Automated Palletizing with a UR5 Robotic Arm using 3D Spatial Management

1. Introduction

In modern logistics, manufacturing, and supply chain management, automation is key to achieving high efficiency and throughput. A critical, physically demanding, and repetitive task in this domain is **palletizing**: the process of stacking goods or products onto a pallet in a stable, organized pattern for storage and shipment. For our robotics project, we will simulate a UR5 robotic arm performing an automated palletizing task, demonstrating procedural logic and 3D spatial management within a controlled industrial environment.

2. Why This Selection

We chose this task because it requires a more sophisticated approach than a simple pick-and-place operation. Instead of moving an object to a single, static destination, palletizing demands that the robot manage a **dynamic state** and calculate a new target position for each object based on a predefined pattern. This introduces the challenge of **3D spatial reasoning** and procedural task execution..

This project will allow us to apply core course concepts like kinematics and trajectory planning while also tackling higher-level challenges such as:

- **State Management:** Keeping track of the current layer, row, and column to determine the next placement location.
- **3D Coordinate Calculation:** Programmatically generating the target coordinates for each box in the stack.
- **Procedural Logic:** Executing a repeatable multi-step sequence to build a stable structure.

This task is an excellent fit for our selected tools, **ROS2** and the **MuJoCo** simulator, which will allow us to accurately model the physics of stacking boxes.

3. Real World Uses

Automated palletizing is a cornerstone of end-of-line automation in virtually every industry that ships physical goods.

- **Logistics and Warehousing:** Companies like Amazon and DHL use large-scale robotic systems to stack packages onto pallets for shipment, operating 24/7 with high precision.
- **Manufacturing:** Consumer goods companies use robots to stack finished products (e.g., cases of drinks, bags of food) as they come off the production line.
- **Shipping:** Robots load and unload cargo by systematically stacking or de-stacking pallets.

Industrial robot manufacturers like KUKA, FANUC, and ABB offer specialized palletizing robots designed for high speed and heavy payloads, making this a highly relevant and commercially significant application.

4. Simulated Environment and Approach

Our project will be simulated in **MuJoCo**, utilizing its robust physics engine to ensure realistic stacking behavior. The environment will include:

- A UR5 robotic arm with a gripper.
- A "pickup zone," such as the end of a conveyor belt, where boxes appear.
- A designated pallet area where the stacking will occur.

Our technical approach will follow this logical sequence:

1. The robot will start in a "home" position and wait for a box to be available in the pickup zone.
2. Once a box is detected, the system will **calculate the coordinates for the next available slot** on the pallet based on a predefined stacking pattern (e.g., a 3x3 grid, 3 layers high).
3. The robot will execute a trajectory to pick the box from the source.
4. It will then move to the calculated 3D position above the pallet and place the box.
5. The system will **update its internal state** (e.g., incrementing the box count and recalculating the next position) and return to the home position to await the next box.

This provides a solid foundation for building a robust motion planning and control system for a practical, multi-step automation task.

5. References

- Todorov, E., Erez, T., & Tassa, Y. (2012). MuJoCo: A physics engine for model-based control. *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 5026-5033.
- Universal Robots. (n.d.). *UR5 Collaborative Robot Arm*. https://www.universal-robots.com/products/ur5-robot/
- KUKA Robotics. (n.d.). *Palletizing Robots*. https://www.kuka.com