Object Retrieval Robot: Autonomous Navigation and Manipulation in Unknown Environments

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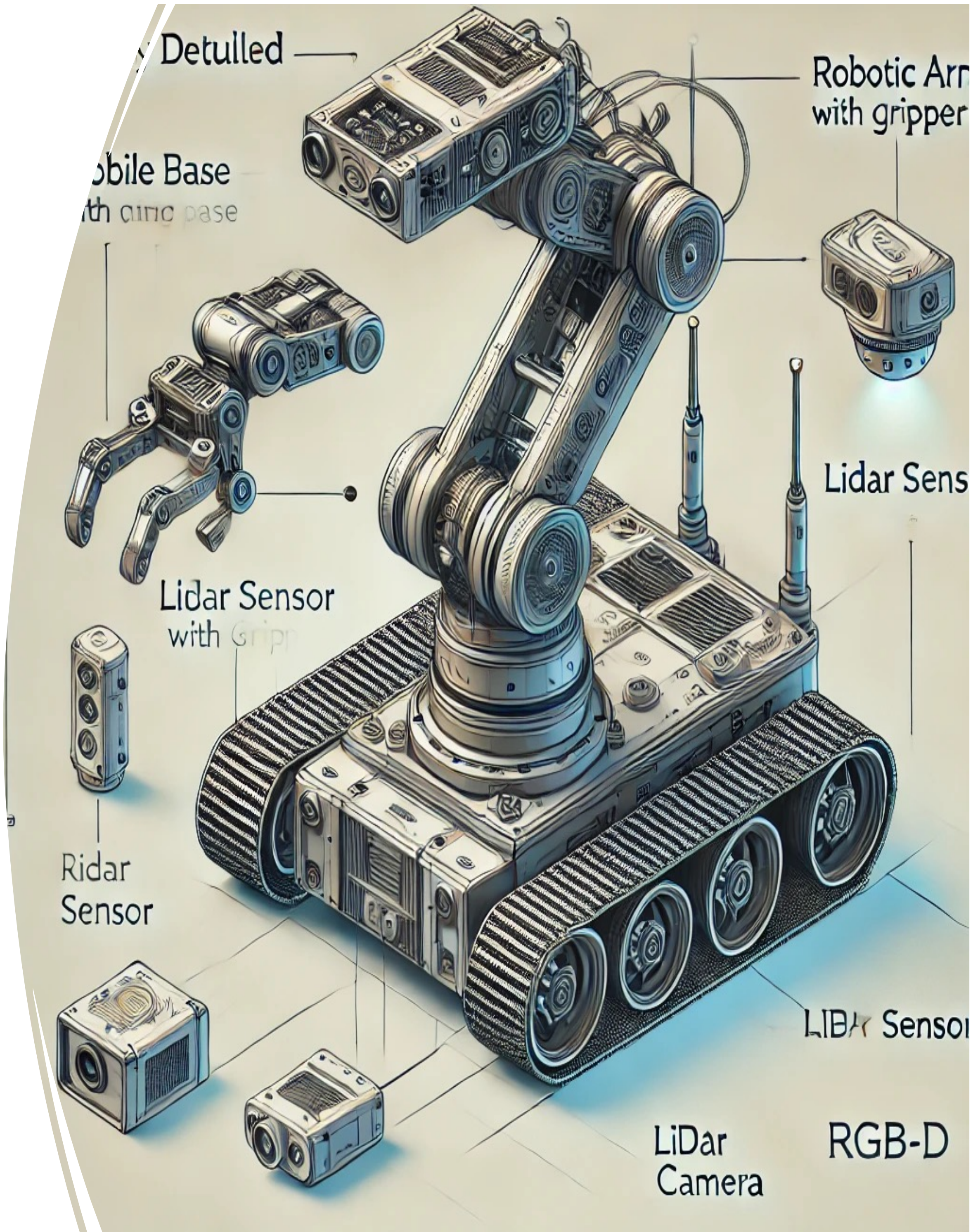


