NTNU
Kunnskap for en bedre verden

Department of Mechanical and Industrial Engineering

TPK4186 - Advanced Tools for Performance Engineering

Assignment 3 - Prodled Bros

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1 Introduction

In this assignment we have designed an automated warehouse by creating a program that simulates the operations of a warehouse. The warehouse operations includes populating shelves, handling orders, managing robots and handling truck loads. To be able to simulate these processes, the warehouse is divided into cells where the robots can move around to perform actions.

2 Data Structures

We have implemented the following data structures in order to create a comprehensive simulation environment for warehouse operations.

2.1 Product

Instances of the product class is characterized by a unique code and a weight.The products have a weight attribute with a maximum weight of 40 kg.

2.2 Catalog

The catalog class stores instances of the product class. It handles operations such as addition, removal, retrieval based on product codes. It also contains a function to create a random catalog of products given the wanted amount of products.

2.3 Shelf

The class shelf represents physical shelves contained in the warehouse. It handles operations for adding and removing the product and calculating remaining capacity.

2.4 Cell

As stated in the assignment order, the warehouse grid contains different types of cells which allow storing, moving, loading and unloading. In order to account for all of the different types, we have created a parent class Cell which consists of a position represented by a tuple and a cell-type represented by a sting. The following cell-types are children of the parent class cell.

2.4.1 Storage cell

The storage cell class extends the functionality of the cell class, with data structure to store instances of the shelf class. It handles operations such as populating shelves with products from a catalog and retrieval of shelf information.

2.4.2 Route cell

The storage cell class extends the functionality of the cell class, with data structure to represent the occupancy status of the cell. The status of the route cell is constantly updated as the normal processes of the warehouse continue.

2.4.3 Loading cell

The loading cell class extends the functionality of the cell class, with data structure to store instances of robots that are available for loading. It handles operations such as adding and removing robots from the loading cell and enabling management of available resources for loading tasks.

2.4.4 Unloading cell

The unloading cell class extends the functionality of the cell class, and specifically represents cells designated for unloading in the warehouse layout.

2.5 Order

The order class contains data regarding customer orders, with attributes such as customer name, order number, catalog, product and quantity to represent individual orders. The order number increases automatically for each new order, and the class contains methods for accessing and modifying order details, as well as generating random orders based on the catalog.

2.6 Truck load

The truck load class represents a batch of products being delivered to the warehouse. It contains a delivery number, a maximum weight capacity and dictionary with products and quantities.

2.7 Printer

The printer class provides functionality to print warehouse related information. We have utilized this class as well as overloading the existing __str__ function for debugging purposes.

2.8 Robot

The robot class represents attributes and functionality of a robot. It contains methods for moving the robot in the warehouse, loading, unloading and restocking products to the storage cells.

Given a customer order, a robot is assigned events such as moving to a storage cell, loading, moving to the unloading cell and ultimately unloading, completing the customer order. The robot are also responsible for handling the restocking of the products that arrive to the warehouse through truck loads.

2.9 Warehouse

The warehouse class represents a warehouse with functionality such as generating warehouse layout, populating shelves, handling orders, managing robots and handling truck loads. The warehouse also has a "handle_next_time_step" function which executes the next state all of the on-going operations currently happening in the warehouse i.e. the next state for robots with an active objective.

As stated in the task, the warehouse class manages most of the processes happening inside the warehouse. All of the classes mentioned above are located and utilized in the warehouse class in order to simulate the possible warehouse operations.

3 Simulator

To enhance our understanding of warehouse operations, we have developed a simulator to visualize the processes taking place. Within the simulator class, the execution method creates a warehouse with specified parameters including aisle size, height of storage cells, number of robots, and product dimensions.

3.1 Schedule

The simulator incorporates parameters to regulate the pace of new customer orders. Its schedule dynamically updates each time an order is received, storing this information in the remaining customer orders variable within the warehouse. Additionally, scheduled arrivals of truckloads carrying products are calculated and tracked through the remaining truckloads variable.

3.2 Event

Upon receiving a new customer order or truckload, corresponding events are generated via functions such as handle order and handle truckload. These functions allocate an available robot to execute the task. For instance, when a new order is received, a robot is assigned a route to retrieve the requested items from storage and return them to the designated location. Throughout each time step, robots with assigned tasks continue to work towards completion, ultimately reporting the time taken to fulfill the objective.

