:15:42
Package ID: 17 Delivery Address: 1488 4800 S Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 2 Status: has not yet left the hub, , will be delivered to 1488 4800 S, and will be delivered at 10:36:00
Package ID: 18 Delivery Address: 177 W Price Ave Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 37 Status: was delivered to 177 W Price Ave at 08:31:24
Package ID: 19 Delivery Address: 3595 Main St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 37 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 20 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84103 Weight: 3 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 21 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 3 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 22 Delivery Address: 6351 South 900 East Deadline: EOD City: Murray Zip Code: 84121 Weight: 2 Status: has not yet left the hub, , will be delivered to 6351 South 900 East at 10:43:18
Package ID: 23 Delivery Address: 5100 South 2700 West Deadline: EOD City: Salt Lake City Zip Code: 84118 Weight: 5 Status: has not yet left the hub, , will be delivered to 5100 South 2700 West at 12:50:00
Package ID: 24 Delivery Address: 5025 State St Deadline: EOD City: Murray Zip Code: 84107 Weight: 7 Status: has not yet left the hub, , will be delivered to 5025 State St at 10:33:00
Package ID: 25 Delivery Address: 5383 South 900 East #104 Deadline: 10:30 AM City: Salt Lake City Zip Code: 84117 Weight: 7 Status: was delivered to 5383 South 900 East #104 at 09:13:00
Package ID: 26 Delivery Address: 3060 Lester St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 25 Status: was delivered to 3060 Lester St at 09:03:48
Package ID: 27 Delivery Address: 1330 2100 S Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 2 Status: has not yet left the hub, , will be delivered to 1330 2100 S at 08:44:06
Package ID: 28 Delivery Address: 306 State St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84103 Weight: 1 Status: was delivered to 306 State St at 09:03:48
Package ID: 29 Delivery Address: 3365 S 900 W Deadline: 10:30 AM City: Salt Lake City Zip Code: 84119 Weight: 1 Status: is en-route to 3365 S 900 W, and will be delivered at 10:12:24
Package ID: 30 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 5 Status: has not yet left the hub, , will be delivered to 3595 Main St at 08:13:00
Package ID: 31 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 37 Status: was delivered to 3595 Main St at 08:29:42
Package ID: 32 Delivery Address: 3595 Main St Deadline: EOD City: Salt Lake City Zip Code: 84117 Weight: 7 Status: was delivered to 3595 Main St at 08:13:00
Package ID: 33 Delivery Address: 4588 S 2300 E Deadline: 10:30 AM City: Holladay Zip Code: 84117 Weight: 7 Status: was delivered to 4588 S 2300 E at 08:13:00
Package ID: 34 Delivery Address: 4588 S 2300 E Deadline: 10:30 AM City: Holladay Zip Code: 84117 Weight: 7 Status: was delivered to 4588 S 2300 E at 08:13:00
Package ID: 35 Delivery Address: 1040 Dalton Ave S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 88 Status: has not yet left the hub, , will be delivered to 1040 Dalton Ave S at 11:31:00
Package ID: 36 Delivery Address: 2300 Parkway Blvd Deadline: EOD City: West Valley City Zip Code: 84119 Weight: 88 Status: was delivered to 2300 Parkway Blvd at 10:22:42
Package ID: 37 Delivery Address: 410 S State St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84111 Weight: 2 Status: was delivered to 410 S State St at 09:47:06
Package ID: 38 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 9 Status: was delivered to 410 S State St at 09:47:06
Package ID: 39 Delivery Address: 2010 W 500 S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 9 Status: was delivered to 2010 W 500 S at 09:17:48
Package ID: 40 Delivery Address: 380 W 2880 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 45 Status: was delivered to 380 W 2880 S, and will be delivered at 09:31:42
Truck 1 Mileage: 34.2
Truck 2 Mileage: 38.3
Truck 3 Mileage: 38.3
Total Final Mileage: 122.8
gabrielsabella@Gabriels-MacBook-Air:~/revision3 %
```

G3. Third Status Check

Selecting ‘all’ and searching for package statuses at 12:30.

```
gabrielisabelle@Gabriels-MacBook-Air:~/C950Revision3 % python3 main.py
Hello, welcome to WGUPS Tracking System. Please enter a time to search by.
Enter hour: 12
Enter minute: 30
Searching for packages at 12:30
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: all
You have chosen to view all packages. Select the hour (military time) and minute to view package info.