Problem Statement

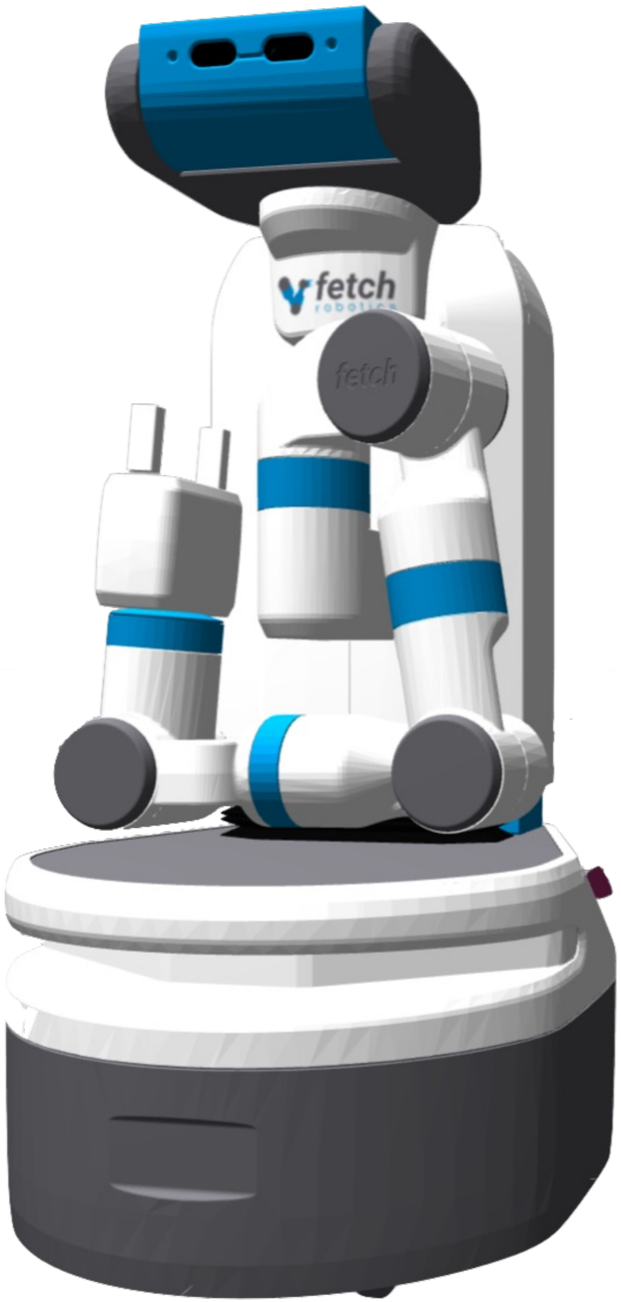
The project addresses the demand for automation in industries such as healthcare, manufacturing, and logistics.

Focuses on challenges including SLAM, object detection, path planning, obstacle avoidance, and manipulation.

Goal: Develop a robot capable of autonomous navigation, object retrieval, and returning to the starting point.

Objectives

- Enable autonomous navigation in unknown environments.
- Implement object detection and retrieval using a robotic arm.
- Optimize the robot's performance for real-world applications.



System Design

Mobile base for navigation: ROS Navigation Stack with SLAM.

Manipulator for object retrieval: Using MoveIt for motion planning.

Sensors: LIDAR and RGB-D camera for perception.

Control system using ROS.

Methodology

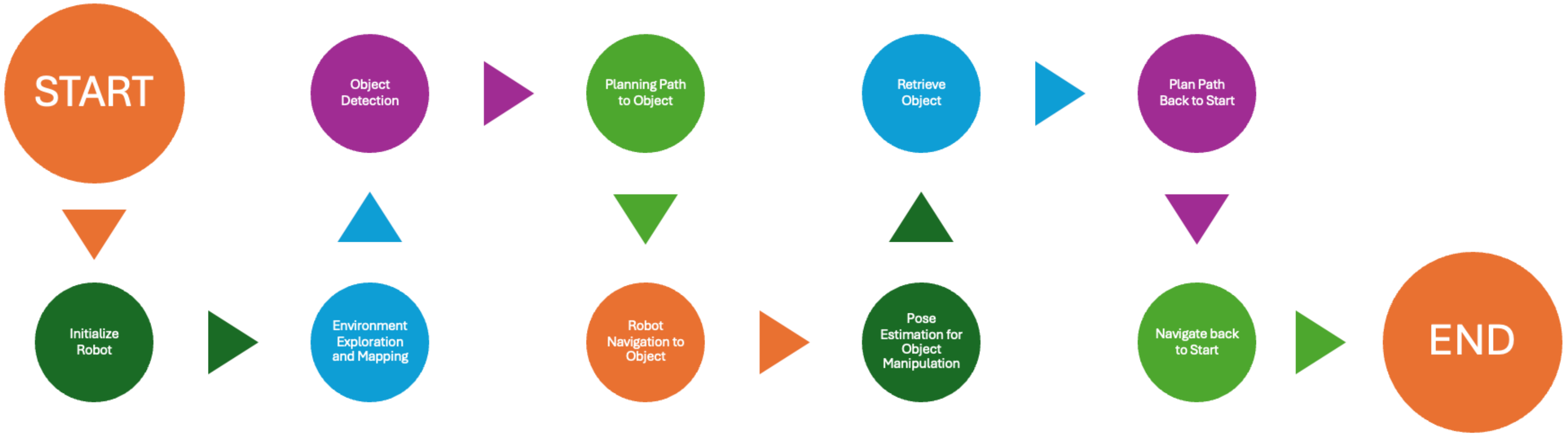
Environment Exploration: Bug Algorithm for space mapping.

