Summative assessment 1: System Design

Object Oriented Programming

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Design Proposal of OOP Software to Support Humanoid Robot operations

Humanoid robots represent a critical frontier in technology, valued for their ability to emulate human form and function within diverse industrial and social environments (Sheng et al., 2025). By integrating advanced manufacturing with breakthroughs in artificial intelligence, these robots are poised to become key drivers of industrial productivity, with applications moving from research to practical work (Ackerman, 2023; Mukherjee et al., 2022; Mulko, 2023). However, realizing this potential requires the design of sophisticated software systems to manage the complex challenges of perception, control, and intelligent manipulation (Sheng et al., 2025).

This document proposes an object-oriented software designed to specifically support a humanoid robot to perform three core operations: Get Next Task, Retrieve Item and Pack Order.

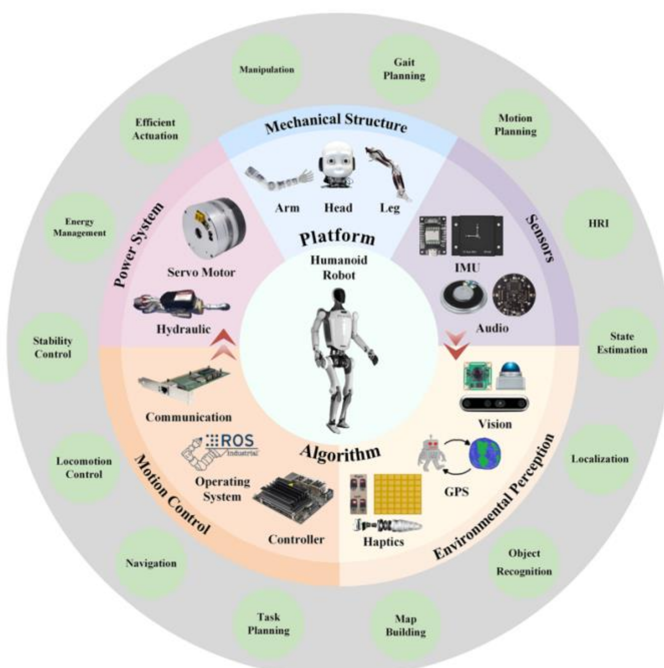

Figure 1 Humanoid Robot Framework

2 Design Rationale

The architectural philosophy is that of a Connected Specialist, where the robot's physical capabilities are augmented by support systems. Rather than employing a monolithic HumanoidRobot class, the design adheres to the Single Responsibility Principle (Ampatzoglou, A. et al., 2019), delegating operations to specialised modules such as TaskManager that handles order additions, InventoryManager that serves as the authority on environmental data from the Warehouse (which uses a List), and a PackagingStation that acts as a physical workspace for the robot to pack order items. This creates a scalable system where the robot can focus on its primary actions while its autonomous behaviour emerges from the interaction between its own capabilities and its support software across its three primary operations.

The process begins when the robot needs to Get Next Task, whereby a human operator first submits an order via the CLI, which is processed by the TaskManager and InventoryManager. The TaskManager then holds a validated order in a Queue data structure, allowing the robot's operation to query this queue, receive its next instruction, and begin work, ensuring it only acts on valid and achievable goals.

The robot's main physical function is to Retrieve Item, which it executes by navigating to a target location and using its simulated SensorArray to scan the area. This represents the collection of environmental data to visually confirm the correct item before performing the pick action, ensuring the robot accurately interacts with the environment through this perception-driven step.

After retrieving all items, the robot must Pack Order by transporting the items to the PackagingStation and autonomously managing the packing sequence. It analyses the weight of each item and uses an internal sorting algorithm, then uses an internal Stack data structure, pushing the sorted items onto it from lightest to heaviest. Due to the Stack's Last-In-First-Out nature, the robot pops items for placement, ensuring the heaviest item is always placed first.

This architecture demonstrates that even simple, direct operations require a sophisticated and coordinated system. By providing the robot with specific software modules, it is empowered to perform its job with efficiency and reliability.