You have requested to view all packages at 12:30
Package ID: 1 Delivery Address: 195 W Oakland Ave Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 21 Status: was delivered to 195 W Oakland Ave at 09:35:24
Package ID: 2 Delivery Address: 2530 S 500 E Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 44 Status: was delivered to 2530 S 500 E at 11:03:18
Package ID: 3 Delivery Address: 233 Canyon Rd Deadline: EOD City: Salt Lake City Zip Code: 84103 Weight: 2 Status: was delivered to 233 Canyon Rd at 09:58:24
Package ID: 4 Delivery Address: 380 W 2880 S Deadline: EOD City: Salt Lake City Zip Code: 84118 Weight: 4 Status: was delivered to 380 W 2880 S at 09:31:42
Package ID: 5 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 5 Status: was delivered to 410 S State St at 09:47:06
Package ID: 6 Delivery Address: 1060 W 2880 S Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 15 Status: was delivered to 1060 W 2880 S at 10:17:24
Package ID: 7 Delivery Address: 1330 2100 S Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 8 Status: was delivered to 1330 2100 S at 12:04:00
Package ID: 8 Delivery Address: 300 State St Deadline: EOD City: Salt Lake City Zip Code: 84103 Weight: 9 Status: was delivered to 300 State St at 09:03:48
Package ID: 9 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 2 Status: was delivered to 410 S State St at 11:51:42
Package ID: 10 Delivery Address: 600 E 900 South Deadline: EOD City: Salt Lake City Zip Code: 84105 Weight: 1 Status: was delivered to 600 E 900 South at 11:45:42
Package ID: 11 Delivery Address: 2600 Taylorsville Blvd Deadline: EOD City: Salt Lake City Zip Code: 84118 Weight: 1 Status: is en-route to 2600 Taylorsville Blvd, and will be delivered at 12:51:18
Package ID: 12 Delivery Address: 3575 W Valley Central Station bus Loop Deadline: EOD City: West Valley City Zip Code: 84119 Weight: 1 Status: was delivered to 3575 W Valley Central Station bus Loop at 12:25:00
Package ID: 13 Delivery Address: 2010 W 500 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84104 Weight: 2 Status: was delivered to 2010 W 500 S at 09:17:48
Package ID: 14 Delivery Address: 4300 S 1300 E Deadline: 10:30 AM City: Millcreek Zip Code: 84117 Weight: 88 Status: was delivered to 4300 S 1300 E at 09:06:18
Package ID: 15 Delivery Address: 4580 S 2300 E Deadline: 9:30 AM City: Holladay Zip Code: 84117 Weight: 4 Status: was delivered to 4580 S 2300 E at 09:13:00
Package ID: 16 Delivery Address: 4580 S 2300 E Deadline: 10:30 AM City: Holladay Zip Code: 84117 Weight: 88 Status: was delivered to 4580 S 2300 E at 09:13:00
Package ID: 17 Delivery Address: 3140 W 1000 S Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 10 Status: was delivered to 3140 W 1000 S at 11:45:42
Package ID: 18 Delivery Address: 440 S 400 N Deadline: EOD City: Salt Lake City Zip Code: 84113 Weight: 6 Status: was delivered to 440 S 400 N at 11:36:42
Package ID: 19 Delivery Address: 177 W Price Ave Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 37 Status: was delivered to 177 W Price Ave at 09:31:24
Package ID: 20 Delivery Address: 3695 Main St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 37 Status: was delivered to 3695 Main St at 09:29:42
Package ID: 21 Delivery Address: 3695 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 2 Status: was delivered to 3695 Main St at 09:29:42
Package ID: 22 Delivery Address: 6351 South 900 East Deadline: EOD City: Murray Zip Code: 84121 Weight: 2 Status: was delivered to 6351 South 900 East at 10:43:18
Package ID: 23 Delivery Address: 5100 South 2700 West Deadline: EOD City: Salt Lake City Zip Code: 84118 Weight: 5 Status: is en-route to 5100 South 2700 West, and will be delivered at 12:50:00
Package ID: 24 Delivery Address: 5025 State St Deadline: EOD City: Murray Zip Code: 84107 Weight: 7 Status: was delivered to 5025 State St at 10:33:00
Package ID: 25 Delivery Address: 5383 South 900 East #104 Deadline: 10:30 AM City: Salt Lake City Zip Code: 84117 Weight: 7 Status: was delivered to 5383 South 900 East #104 at 09:13:00
