

## C950 Task-2 WGUPS Write-Up

(Task-2: The implementation phase of the WGUPS Routing Program).

(Zip your source code and upload it with this file)

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C950 Data Structures and Algorithms II

D1. First Status Check

First status check at 8:45.

```
4. Exit
-----
3
Enter a time to check (HH:MM). 8:45

Delivered items:
Package ID | Address | Weight | Truck | Deadline | Status
1 | 195 W Oakland Ave, Salt Lake City, UT, 84115 | 21kgs | 1 | 10:30 AM | Delivered at 08:37:20
4 | 380 W 2800 S, Salt Lake City, UT, 84115 | 4kgs | 1 | EOD | Delivered at 08:41:00
7 | 1330 2100 S, Salt Lake City, UT, 84106 | 8kgs | 1 | EOD | Delivered at 08:28:00
12 | 3575 W Valley Central Station bus Loop, West Valley City, UT, 84119 | 1kgs | 2 | EOD | Delivered at 08:36:00
14 | 4300 S 1300 E, Millcreek, UT, 84117 | 88kgs | 2 | 10:30 AM | Delivered at 08:06:20
15 | 4580 S 2300 E, Holladay, UT, 84117 | 4kgs | 1 | 9:00 AM | Delivered at 08:11:20
16 | 4580 S 2300 E, Holladay, UT, 84117 | 88kgs | 2 | 10:30 AM | Delivered at 08:13:00
19 | 177 W Price Ave, Salt Lake City, UT, 84115 | 37kgs | 2 | EOD | Delivered at 08:31:20
20 | 3595 Main St, Salt Lake City, UT, 84115 | 37kgs | 2 | 10:30 AM | Delivered at 08:29:40
21 | 3595 Main St, Salt Lake City, UT, 84115 | 3kgs | 2 | EOD | Delivered at 08:29:40
29 | 1330 2100 S, Salt Lake City, UT, 84106 | 2kgs | 1 | 10:30 AM | Delivered at 08:28:00
34 | 4580 S 2300 E, Holladay, UT, 84117 | 2kgs | 1 | 10:30 AM | Delivered at 08:11:20
40 | 380 W 2800 S, Salt Lake City, UT, 84115 | 45kgs | 1 | 10:30 AM | Delivered at 08:41:00

Packages on truck 1:
Package ID | Address | Weight | Truck | Deadline | Status
5 | 410 S State St, Salt Lake City, UT, 84111 | 5kgs | 1 | EOD | En Route
30 | 300 State St, Salt Lake City, UT, 84103 | 1kgs | 1 | 10:30 AM | En Route
31 | 3365 S 900 W, Salt Lake City, UT, 84119 | 1kgs | 1 | 10:30 AM | En Route
37 | 410 S State St, Salt Lake City, UT, 84111 | 2kgs | 1 | 10:30 AM | En Route

Packages on truck 2:
Package ID | Address | Weight | Truck | Deadline | Status
2 | 2530 S 500 E, Salt Lake City, UT, 84106 | 44kgs | 2 | EOD | En Route
3 | 233 Canyon Rd, Salt Lake City, UT, 84103 | 2kgs | 2 | EOD | En Route
10 | 600 E 900 South, Salt Lake City, UT, 84105 | 1kgs | 2 | EOD | En Route
13 | 2010 W 500 S, Salt Lake City, UT, 84104 | 2kgs | 2 | 10:30 AM | En Route
17 | 3140 S 1100 W, Salt Lake City, UT, 84119 | 2kgs | 2 | EOD | En Route
18 | 1480 4000 S, Salt Lake City, UT, 84123 | 6kgs | 2 | EOD | En Route
33 | 2530 S 500 E, Salt Lake City, UT, 84106 | 1kgs | 2 | EOD | En Route
36 | 2300 Parkway Blvd, West Valley City, UT, 84119 | 88kgs | 2 | EOD | En Route
38 | 410 S State St, Salt Lake City, UT, 84111 | 9kgs | 2 | EOD | En Route
39 | 2010 W 500 S, Salt Lake City, UT, 84104 | 9kgs | 2 | EOD | En Route

Packages on truck 3:
Package ID | Address | Weight | Truck | Deadline | Status
6 | 3060 Lester St, West Valley City, UT, 84119 | 88kgs | 3 | 10:30 AM | At the hub
8 | 300 State St, Salt Lake City, UT, 84103 | 9kgs | 3 | EOD | At the hub
9 | 410 S State St, Salt Lake City, UT, 84103 | 2kgs | 3 | EOD | At the hub
11 | 2600 Taylorsville Blvd, Salt Lake City, UT, 84118 | 1kgs | 3 | EOD | At the hub
22 | 6351 South 900 East, Murray, UT, 84121 | 2kgs | 3 | EOD | At the hub
23 | 5100 South 2700 West, Salt Lake City, UT, 84118 | 5kgs | 3 | EOD | At the hub
24 | 5025 State St, Murray, UT, 84107 | 7kgs | 3 | EOD | At the hub
25 | 5383 South 900 East #104, Salt Lake City, UT, 84117 | 7kgs | 3 | 10:30 AM | At the hub
26 | 5383 South 900 East #104, Salt Lake City, UT, 84117 | 25kgs | 3 | EOD | At the hub
27 | 1060 Dalton Ave S, Salt Lake City, UT, 84104 | 5kgs | 3 | EOD | At the hub
28 | 2835 Main St, Salt Lake City, UT, 84115 | 7kgs | 3 | EOD | At the hub
32 | 3365 S 900 W, Salt Lake City, UT, 84119 | 1kgs | 3 | EOD | At the hub
35 | 1060 Dalton Ave S, Salt Lake City, UT, 84104 | 88kgs | 3 | EOD | At the hub
```