Object Detection: Using pre-trained CNN for target identification.

Path Planning: RRT algorithm for efficient navigation.

Object Manipulation: Grasping using pose estimation and point cloud data.

Workflow



- **Start**: Robot initialization and setup in the simulation environment.
- **Environment Exploration**: Bug-1 algorithm for obstacle avoidance and navigation to the table.
- **Object Detection**: Using CNN to identify and locate the cube.
- **Grasp Planning**: Using RRT for collision-free manipulator motion planning.
- **Object Retrieval**: Execution of the grasping task.
- **Return to Origin**: Bug-2 algorithm to navigate back to the starting point.
- **End**: Completion of the task.

Transition Overview: PyBullet

- PyBullet is a physics simulation library that is often used for robotics and machine learning.
- It provides an easy-to-use interface for simulating rigid body dynamics, making it suitable for educational purposes and simple simulations.

Initial Use in the Project:

- PyBullet was initially chosen for its simplicity and ease of use in classroom settings.
- It allowed for quick prototyping of robotic behaviors and manipulation tasks.

Limitations Encountered:

- Lacked support for complex simulations involving advanced manipulations and sensor integrations.
- Transitioned to **Gazebo and ROS** for more comprehensive simulation capabilities, which better suited the project's needs.

System Design

Mobile Base:

- Provides autonomous navigation capabilities in simulated environments.
- Utilizes ROS's navigation stack, which includes SLAM (Simultaneous Localization and Mapping) and path planning algorithms.

Manipulator (Robotic Arm):

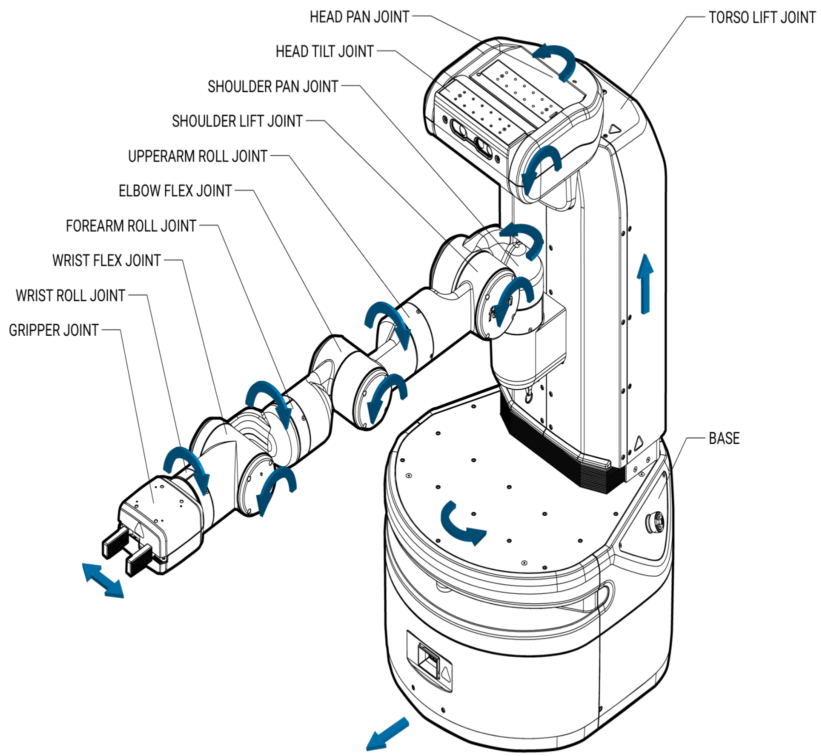
- Equipped with a gripper capable of grasping and lifting objects.
- Uses the 'MoveIt' package in ROS for motion planning and execution, allowing precise manipulation tasks.

Sensors:

- Includes LIDAR and an RGB-D camera for perception tasks.
- These sensors are crucial for object detection, environment mapping, and obstacle avoidance.

Control System:

- Managed through ROS to integrate various components seamlessly.
- Enables decision-making based on sensor feedback to perform tasks like object grasping and navigation.