Package ID: 26 Delivery Address: 5383 South 900 East #104 Deadline: EOD City: Salt Lake City Zip Code: 84117 Weight: 25 Status: was delivered to 5383 South 900 East #104 at 09:13:00
Package ID: 27 Delivery Address: 1060 Dalton Ave S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 5 Status: was delivered to 1060 Dalton Ave S at 11:31:00
Package ID: 28 Delivery Address: 2835 Main St Deadline: EOD City: Salt Lake City Zip Code: 84115 Weight: 7 Status: was delivered to 2835 Main St at 11:07:00
Package ID: 29 Delivery Address: 1330 2100 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84106 Weight: 2 Status: was delivered to 1330 2100 S at 09:46:06
Package ID: 30 Delivery Address: 300 S State St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84103 Weight: 1 Status: was delivered to 300 S State St at 09:03:48
Package ID: 31 Delivery Address: 300 S State St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84103 Weight: 1 Status: was delivered to 300 S State St at 09:03:48
Package ID: 32 Delivery Address: 3345 S 900 W Deadline: EOD City: Salt Lake City Zip Code: 84119 Weight: 1 Status: was delivered to 3345 S 900 W at 10:12:24
Package ID: 33 Delivery Address: 2530 S 500 E Deadline: EOD City: Salt Lake City Zip Code: 84106 Weight: 1 Status: was delivered to 2530 S 500 E at 11:03:18
Package ID: 34 Delivery Address: 4580 S 2300 E Deadline: 10:30 AM City: Holladay Zip Code: 84117 Weight: 2 Status: was delivered to 4580 S 2300 E at 09:13:00
Package ID: 35 Delivery Address: 1060 Dalton Ave S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 88 Status: was delivered to 1060 Dalton Ave S at 11:31:00
Package ID: 36 Delivery Address: 2300 Parkway Blvd Deadline: EOD City: West Valley City Zip Code: 84119 Weight: 88 Status: was delivered to 2300 Parkway Blvd at 10:22:42
Package ID: 37 Delivery Address: 410 S State St Deadline: 10:30 AM City: Salt Lake City Zip Code: 84111 Weight: 2 Status: was delivered to 410 S State St at 09:47:06
Package ID: 38 Delivery Address: 410 S State St Deadline: EOD City: Salt Lake City Zip Code: 84111 Weight: 9 Status: was delivered to 410 S State St at 09:47:06
Package ID: 39 Delivery Address: 2010 W 500 S Deadline: EOD City: Salt Lake City Zip Code: 84104 Weight: 9 Status: was delivered to 2010 W 500 S at 09:17:48
Package ID: 40 Delivery Address: 380 W 2880 S Deadline: 10:30 AM City: Salt Lake City Zip Code: 84115 Weight: 45 Status: was delivered to 380 W 2880 S at 09:31:42
Truck 1 Mileage: 34.2
Truck 2 Mileage: 38.3
Truck 3 Mileage: 50.3
Total Final Mileage: 122.8
gabrielisabelle@Gabriels-MacBook-Air:~/C950Revision3 %
```

H. Screenshots of Code Execution

The following screenshots show searching by all required search functions, including packageID, delivery address, delivery deadline, city, zip code, weight, and status.

Searching by package ID:

```
gabrielisabelle@Gabriels-MacBook-Air:~/C950Revision3 % python3 main.py
Hello, welcome to WGUPS Tracking System. Please enter a time to search by.
Enter hour: 10
Enter minute: 30
Searching for packages at 10:30
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: package
You have chosen to search for packages by one of their attributes. Use the following list to choose which attribute to search by. First enter a time, then choose one of the following search options.
1 - Search by ID
2 - Search by delivery address
3 - Search by deadline
4 - Search by city
5 - Search by zipcode
6 - Search by weight
7 - Search by status
Please choose an attribute to search by: 1
Enter an ID: 15
Package ID: 15 | City: Holladay | State: UT | Zipcode: 84117| Deadline: 9:00 AM | Weight: 4 | Status: Delivered at 08:13:00 | Delivery Address: 4580 S 2300 E
gabrielisabelle@Gabriels-MacBook-Air:~/C950Revision3 %
```

Searching by delivery address:

```
[gabrielsabella@Gabriels-MacBook-Air C950Revision3 % python3 main.py
Hello, welcome to WGUUPS Tracking System. Please enter a time to search by.