## D2. Second Status Check

### Second status check at 10:00

```
1. Print all packages and total miles
2. Get a single package with a time
3. Get all packages with a time
4. Exit
-----
3
Enter a time to check (HH:MM). 10:00

Delivered items:
Package ID | Address | Weight | Truck | Deadline | Status
1 | 195 W Oakland Ave, Salt Lake City, UT, 84115 | 21kgs | 1 | 10:30 AM | Delivered at 08:37:20
2 | 2530 S 500 E, Salt Lake City, UT, 84106 | 44kgs | 2 | E00 | Delivered at 09:09:40
3 | 233 Canyon Rd, Salt Lake City, UT, 84103 | 2kgs | 2 | E00 | Delivered at 09:29:40
4 | 380 W 2880 S, Salt Lake City, UT, 84115 | 4kgs | 1 | E00 | Delivered at 08:41:00
5 | 410 S State St, Salt Lake City, UT, 84111 | 5kgs | 1 | E00 | Delivered at 09:08:00
7 | 1330 2100 S, Salt Lake City, UT, 84106 | 8kgs | 1 | E00 | Delivered at 08:28:00
10 | 600 E 900 South, Salt Lake City, UT, 84105 | 1kgs | 2 | E00 | Delivered at 09:28:20
12 | 3575 W Valley Central Station bus Loop, West Valley City, UT, 84119 | 1kgs | 2 | E00 | Delivered at 08:36:00
13 | 2010 W 500 S, Salt Lake City, UT, 84104 | 2kgs | 2 | 10:30 AM | Delivered at 09:43:40
14 | 4300 S 1300 E, Millcreek, UT, 84117 | 88kgs | 2 | 10:30 AM | Delivered at 08:06:20
15 | 4580 S 2300 E, Holladay, UT, 84117 | 4kgs | 1 | 9:00 AM | Delivered at 08:11:20
16 | 4580 S 2300 E, Holladay, UT, 84117 | 88kgs | 2 | 10:30 AM | Delivered at 08:13:00
17 | 3148 S 1100 W, Salt Lake City, UT, 84119 | 2kgs | 2 | E00 | Delivered at 08:57:20
19 | 177 W Price Ave, Salt Lake City, UT, 84115 | 37kgs | 2 | E00 | Delivered at 08:31:20
20 | 3595 Main St, Salt Lake City, UT, 84115 | 37kgs | 2 | 10:30 AM | Delivered at 08:29:40
21 | 3595 Main St, Salt Lake City, UT, 84115 | 3kgs | 2 | E00 | Delivered at 08:29:40
22 | 6351 South 900 East, Murray, UT, 84121 | 2kgs | 3 | E00 | Delivered at 09:49:00
24 | 5025 State St, Murray, UT, 84107 | 7kgs | 3 | E00 | Delivered at 09:59:20
25 | 5383 South 900 East #104, Salt Lake City, UT, 84117 | 7kgs | 3 | 10:30 AM | Delivered at 09:44:40
26 | 5383 South 900 East #104, Salt Lake City, UT, 84117 | 25kgs | 3 | E00 | Delivered at 09:44:40
29 | 1330 2100 S, Salt Lake City, UT, 84106 | 2kgs | 1 | 10:30 AM | Delivered at 08:28:00
30 | 300 State St, Salt Lake City, UT, 84103 | 1kgs | 1 | 10:30 AM | Delivered at 09:11:20
31 | 3365 S 900 W, Salt Lake City, UT, 84119 | 1kgs | 1 | 10:30 AM | Delivered at 08:46:40
33 | 2530 S 500 E, Salt Lake City, UT, 84106 | 1kgs | 2 | E00 | Delivered at 09:09:40
34 | 4580 S 2300 E, Holladay, UT, 84117 | 2kgs | 1 | 10:30 AM | Delivered at 08:11:20
36 | 2300 Parkway Blvd, West Valley City, UT, 84119 | 88kgs | 2 | E00 | Delivered at 08:46:20
37 | 410 S State St, Salt Lake City, UT, 84111 | 2kgs | 1 | 10:30 AM | Delivered at 09:08:00
38 | 410 S State St, Salt Lake City, UT, 84111 | 9kgs | 2 | E00 | Delivered at 09:26:20
39 | 2010 W 500 S, Salt Lake City, UT, 84104 | 9kgs | 2 | E00 | Delivered at 09:43:40
40 | 380 W 2880 S, Salt Lake City, UT, 84115 | 45kgs | 1 | 10:30 AM | Delivered at 08:41:00

Packages on truck 2:
Package ID | Address | Weight | Truck | Deadline | Status
18 | 1408 4800 S, Salt Lake City, UT, 84123 | 6kgs | 2 | E00 | En Route

Packages on truck 3:
Package ID | Address | Weight | Truck | Deadline | Status
6 | 3060 Lester St, West Valley City, UT, 84119 | 88kgs | 3 | 10:30 AM | En Route
8 | 300 State St, Salt Lake City, UT, 84103 | 9kgs | 3 | E00 | En Route
9 | 410 S State St, Salt Lake City, UT, 84103 | 2kgs | 3 | E00 | En Route
11 | 2600 Taylorsville Blvd, Salt Lake City, UT, 84118 | 1kgs | 3 | E00 | En Route
23 | 5100 South 2700 West, Salt Lake City, UT, 84118 | 5kgs | 3 | E00 | En Route
27 | 1060 Dalton Ave S, Salt Lake City, UT, 84104 | 5kgs | 3 | E00 | En Route
28 | 2835 Main St, Salt Lake City, UT, 84115 | 7kgs | 3 | E00 | En Route
32 | 3365 S 900 W, Salt Lake City, UT, 84119 | 1kgs | 3 | E00 | En Route
35 | 1060 Dalton Ave S, Salt Lake City, UT, 84104 | 88kgs | 3 | E00 | En Route
```