3 Research Keywords Table

Keyword	Justification for Inclusion
Humanoid Robot	Essential for understanding the physical capabilities, limitations and design considerations specific to human-form robots in industrial settings.
Human-Robot Interaction	Helped with designing and understanding how operators can interact with the system.
Collaborative Robot	Warehouse environments require robots to work alongside human operators and understanding collaborative robotics principles ensures safety and efficiency.
Warehouse Automation	Provides context for the specific operational environment, including industry standards for inventory management, order fulfillment and logistics optimization.
Robot Navigation Systems	Helps inform the design of the NavigationSystem class and understanding of spatial awareness requirements.
Robot Task Planning	Informs the TaskManager design and understanding of how robots execute sequential operations in dynamic environments.
Industrial IoT (Internet of Things)	Supports the "Connected Specialist" architecture concept, understanding how distributed systems communicate and share environmental data.

Table 1 Keywords

4 UML Diagrams

To represent the architecture and interactions described in the design rationale, this section presents diagrams created using the Unified Modelling Language, an industry-standard graphical language for constructing and documenting the artifacts of a software systems (Booch et al., 2005). The design and structure of the following diagrams are informed by established principles of object-oriented systems analysis, ensuring the models are both comprehensive and clear (Bennett et al., 2010).

4.1 Class Diagram

The class diagram below (Figure 2 Class Diagram) provides a static representation of the system, showing classes, attributes, operations and their relationships, where the the HumanoidRobot is composed of subsystems for navigation, sensing, gripping and packing optimisation and other classes manage inventory, tasks, and packaging. Composition links illustrate strong ownership, whereas associations show interactions. The diagram also demonstrates the deliberate use of Lists, a Queue, and a Stack to support the robot's core operations.