Enter hour: 10
Enter minute: 45
Searching for packages at 10:45
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: package
You have chosen to search for packages by one of their attributes. Use the following list to choose which attribute to search by. First enter a time, then choose one of the following search options.
1 - Search by ID
2 - Search by delivery address
3 - Search by deadline
4 - Search by city
5 - Search by zipcode
6 - Search by weight
7 - Search by status
Please choose an attribute to search by: 2
Enter a delivery address, for example "410 S State St" (case sensitive): 410 S State St
You have selected to view packages being delivered to 410 S State St
Package ID: 5 | City: Salt Lake City | State: UT | Zipcode: 84111| Deadline: EOD | Weight: 5 | Status: Delivered at 09:47:06 | Delivery Address: 410 S State St
Package ID: 9 | City: Salt Lake City | State: UT | Zipcode: 84111| Deadline: EOD | Weight: 2 | Status: En-route, will be delivered at 11:51:42 | Delivery Address: 410 S State St
Package ID: 37 | City: Salt Lake City | State: UT | Zipcode: 84111| Deadline: 10:38 AM | Weight: 2 | Status: Delivered at 09:47:06 | Delivery Address: 410 S State St
Package ID: 38 | City: Salt Lake City | State: UT | Zipcode: 84111| Deadline: EOD | Weight: 9 | Status: Delivered at 09:47:06 | Delivery Address: 410 S State St
gabrielsabella@Gabriels-MacBook-Air C950Revision3 % ]
```

Searching by deadline:

```
[gabrielsabella@Gabriels-MacBook-Air C950Revision3 % python3 main.py
Hello, welcome to WGUUPS Tracking System. Please enter a time to search by.
Enter hour: 9
Enter minute: 30
Searching for packages at 09:30
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: package
You have chosen to search for packages by one of their attributes. Use the following list to choose which attribute to search by. First enter a time, then choose one of the following search options.
1 - Search by ID
2 - Search by delivery address
3 - Search by deadline
4 - Search by city
5 - Search by zipcode
6 - Search by weight
7 - Search by status
Please choose an attribute to search by: 3
Enter delivery deadline, example "9:00 AM" or "EOD": 10:30 AM
Package ID: 1 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: 10:30 AM | Weight: 21 | Status: En-route, will be delivered at 09:35:24 | Delivery Address: 195 W Oakland Ave
Package ID: 6 | City: West Valley City | State: UT | Zipcode: 84119| Deadline: 10:30 AM | Weight: 88 | Status: En-route, will be delivered at 10:17:24 | Delivery Address: 3060 Lester St
Package ID: 13 | City: Salt Lake City | State: UT | Zipcode: 84104| Deadline: 10:30 AM | Weight: 2 | Status: Delivered at 09:17:48 | Delivery Address: 2010 W 500 S
Package ID: 14 | City: Millcreek | State: UT | Zipcode: 84117| Deadline: 10:30 AM | Weight: 88 | Status: Delivered at 08:06:18 | Delivery Address: 4300 S 1300 E
Package ID: 16 | City: Holladay | State: UT | Zipcode: 84117| Deadline: 10:30 AM | Weight: 88 | Status: Delivered at 08:13:00 | Delivery Address: 4500 S 2300 E
Package ID: 28 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: 10:30 AM | Weight: 37 | Status: Delivered at 08:29:42 | Delivery Address: 3595 Main St
Package ID: 29 | City: Salt Lake City | State: UT | Zipcode: 84104| Deadline: 10:30 AM | Weight: 2 | Status: Delivered at 09:17:48 | Delivery Address: 3365 South 900 East #104
Package ID: 30 | City: Salt Lake City | State: UT | Zipcode: 84046| Deadline: 10:30 AM | Weight: 2 | Status: Delivered at 09:44:23 | Delivery Address: 195 W 100 S
Package ID: 39 | City: Salt Lake City | State: UT | Zipcode: 84103| Deadline: 10:30 AM | Weight: 1 | Status: Delivered at 09:03:48 | Delivery Address: 300 State St
Package ID: 31 | City: Salt Lake City | State: UT | Zipcode: 84119| Deadline: 10:30 AM | Weight: 1 | Status: En-route, will be delivered at 10:12:24 | Delivery Address: 3365 S 900 W
Package ID: 34 | City: Holladay | State: UT | Zipcode: 84117| Deadline: 10:30 AM | Weight: 2 | Status: Delivered at 08:13:00 | Delivery Address: 4500 S 2300 E
Package ID: 37 | City: Salt Lake City | State: UT | Zipcode: 84111| Deadline: 10:30 AM | Weight: 2 | Status: En-route, will be delivered at 09:47:06 | Delivery Address: 410 S State St
Package ID: 40 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: 10:30 AM | Weight: 45 | Status: En-route, will be delivered at 09:31:42 | Delivery Address: 300 W 2800 S
gabrielsabella@Gabriels-MacBook-Air C950Revision3 % ]
```

Searching by city:

```
[gabrielsabella@Gabriels-MacBook-Air C950Revision3 % python3 main.py
Hello, welcome to WGUUPS Tracking System. Please enter a time to search by.
