Project Astrid: Logistics Robot for Moon Base Operations and Human-Robot Collaboration

OBJECT ORIENTATED PROGRAMMING

Table of Contents

Design Proposal for Project Astrid

Introduction

“In 2040, there will be more humanoid robot than there are people… autonomy is here.” (FII Institute, 2024)

This proposal outlines the design of control software for Project Astrid. Astrid is designed to assist astronauts with various tasks related to the transportation and management of equipment and supplies. By leveraging object-oriented programming (OOP), the system will ensure modularity, flexibility, and efficient management of tasks.

Background Research

Designing software to support the operation of a humanoid robot required a thorough exploration of existing technologies, applications, and current research.

Humanoid Robots

Research from NVIDIA and Tesla highlights advancements in humanoid robot design, focusing on mobility, dexterity, and adaptability in dynamic environments. Humanoid robots aim to perform tasks typically conducted by humans, making them versatile for collaborative work (NVIDIA, 2024; Tesla, 2024).

Collaborative Robots in Logistics

Ackerman (2023) discusses how humanoid robots are shifting from experimental prototypes to practical, real world applications. The article highlights specific case studies, such as their roles in logistics, where humanoid robots efficiently handle tasks like sorting and delivering packages.

Examples from Kardex highlight service robots in logistics efficiently navigating warehouses, identifying objects, and transporting items. These practical applications informed the decision to prioritise task execution and environment navigation in the system design (Kardex, ND).

Key Finding

Humanoid robots exhibit significant potential, with their capabilities making them highly valuable in logistics operations, such as package handling, delivery, and warehouse management.

System Design Overview

The humanoid robot delivery system adopts a modular object-oriented architecture to ensure adaptability and efficiency in dynamic environments. Python was selected for its ability to support AI algorithms, handle CLI based interactions effectively, and facilitate object-oriented design.

The core system consists of four primary classes:

Robot	The Robot class serves as the system's central operational entity, managing delivery tasks, navigation and user interactions directly. A Task Manager was excluded to avoid unnecessary complexity, as the single robot, single task design allows efficient scheduling.
Interface	The Interface class manages user interactions, displaying delivery statuses, maps and robot diagnostics. Separating it from the Robot class ensures a clear separation of concerns. Embedding interface logic into the Robot class would tightly couple user interaction with task execution.
Environment	The Environment class simulates the robot’s surroundings and route planning while keeping navigation and obstacle operations modular. BFS was chosen over A* or Dijkstra’s for its simplicity and efficiency in grid based, unweighted maps.
Package	The Package class represents delivery items, with subclasses for fragile or perishable goods. While a dictionary could suffice, the class based design offers greater scalability and maintainability.