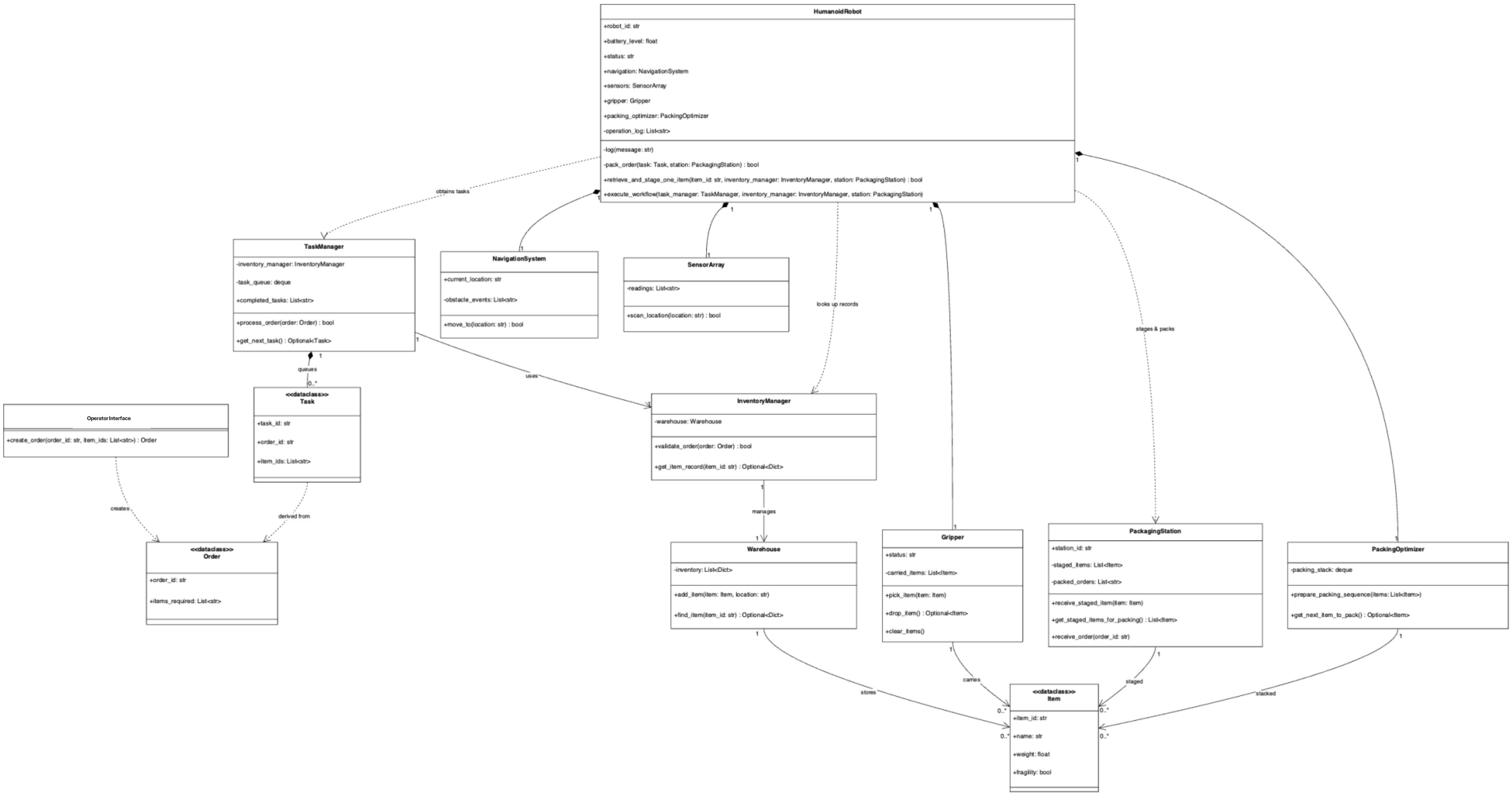

Figure 2 Class Diagram

4.2 Sequence Diagram

The sequence diagrams capture the order of interactions between system components. The first focuses on order creation, showing how a request from the CLI is validated, whereas the second represents the robot workflow, where the HumanoidRobot collaborates with subsystems to retrieve, stage, and pack items. Both diagrams also indicate alternative paths for errors such as unavailable stock or failed navigation.