## D3. Third Status Check

### Third check at 12:30

```
-----
1. Print all packages and total miles
2. Get a single package with a time
3. Get all packages with a time
4. Exit
-----
3
Enter a time to check (HH:MM). 12:30

Delivered items:
Package ID | Address | Weight | Truck | Deadline | Status
1 | 195 W Oakland Ave, Salt Lake City, UT, 84115 | 21kgs | 1 | 10:30 AM | Delivered at 08:37:20
2 | 2530 S 500 E, Salt Lake City, UT, 84106 | 44kgs | 2 | E00 | Delivered at 09:09:40
3 | 233 Canyon Rd, Salt Lake City, UT, 84103 | 2kgs | 2 | E00 | Delivered at 09:29:40
4 | 300 W 2800 S, Salt Lake City, UT, 84115 | 4kgs | 1 | E00 | Delivered at 08:41:00
5 | 410 S State St, Salt Lake City, UT, 84111 | 5kgs | 1 | E00 | Delivered at 09:08:00
6 | 3060 Lester St, West Valley City, UT, 84119 | 88kgs | 3 | 10:30 AM | Delivered at 10:25:20
7 | 1330 2100 S, Salt Lake City, UT, 84106 | 8kgs | 1 | E00 | Delivered at 08:28:00
8 | 300 State St, Salt Lake City, UT, 84103 | 9kgs | 3 | E00 | Delivered at 10:51:20
9 | 410 S State St, Salt Lake City, UT, 84103 | 2kgs | 3 | E00 | Delivered at 10:54:40
10 | 600 E 900 South, Salt Lake City, UT, 84105 | 1kgs | 2 | E00 | Delivered at 09:20:20
11 | 2600 Taylorsville Blvd, Salt Lake City, UT, 84118 | 1kgs | 3 | E00 | Delivered at 11:34:00
12 | 3575 W Valley Central Station bus Loop, West Valley City, UT, 84119 | 1kgs | 2 | E00 | Delivered at 08:36:00
13 | 2010 W 500 S, Salt Lake City, UT, 84104 | 2kgs | 2 | 10:30 AM | Delivered at 09:43:40
14 | 4300 S 1300 E, Millcreek, UT, 84117 | 88kgs | 2 | 10:30 AM | Delivered at 08:06:20
15 | 4500 S 2300 E, Holladay, UT, 84117 | 4kgs | 1 | 9:00 AM | Delivered at 08:11:20
16 | 4500 S 2300 E, Holladay, UT, 84117 | 88kgs | 2 | 10:30 AM | Delivered at 08:13:00
17 | 3148 S 1100 W, Salt Lake City, UT, 84119 | 2kgs | 2 | E00 | Delivered at 08:57:20
18 | 1488 4000 S, Salt Lake City, UT, 84123 | 6kgs | 2 | E00 | Delivered at 10:12:20
19 | 177 W Price Ave, Salt Lake City, UT, 84115 | 37kgs | 2 | E00 | Delivered at 08:31:20