Data Structures

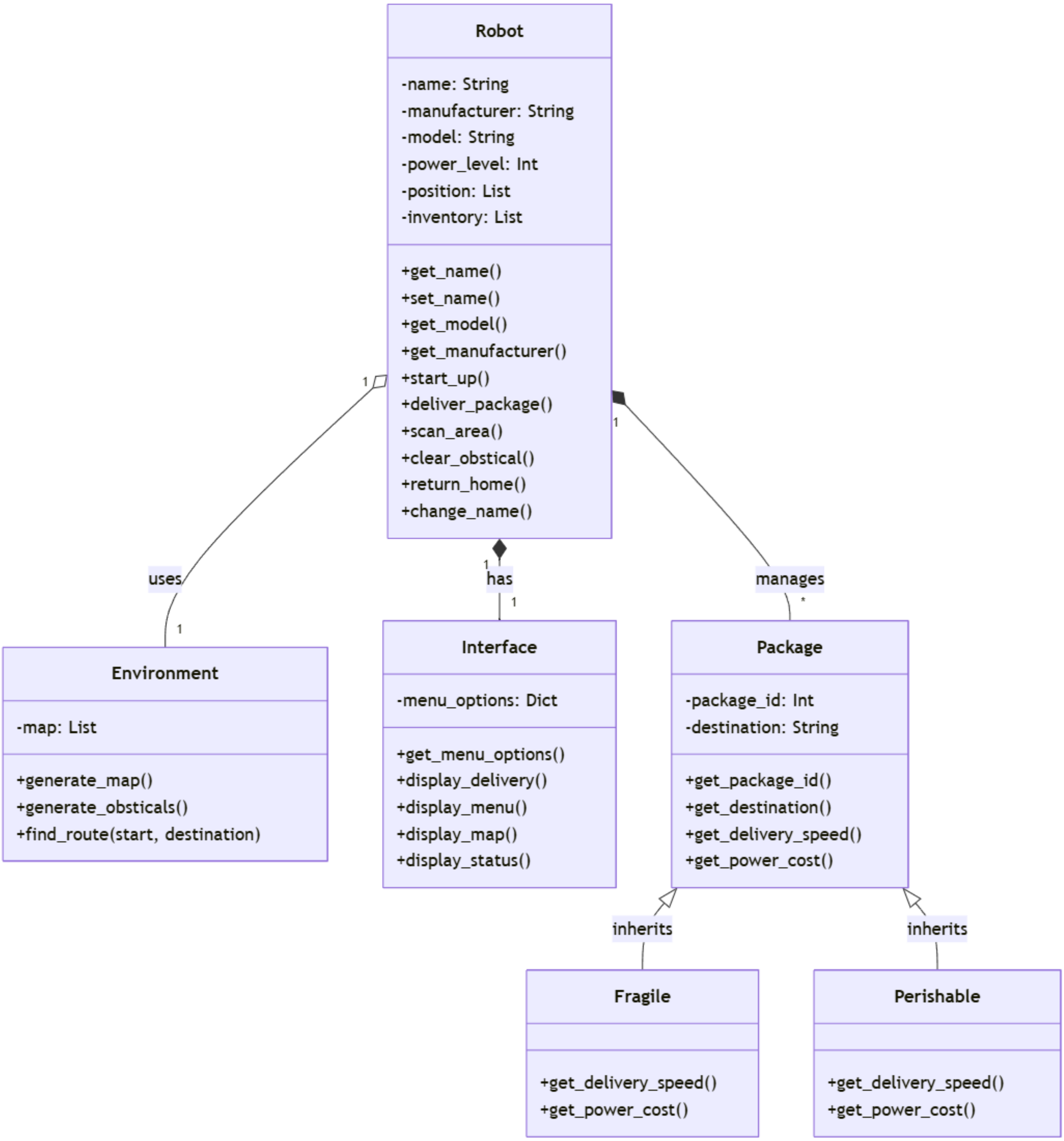
The humanoid robot delivery system employs various data structures to optimise efficiency and ensure seamless functionality.

Lists	Used for the Robot class's position and inventory, as well as the Environment map, because they provide straightforward, indexed access and are ideal for sequential data storage.
Stacks	In the Robot class, a stack is used to track the path taken, leveraging its last-in, first-out (LIFO) nature to efficiently backtrack to previous positions.
Queues	In the Environment class, a queue is used to implement Breadth First Search (BFS) for pathfinding. The queue's first-in, first-out (FIFO) behaviour ensures systematic exploration of grid spaces to identify the shortest path.

