Introduction

Background

Robots were originally designed to assist or replace humans by performing repetitive and/or dangerous tasks that humans usually prefer not to do, or are unable to do because of physical limitations imposed by extreme environments. With the continuous developments in mechanics, sensing technology, intelligent control and other modern technologies, robots have improved autonomy capabilities and are more dexterous.

Articulated robots are among the most common robots used today. They look like human arms and that is why they are also called robotic arms or manipulator arms. In some contexts, a robotic arm may also refer to a part of a more complex robot. A robotic arm can be described as a chain of links that are moved by joints that are actuated by motors [1].

The majority of robotics applications focus either on navigation aspects of mobile platforms (e.g. industrial transportation systems, guide robots), or the manipulation of goods with robotic arms (e.g., bin-picking applications). Nonetheless, few applications consider mobile manipulation itself combining both robotic tasks. There is a lack of real applications of mobile manipulation systems due to the complexity and uncertainty introduced by combining both manipulation and navigation [1].

Challenges and Research

Traditionally, such mobile manipulation operations have been solved using analytical planning and control methods. These methods require explicit programming of the skills which can be very costly and error-prone, particularly in problems where decision-making is complex and the environment dynamic and partially known. The performance of these models depends on how well the reality fits the assumptions made by the model. Well-known planning and control methods have been widely used for scheduling mobile manipulation behaviors, for example using the NAV2 navigation stack and SLAM algorithms for localization and navigation and MoveIt for arm and object manipulation.

The main challenge in mobile manipulation is to combine the navigation and manipulation tasks in a single system. The navigation task requires the robot to move from one place to another, while the manipulation task requires the robot to interact with objects in the environment. The robot must be able to plan and execute both tasks in a coordinated manner. This requires the robot to have a good understanding of the environment, including the location of objects and obstacles, and the ability to plan and execute complex manipulation tasks.

Objectives of the Project

This Thesis project aims to develop a mobile manipulation system that can perform simple manipulation tasks in a dynamic environment. The system is based on 2 robots: a mobile robot and a robotic arm. The mobile robot is equipped with a LIDAR sensor for navigation and the robotic arm is equipped with a camera for object detection and perception. The system can perform simple mobile manipulation tasks in both agricultural and industrial environments. The entire project revolves around the development of software components that will enable the robots to perform high-level tasks in a completely autonomous fashion, without human intervention, and minimal human supervision. The core focus of the project is the complete autonomy of the system, including navigation, object detection, manipulation, and task planning.

This project will be limited to the development of algorithms, software packages and libraries that will be used to control the mobile manipulation system and perform high-level tasks. The project is based on already available robotic platforms and hardware, and the focus will be on the development of software components that will enable the robots to perform mobile manipulation tasks.

The final objective of the project is the development and realisation of two Demonstrations that will showcase the capabilities of the mobile manipulation system. The first demonstration is a system that can interact with a control panel in an industrial environmentm, specifically pressing buttons on a box knowing only the relative positioning of the buttons and the Aruco markers on the box. The second demonstration is a system that can interact with a plant in an agricultural environment, specifically picking up fake apples (or colored balls) from a plastic tree.

Structure of the Thesis

This Thesis is structured as follows:

- Chapter 1: **Introduction**. This chapter provides an overview of the thesis project, the challenges and the objectives.
- Chapter 2: **State of the Art and Literature Review**. This chapter provides an overview of the state-of-the-art and a review of the relevant literature on mobile manipulation.
- Chapter 3: **Robotic Platform for Mobile Manipulation**. This chapter describes the robotic platform used in the project, including all the hardware components and sensors.
- Chapter 4: **Software Architecture and Simulation environments**. This chapter describes the software architecture of the system, all the algorithms, software libraries and the simulation environments used for testing and development of the system.
- Chapter 5: **Experimental Setup and Demonstrations**. This chapter describes the experimental setups used to test the system and demonstrate the capabilities of the entire system.
- Chapter 6: **Results and Future Work**. This chapter presents the results of the experiments and discusses the limitations of the system and future work.