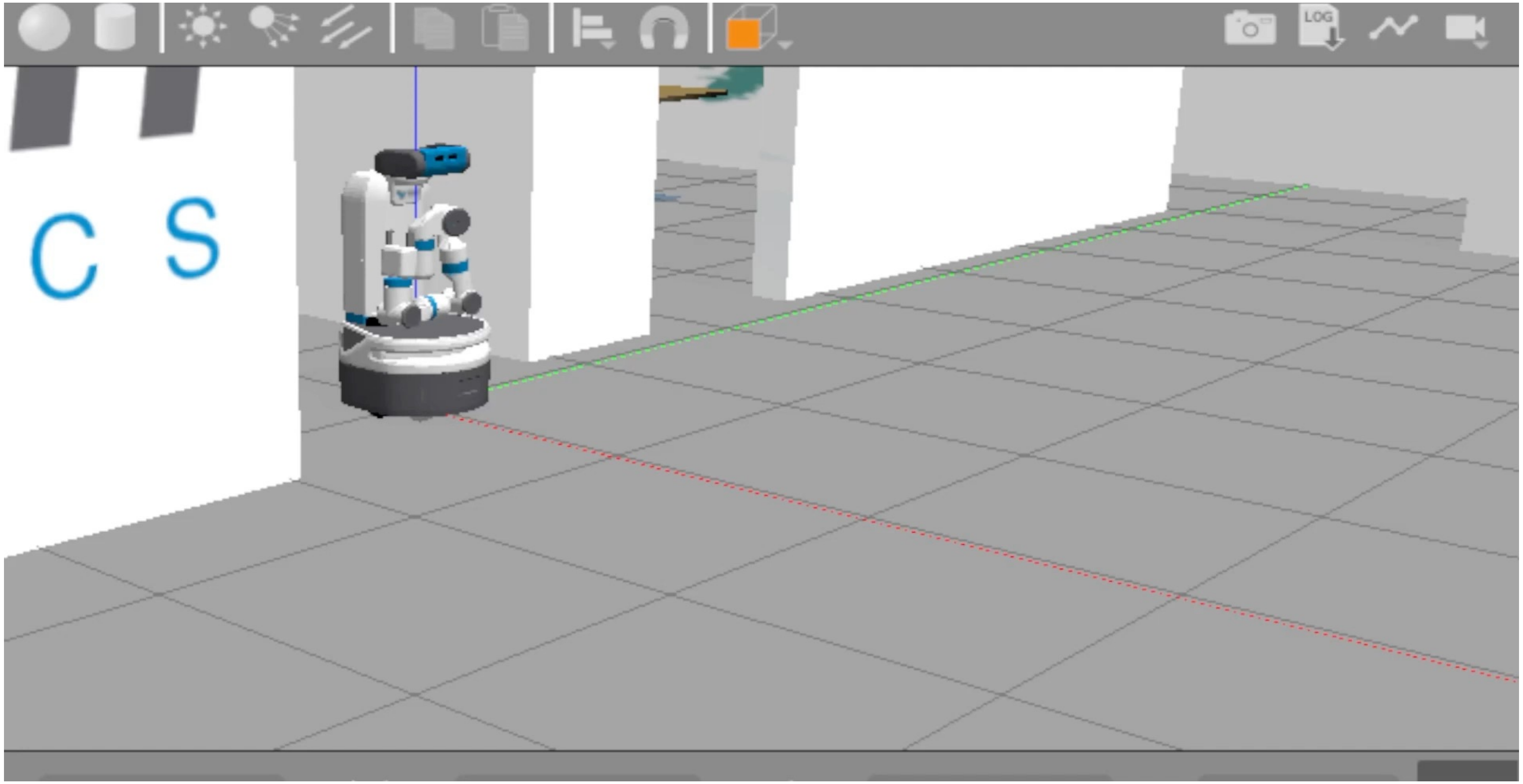
Simulation Environment

Gazebo integrated with ROS for simulation.

Custom virtual environment with obstacles and target objects.

Includes a table, a cube target object, and randomly generated obstacles.

Demo



Evaluation Metrics

Navigation accuracy and task completion time.

Object detection accuracy.

Grasping success rate.

System robustness and energy efficiency.

Challenges and Solutions

Challenges:

- Translating simulation results to real-world applications.
- Complex simulations in PyBullet.

Solutions:

- Transition to Gazebo for advanced simulation capabilities.
- Use of ROS for modular and robust system design.

Preliminary Results

Successful basic navigation and manipulation tests.

Use of A* algorithm for path planning.

Basic object detection and retrieval verified in simulation.

Future Work

- IMPLEMENT ADVANCED OBJECT DETECTION ALGORITHMS.
- IMPROVE PATH PLANNING FOR DYNAMIC OBSTACLES.
- INTEGRATE REAL-TIME DECISION-MAKING CAPABILITIES.
- TEST PERFORMANCE IN MORE COMPLEX ENVIRONMENTS.

Conclusion

This project demonstrates the potential of autonomous robots in streamlining operations.

Highlights the significance of advanced robotic manipulation and navigation.

Paves the way for future real-world applications in automation.

Questions?

Thank you for your attention!