UML Diagrams

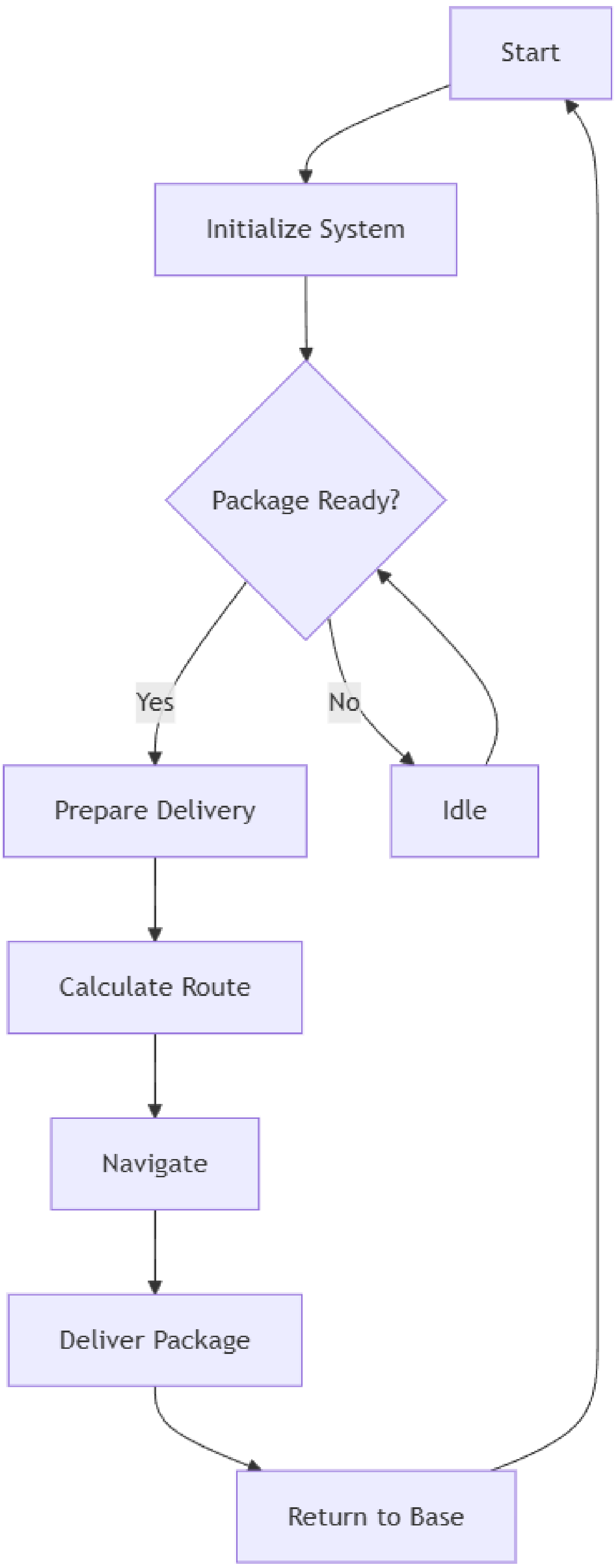
Class Diagram

The class diagram depicts the core classes and their relationships within the Robot Delivery System, highlighting the structure and responsibilities of the key components.



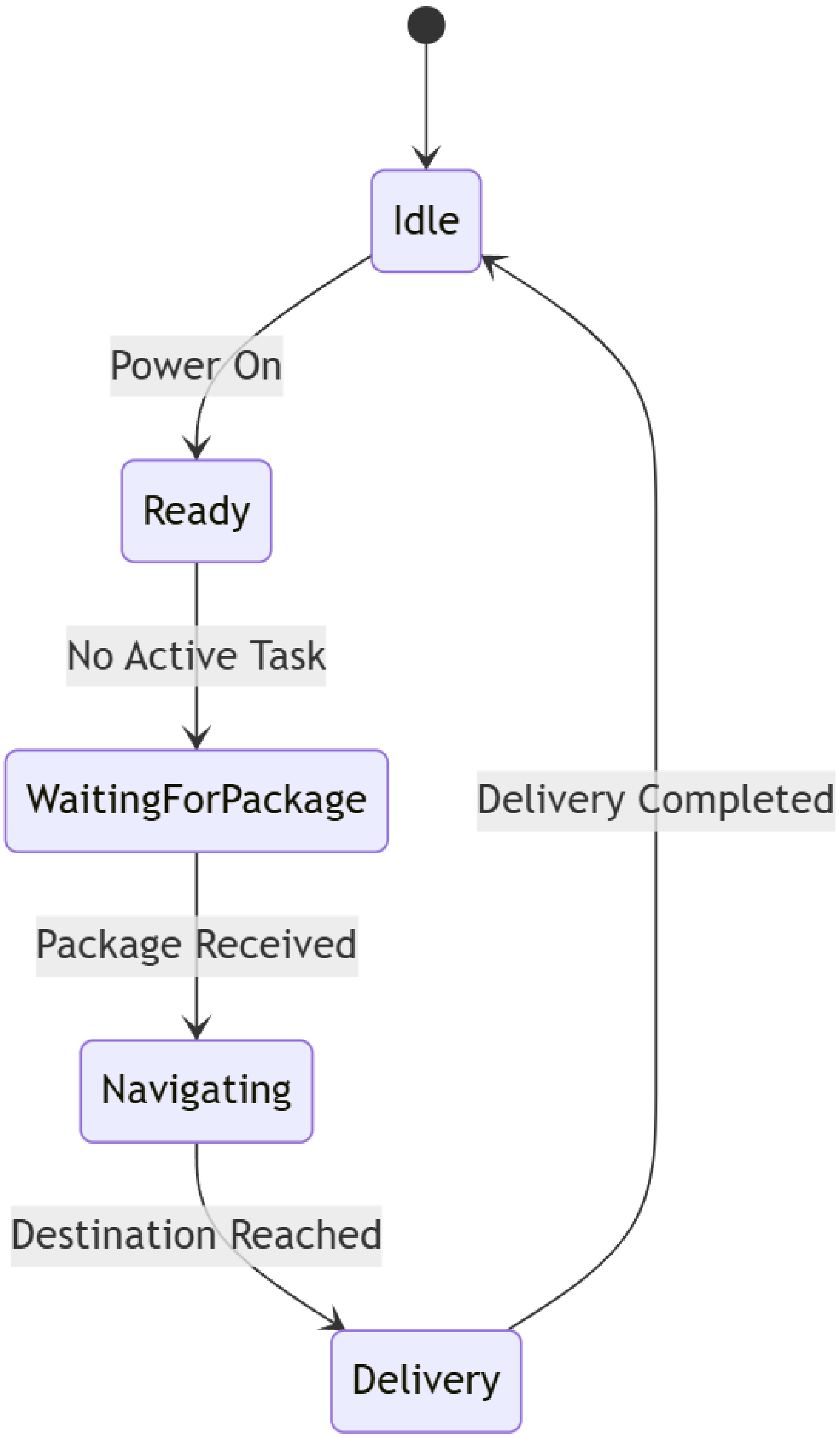
Activity Diagram – Delivery

The activity diagram provides a view of the robot's operational workflow, outlining the activities involved in managing a delivery.