20 | 3595 Main St, Salt Lake City, UT, 84115 | 37kgs | 2 | 10:30 AM | Delivered at 08:29:40
21 | 3595 Main St, Salt Lake City, UT, 84115 | 3kgs | 2 | E00 | Delivered at 08:29:40
22 | 6351 South 900 East, Murray, UT, 84121 | 2kgs | 3 | E00 | Delivered at 09:49:00
23 | 5100 South 2700 West, Salt Lake City, UT, 84118 | 5kgs | 3 | E00 | Delivered at 11:32:40
24 | 5025 State St, Murray, UT, 84107 | 7kgs | 3 | E00 | Delivered at 09:59:20
25 | 5383 South 900 East #104, Salt Lake City, UT, 84117 | 7kgs | 3 | 10:30 AM | Delivered at 09:44:40
26 | 5383 South 900 East #104, Salt Lake City, UT, 84117 | 25kgs | 3 | E00 | Delivered at 09:44:40
27 | 1060 Dalton Ave S, Salt Lake City, UT, 84104 | 5kgs | 3 | E00 | Delivered at 10:35:20
28 | 2835 Main St, Salt Lake City, UT, 84115 | 7kgs | 3 | E00 | Delivered at 10:10:40
29 | 1330 2100 S, Salt Lake City, UT, 84106 | 2kgs | 1 | 10:30 AM | Delivered at 08:28:00
30 | 300 State St, Salt Lake City, UT, 84103 | 1kgs | 1 | 10:30 AM | Delivered at 09:11:20
31 | 3365 S 900 W, Salt Lake City, UT, 84119 | 1kgs | 1 | 10:30 AM | Delivered at 08:46:40
32 | 3365 S 900 W, Salt Lake City, UT, 84119 | 1kgs | 3 | E00 | Delivered at 10:20:20
33 | 2530 S 500 E, Salt Lake City, UT, 84106 | 1kgs | 2 | E00 | Delivered at 09:09:40
34 | 4500 S 2300 E, Holladay, UT, 84117 | 2kgs | 1 | 10:30 AM | Delivered at 08:11:20
35 | 1060 Dalton Ave S, Salt Lake City, UT, 84104 | 88kgs | 3 | E00 | Delivered at 10:35:20
36 | 2300 Parkway Blvd, West Valley City, UT, 84119 | 88kgs | 2 | E00 | Delivered at 08:46:20
37 | 410 S State St, Salt Lake City, UT, 84111 | 2kgs | 1 | 10:30 AM | Delivered at 09:08:00
38 | 410 S State St, Salt Lake City, UT, 84111 | 9kgs | 2 | E00 | Delivered at 09:26:20
39 | 2010 W 500 S, Salt Lake City, UT, 84104 | 9kgs | 2 | E00 | Delivered at 09:43:40
40 | 300 W 2800 S, Salt Lake City, UT, 84115 | 45kgs | 1 | 10:30 AM | Delivered at 08:41:00

-----
1. Print all packages and total miles
2. Get a single package with a time
3. Get all packages with a time
```