Priority is given to fulfilling customer orders over restocking truckloads. Consequently, available robots always prioritize completing an order before handling a truckload.

3.3 Animation

To provide a visual representation of warehouse operations, we leverage the animation capabilities of the matplotlib library. Initially, a grid representing the warehouse layout is plotted. Through the use of the FuncAnimation function, the positions of robots within the warehouse are updated, effectively illustrating their movements in real-time.

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Simulation has ended

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At the end of the simulation of 20000 seconds, with 4 robots, in a 12 X 12 Warehouse, these are our results:

The total amount of orders delivered were: 137

The total amount of cancelled orders were: 0

The amount of remaining orders we could not deliver: 2

The average amount of time it took to pick up the order was 480.94890510948903

The amount of truck loads that were handled are: 3

The average amount of time it took to handle a truck load was: 350.0

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Figure 2: The simulations results from 4 robots

4 Experiments

4.1 12 x 12 warehouse, 10 products

The following picture demonstrates a 12 x 12 warehouse used for experiments in this section. With a order frequency of current_time modulus 140.

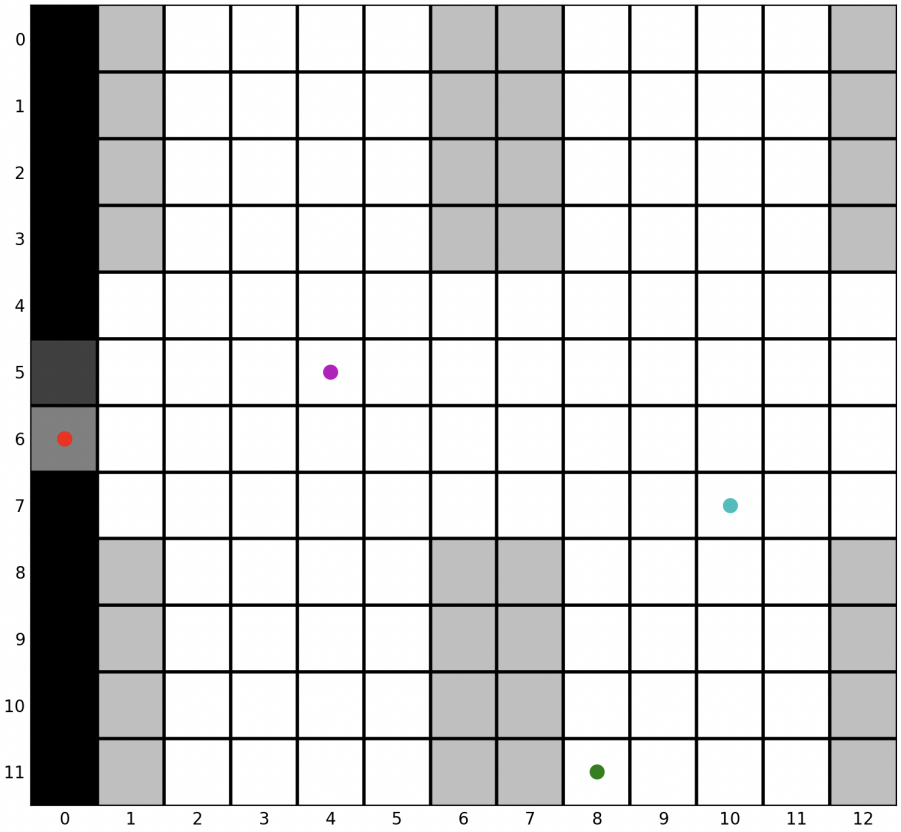

Figure 1: A 12 x 12 warehouse

4.1.1 4 robots

4.1.2 3 robots

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Simulation has ended

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At the end of the simulation of 20000 seconds, with 3 robots, in a 12 X 12 Warehouse, these are our results:

The total amount of orders delivered were: 123

The total amount of cancelled orders were: 0

The amount of remaining orders we could not deliver: 17

The average amount of time it took to pick up the order was 471.1382113821138

The amount of truck loads that were handled are: 0

There were no truck loads handled

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Figure 3: The simulations results from 3 robots