Enter hour: 10
Enter minute: 30
Searching for packages at 10:30
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: package
You have chosen to search for packages by one of their attributes. Use the following list to choose which attribute to search by. First enter a time, then choose one of the following search options.
1 - Search by ID
2 - Search by delivery address
3 - Search by deadline
4 - Search by city
5 - Search by zipcode
6 - Search by weight
7 - Search by status
Please choose an attribute to search by: 4
Enter city, for example "Murray" or "Salt Lake City": Murray
Package ID: 22 | City: Murray | State: UT | Zipcode: 84121| Deadline: EOD | Weight: 2 | Status: En-route, will be delivered at 10:43:18 | Delivery Address: 6351 South 900 East
Package ID: 24 | City: Murray | State: UT | Zipcode: 84107| Deadline: EOD | Weight: 7 | Status: En-route, will be delivered at 10:33:00 | Delivery Address: 5025 State St
gabrielsabella@Gabriels-MacBook-Air C950Revision3 % ]
```

Searching by zip code:

```
[gabrielsabella@Gabriels-MacBook-Air C950Revision3 % python3 main.py
Hello, welcome to WGUUPS Tracking System. Please enter a time to search by.
Enter hour: 9
Enter minute: 45
Searching for packages at 09:45
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: package
You have chosen to search for packages by one of their attributes. Use the following list to choose which attribute to search by. First enter a time, then choose one of the following search options.
1 - Search by ID
2 - Search by delivery address
3 - Search by deadline
4 - Search by city
5 - Search by zipcode
6 - Search by weight
7 - Search by status
Please choose an attribute to search by: 5
Enter zipcode, for example "84115": 84115
Package ID: 1 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: 10:30 AM | Weight: 21 | Status: Delivered at 09:35:24 | Delivery Address: 195 W Oakland Ave
Package ID: 1 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: EOD | Weight: 4 | Status: Delivered at 09:31:42 | Delivery Address: 388 W 2800 S
Package ID: 19 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: EOD | Weight: 37 | Status: Delivered at 08:31:24 | Delivery Address: 177 W Price Ave
Package ID: 20 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: 10:30 AM | Weight: 37 | Status: Delivered at 08:29:42 | Delivery Address: 3595 Main St
Package ID: 21 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: EOD | Weight: 3 | Status: Delivered at 08:29:42 | Delivery Address: 3595 Main St
Package ID: 28 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: EOD | Weight: 7 | Status: At the hub, will be delivered at | Delivery Address: 2835 Main St
Package ID: 40 | City: Salt Lake City | State: UT | Zipcode: 84115| Deadline: 10:30 AM | Weight: 45 | Status: Delivered at 09:31:42 | Delivery Address: 388 W 2800 S
gabrielsabella@Gabriels-MacBook-Air C950Revision3 % ]
```

Searching by package weight:

```
gabrielsabellas@Gabriels-MacBook-Air C950Revision3 % python3 main.py
Hello, welcome to WGUPS Tracking System. Please enter a time to search by.
Enter hour: 10
Enter minute: 15
Searching for packages at 10:15
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: package
You have chosen to search for packages by one of their attributes. Use the following list to choose which attribute to search by. First enter a time, then choose one of the following search options.