4.2.1 Sequence Diagram 1

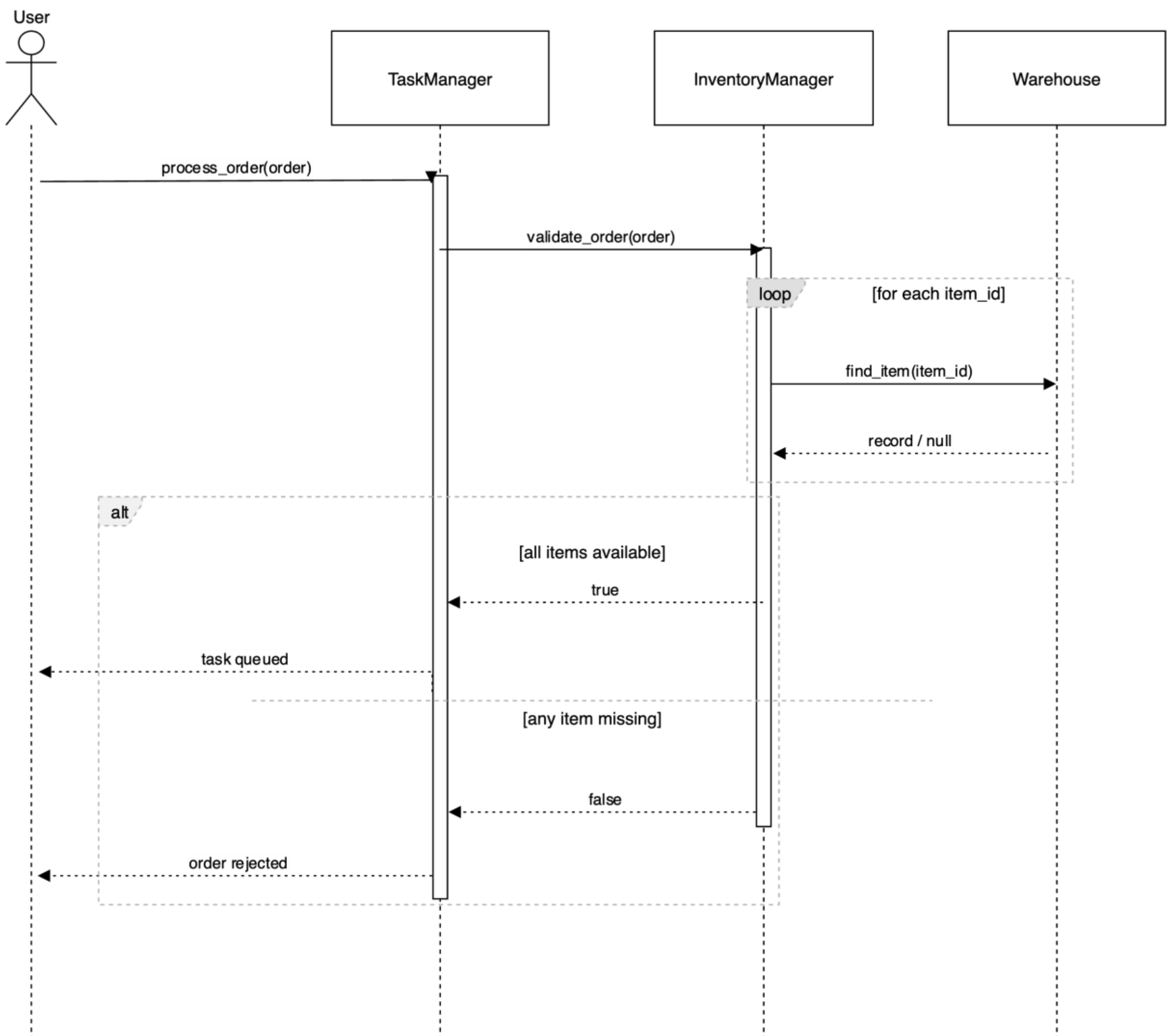

Figure 3 Sequence Diagram 1

4.2.2 Sequence Diagram 2

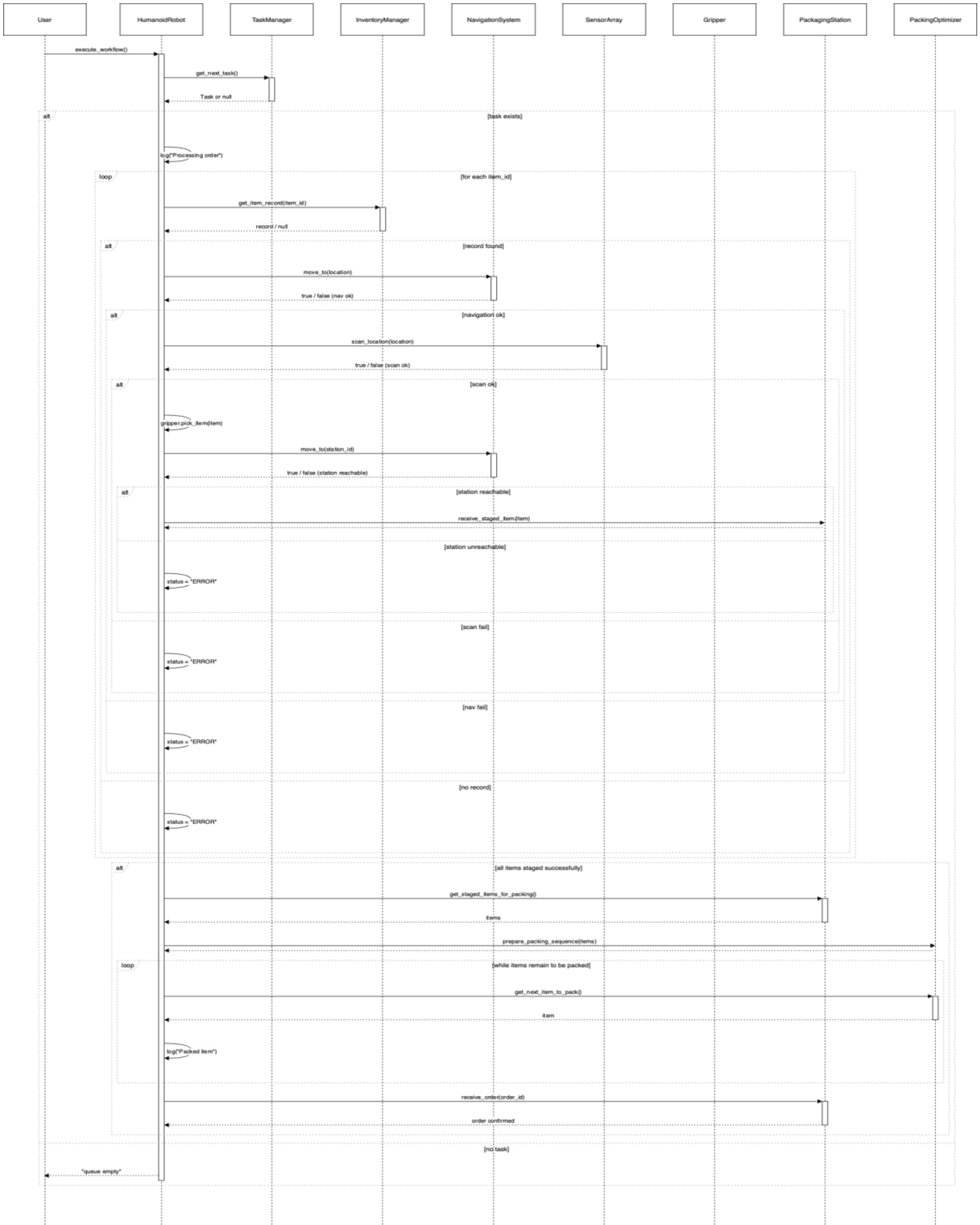

Figure 4 Sequence Diagram 2

4.3 Activity Diagram

The activity diagram illustrates the flow of a robot run cycle. Beginning with task retrieval, the process either terminates if no tasks exist or enters a loop