## E. Screenshot of Code Execution

### First screenshot showing start of run with total miles:

```
/Users/harrisonplummer/PycharmProjects/WGUPS/venv/bin/python /Users/harrisonplummer/PycharmProjects/WGUPS/main.py
-----
1. Print all packages and total miles
2. Get a single package with a time
3. Get all packages with a time
4. Exit
-----
1
Total miles: 121.3
```

### Second screenshot showing successful completion of code:

```
-----
1. Print all packages and total miles
2. Get a single package with a time
3. Get all packages with a time
4. Exit
-----
4

Process finished with exit code 0
```

## F1. Strengths of the Chosen Algorithm

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One strength of the nearest neighbor algorithm is its adaptability. We could theoretically add an unlimited number of items and it would get them all delivered. Another strength is its heuristic nature. It is able to find a solution faster than an algorithm trying to find the optimal solution.

## F2. Verification of Algorithm

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The nearest neighbor algorithm meets all requirements. The trucks ended with under 40 miles. All packages were delivered prior to their deadlines. The `load_trucks` function ensured no truck had more than 16 packages. All packages with special notes were sorted according to their requirements. Packages with delays were loaded onto the third truck and logic was used to make sure it didn't leave until that time, or until one of the two drivers returned.

## F3. Other Possible Algorithms

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One possible algorithms would be a shortest path algorithms like Dijkstra's shortest path algorithm. Another would be Clark and Wright's savings algorithm.

### F3a. Algorithm Differences

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The nearest neighbor algorithm doesn't care about the path, it only finds and visits the nearest neighbor.

Dijkstra's shortest path algorithm finds the shortest path for all items (or vertices). It finds the shortest path to each adjacent vertex and adds that to the adjacent vertex. It then moves to the next vertex and if the sum of the shortest path to the current vertex and the distance to an adjacent vertex is shorter than the adjacent vertex's current shortest path, it replaces the adjacent vertex's shortest path. After going through each vertex, it has the shortest path to each vertex (Lysecky, R., & Vahid, F.).

Clark and Wright's savings algorithm also looks at the entire path with a different approach. It finds the savings between every 2 locations with the following formula:  $\text{savings} = \text{distance\_hub\_to\_loc1} + \text{distance\_hub\_to\_loc2} - \text{distance\_loc1\_to\_loc2}$ . It then ranks the savings from most to least, and loads items in that order (with some exceptions) (Section 6-4-12, n.d.).

## G. Different Approach

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One thing that would make the code closer to a real-life scenario would be to edit how the special notes are handles. I imagine any notes on packages must be reviewed by a human. To make this more realistic I would have the `load_packages` function print the package id, note, and deadline and ask for input on which truck to place the item on. I could also have a continue option that loads it according to the remaining criteria if the note doesn't affect loading.

## H. Verification of Data Structure

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The data structure used is a hash table. It stores all items as a key-value pair, with the search function using the key. All the required information is stored in a package class item. Each package item is stored as the value in the key-value pair, so the hash map stores all the necessary information.

### H1. Other Data Structures

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A doubly linked list or a queue could also be used.

## H1a. Data Structure Differences

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A doubly linked list is a list that holds next and previous item pointers, and the item itself while a hash table stores items in buckets determined by a modulo function. Doubly linked lists would work fine to store packages but would suffer from worse search times. If they were used in the implementation of the Truck class packages instead, I don't believe any negative impact would occur.

A queue is a list that can only add items on the back and remove items from the front. This would be a good way to deliver the items if the `load_trucks` function was altered to load items to the queue in order of delivery. It could also be used to store all packages, though only being able to access the first item would require excessive changes to the code. It would also be useful if Dijkstra's algorithm were implemented.

## I. Sources

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