1 - Search by ID
2 - Search by delivery address
3 - Search by deadline
4 - Search by city
5 - Search by zipcode
6 - Search by weight
7 - Search by status
Please choose an attribute to search by: 6
Enter package weight, for example "9": 9
Package ID: 8 | City: Salt Lake City | State: UT | Zipcode: 84103| Deadline: EOD | Weight: 9 | Status: Delivered at 09:03:48 | Delivery Address: 300 State St
Package ID: 38 | City: Salt Lake City | State: UT | Zipcode: 84111| Deadline: EOD | Weight: 9 | Status: Delivered at 09:47:06 | Delivery Address: 410 S State St
Package ID: 39 | City: Salt Lake City | State: UT | Zipcode: 84104| Deadline: EOD | Weight: 9 | Status: Delivered at 09:17:48 | Delivery Address: 2010 W 500 S
gabrielsabellas@Gabriels-MacBook-Air C950Revision3 %
```

Searching by package status

```
gabrielsabellas@Gabriels-MacBook-Air C950Revision3 % python3 main.py
Hello, welcome to WGUPS Tracking System. Please enter a time to search by.
Enter hour: 
Enter minute: 12
Searching for packages at 09:12
To view all packages at once, type 'all'. To search for packages by their attributes, type anything else: package
You have chosen to search for packages by one of their attributes. Use the following list to choose which attribute to search by. First enter a time, then choose one of the following search options.
1 - Search by ID
2 - Search by delivery address
3 - Search by deadline
4 - Search by city
5 - Search by zipcode
6 - Search by weight
7 - Search by status
Please choose an attribute to search by: 7
Enter deadline, for example "10:00 AM", "en-route", or "delivered": en-route
Package ID: 1 City: Salt Lake City State: UT Zipcode: 84115 Deadline: 10:30 AM Weight: 21 Status: en-route, will be delivered at 09:35:24 Delivery Address: 195 W Oakland Ave
Package ID: 3 City: Salt Lake City State: UT Zipcode: 84103 Deadline: EOD Weight: 2 Status: en-route, will be delivered at 09:50:24 Delivery Address: 233 Canyon Rd
Package ID: 4 City: Salt Lake City State: UT Zipcode: 84115 Deadline: EOD Weight: 4 Status: en-route, will be delivered at 09:31:42 Delivery Address: 380 W 2880 S
Package ID: 5 City: Salt Lake City State: UT Zipcode: 84111 Deadline: EOD Weight: 5 Status: en-route, will be delivered at 09:47:06 Delivery Address: 410 S State St
Package ID: 13 City: West Valley City State: UT Zipcode: 84119 Deadline: 10:30 AM Weight: 88 Status: en-route, will be delivered at 10:17:24 Delivery Address: 3068 Lester St
Package ID: 13 City: Salt Lake City State: UT Zipcode: 84104 Deadline: 10:30 AM Weight: 2 Status: en-route, will be delivered at 09:17:48 Delivery Address: 2010 W 500 S
Package ID: 18 City: Salt Lake City State: UT Zipcode: 84123 Deadline: EOD Weight: 6 Status: en-route, will be delivered at 10:36:00 Delivery Address: 1488 4800 S
Package ID: 25 City: Salt Lake City State: UT Zipcode: 84117 Deadline: 10:30 AM Weight: 7 Status: en-route, will be delivered at 09:13:00 Delivery Address: 5383 South 900 East #104
Package ID: 26 City: Salt Lake City State: UT Zipcode: 84117 Deadline: EOD Weight: 25 Status: en-route, will be delivered at 09:13:00 Delivery Address: 5383 South 900 East #104
Package ID: 31 City: Salt Lake City State: UT Zipcode: 84119 Deadline: 10:30 AM Weight: 1 Status: en-route, will be delivered at 10:12:24 Delivery Address: 3365 S 900 W
Package ID: 32 City: Salt Lake City State: UT Zipcode: 84119 Deadline: EOD Weight: 1 Status: en-route, will be delivered at 10:12:24 Delivery Address: 3365 S 900 W
Package ID: 34 City: West Valley City State: UT Zipcode: 84119 Deadline: EOD Weight: 88 Status: en-route, will be delivered at 10:22:42 Delivery Address: 2300 Parkway Blvd
Package ID: 37 City: Salt Lake City State: UT Zipcode: 84115 Deadline: 10:30 AM Weight: 2 Status: en-route, will be delivered at 09:47:06 Delivery Address: 410 S State St
Package ID: 38 City: Salt Lake City State: UT Zipcode: 84111 Deadline: EOD Weight: 9 Status: en-route, will be delivered at 09:50:24 Delivery Address: 233 Canyon Rd
Package ID: 40 City: Salt Lake City State: UT Zipcode: 84104 Deadline: EOD Weight: 9 Status: en-route, will be delivered at 09:17:48 Delivery Address: 2010 W 500 S
Package ID: 40 City: Salt Lake City State: UT Zipcode: 84115 Deadline: 10:30 AM Weight: 45 Status: en-route, will be delivered at 09:31:42 Delivery Address: 380 W 2880 S
gabrielsabellas@Gabriels-MacBook-Air C950Revision3 %
```

11. Strengths of Chosen Algorithm

The reason I chose the nearest neighbor algorithm is that it is the only algorithm I intuitively understood at the start of the project. I knew that I could find a more efficient algorithm, but decided I would improve more at programming if I implemented the algorithm myself. One of the strengths of the nearest neighbor algorithm is that it will be able to handle an increasing size of data and is fairly efficient. In general this algorithm is incredibly versatile and can be adapted to meet changing needs. Another strength is that it is easy to understand. This would be a huge strength if this were a production application with an ever changing team, as new developers would have a fast learning curve and would be able to contribute more quickly.