retrieve and stage items. When complete, the control passes to the packing sequence, which applies the stack structure for order assembly.

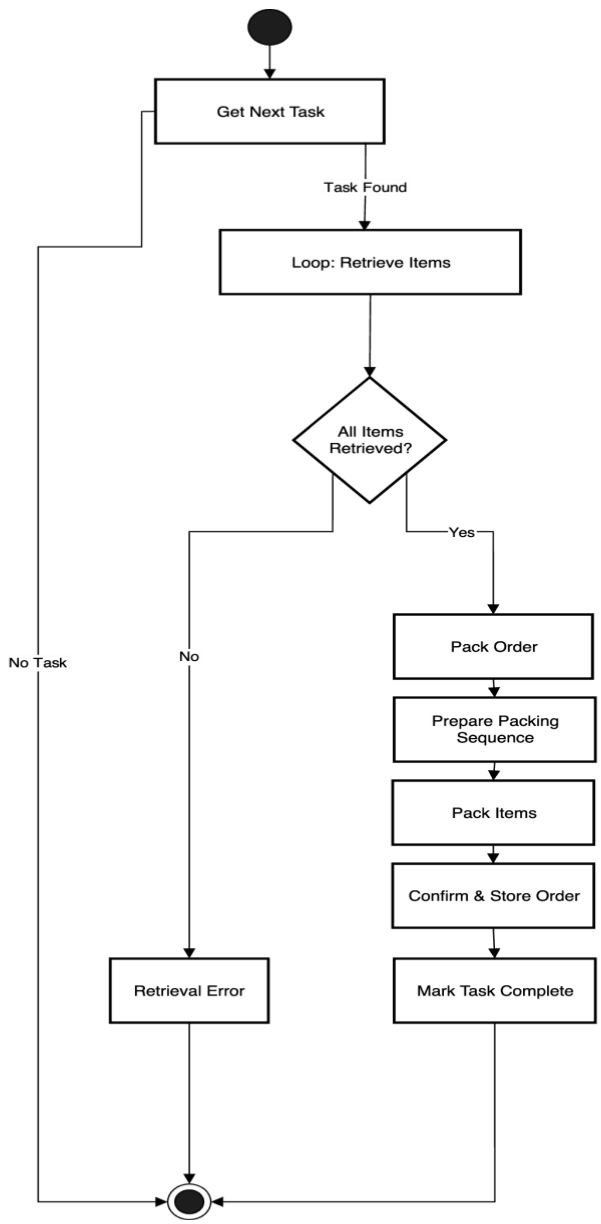

Figure 5 Activity Diagram

4.4 State transition diagram

The state machine diagram presents the dynamic behaviour of the HumanoidRobot and the states it can potentially reach through its operations.