4.2 16 x 25 warehouse, 120 products (assignment example)

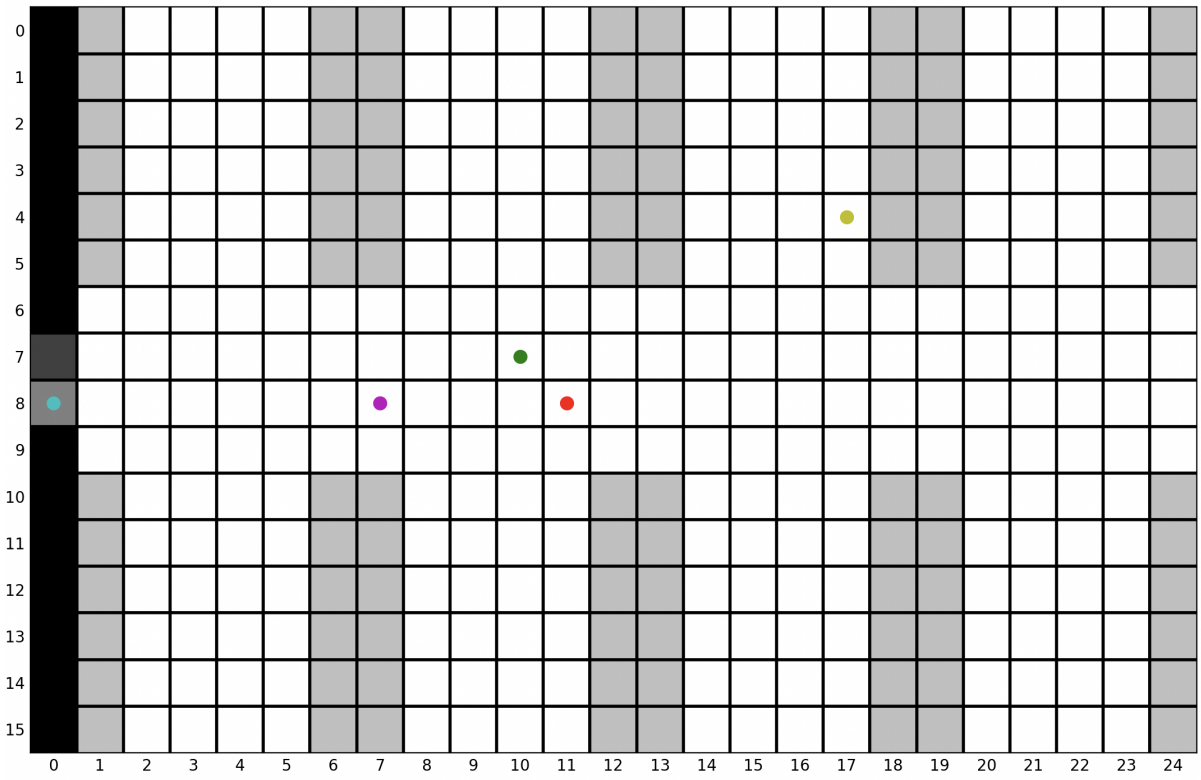

Figure 4: A 16 x 25 warehouse as demonstrated in the assignment order

4.2.1 5 robots

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Simulation has ended

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At the end of the simulation of 20000 seconds, with 5 robots, in a 16 X 24 Warehouse, these are our results:

The total amount of orders delivered were: 95

The total amount of cancelled orders were: 23

The amount of remaining orders we could not deliver: 22

The average amount of time it took to pick up the order was 616.7368421052631

The amount of truck loads that were handled are: 1

The average amount of time it took to handle a truck load was: 410.0

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Figure 5: The simulations results from 5 robots

4.2.2 6 robots

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Simulation has ended

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At the end of the simulation of 20000 seconds, with 6 robots, in a 16 X 24 Warehouse, these are our results:

The total amount of orders delivered were: 102

The total amount of cancelled orders were: 21

The amount of remaining orders we could not deliver: 17

The average amount of time it took to pick up the order was 598.6274509803922

The amount of truck loads that were handled are: 1

The average amount of time it took to handle a truck load was: 430.0

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Figure 6: The simulations results from 6 robots