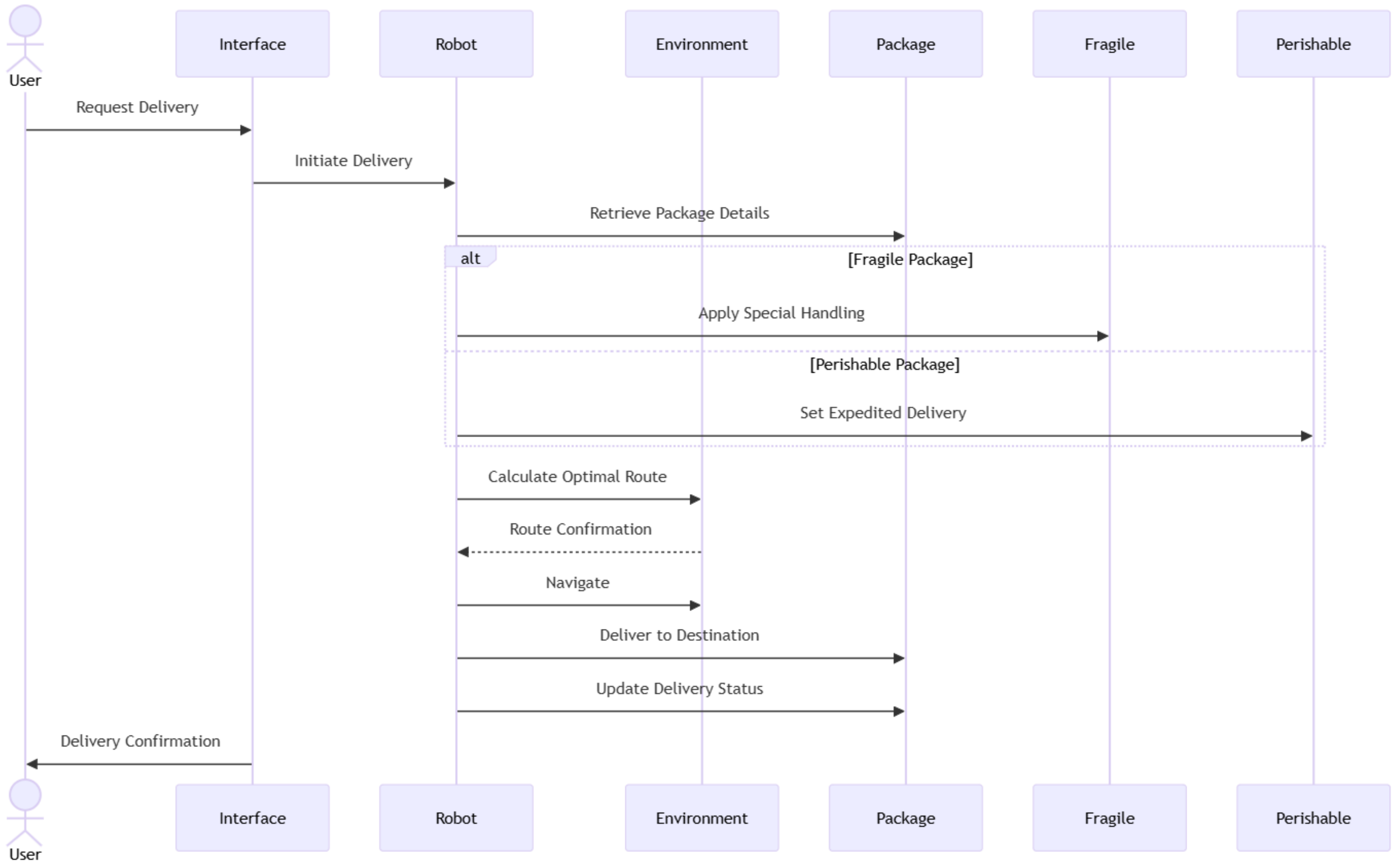
State Transition Diagram – Delivery

The state diagram presents a high level overview of the robot's lifecycle, highlighting the key states it transitions through, from initialisation to delivery completion.



Sequence diagram – Delivery

The sequence diagram illustrates the flow of interactions between the system's entities, user, robot, environment and package, during the delivery process.



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