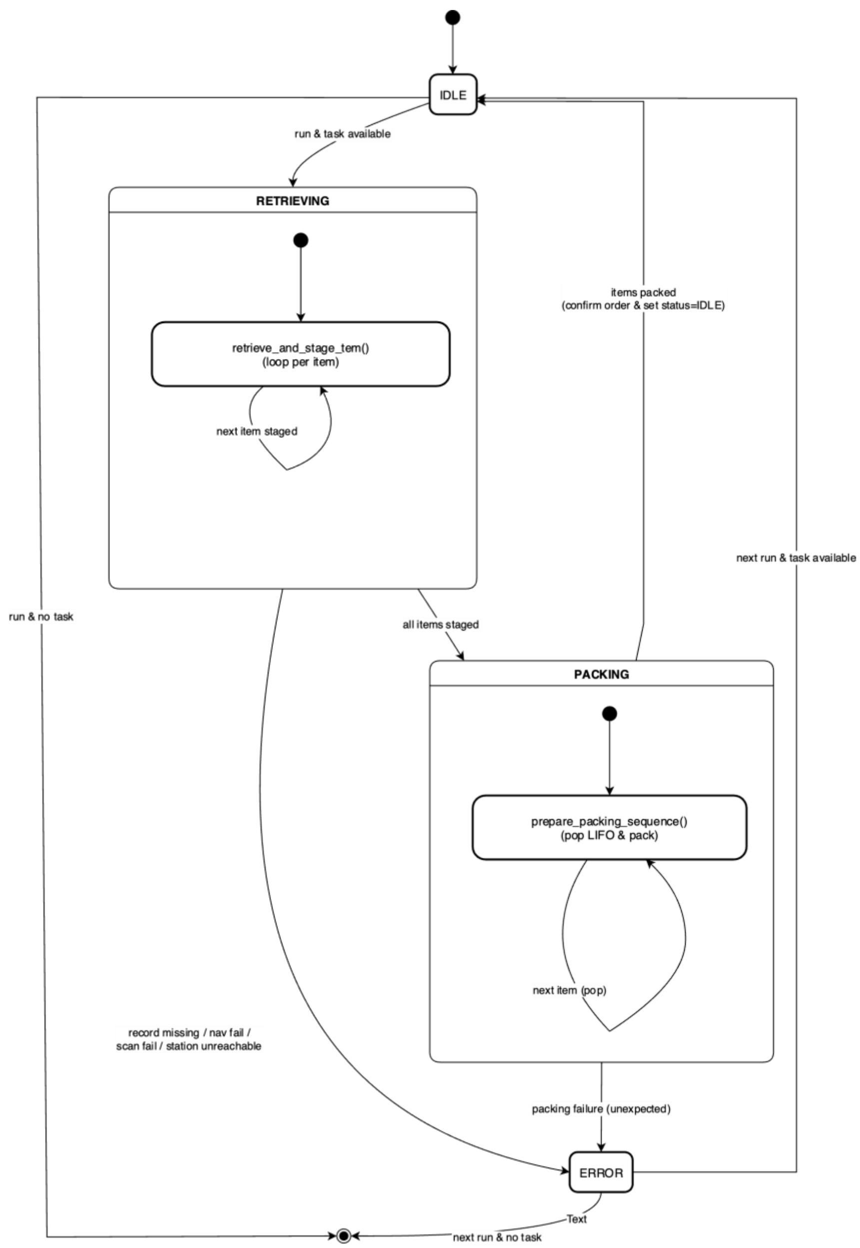

Figure 6 State transition diagram

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