12. Verification of Algorithm

The algorithm used in the solution meets all requirements because each of the packages are delivered before their deadline. All of the package constraints are also accounted for, such as which packages must be on a certain truck or be on the same truck as another package. I also made sure the trucks departed at times that accounted for any special cases, for example with package number 9 that had an incorrect address until 10:20. The trucks all contained fewer than 16 packages, and delivered all packages in 122.8 miles total.

I3. Other possible Algorithms

Two other algorithms that also be used for this assignment are Dijkstra's shortest path or some form of insertion algorithm, such as farthest insertion.

I3A. Algorithm Differences

Dijkstra's algorithm is different from the nearest neighbor in that it begins from the source node (in this case the hub) and calculates the shortest distances between it and all other nodes on the graph (Ginting, 3). This algorithm uses weighted edges between each vertex, which are the pieces of distance data associated with each destination for this project. This would more than likely find a more optimal solution than the nearest neighbor.

J. Different Approach

Like the name suggests, the farthest insertion algorithm starts with the starting point and the destination that is farthest away. What makes this algorithm find an efficient path is that it incorporates those out of the way cities first, which eventually leads to an optimal path (Mumford, 1). This algorithm would also find a much more efficient route than the nearest neighbor, and would be the one I would choose were I to do this assignment again.

K1. Verification of Data Structure

If I were to do this project again, I would firstly write a function to load the trucks based on time constraints and proximity to one another. I did not give any weight to route optimization for this submission; I was more focused on practicing object oriented programming in Python, which I had no previous experience with. I would also focus on writing code that could adapt to new data, such as more packages, deadlines, available trucks/drivers, or constraints. These things would be my top priorities were I to give this another go.

K1A. Efficiency

The chaining hash table is a great option for this assignment. It is efficient and is able to be used to load/update packages as needed. The biggest justification for this data structure is that all packages were delivered on time taking into account all constraints. The time needed to complete the look-up function for packages would not change with more or less packages since hash tables perform searches in $O(1)$ time on average. If the table were way too small for the number of packages, the worst case scenario is a search that takes $O(n)$ time, which is not terrible when compared to other data structures.

K1B. Overhead

The amount of space usage of a hashmap changes proportionally to the number of packages to be delivered since hash tables have a space complexity of $O(n)$.

K1C. Implications

Changes to the number of trucks would increase space usage proportionately to the number of trucks in the WGUPS fleet, as each truck has its own list of packages to deliver. Adding cities, however, would increase space usage exponentially, since each destination references one another in the delivery algorithm. The look-up function would remain $O(1)$ regardless of these changes.

K2. Other Data Structures

Alternatives to the hash map that would also work for this application would be a binary search tree or some type of queue.

K2a. Data Structure Differences

The binary search tree completes all the same operations as the hash map in $O(\log n)$ time. Although all of these common operations are generally less efficient, binary search trees always perform them at this rate whereas hash maps can be slower in their worst case. Binary search trees are also more memory efficient and will never have to be resized.

A queue would have similar time complexity as a hash table since they are $O(1)$, and would have a more efficient space complexity at $O(1)$ when compared to hash tables which are $O(n)$. However, the disadvantages of queues may outweigh the efficient space complexity, such as having to delete an element in order to add a new one.

M. Professional Communication

L. Sources - Works Cited

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