Project Details Report: FRedBots

Introduction:

The utilisation of robotics in solving the problem of intra-warehouse package delivery brings numerous benefits. Robots equipped with advanced sensors and capable of autonomous decision-making can significantly improve the efficiency and coordination of package delivery operations. By employing MARL algorithms, the robots can communicate, collaborate, and optimise their actions to perform tasks such as task scheduling, deadlock avoidance, and efficient package transportation. The combination of robotics, sensor technologies, and intelligent algorithms provides a promising solution to enhance the productivity and reliability of intra-warehouse package delivery systems.

The objective of this project is to design a Multi-Agent Reinforcement Learning (MARL) setup using wheeled robots to optimise and improve the efficiency of intra-warehouse package delivery. The robots will be equipped with various sensors such as cameras, lidar, and motors, and will communicate with each other using advanced algorithms to achieve effective task scheduling, deadlock avoidance, and efficient transportation of packages while avoiding obstacles. The project will employ variants of Reinforcement Learning (RL) algorithms, including Q-learning, A2C (Advantage Actor-Critic), A3C(Asynchronous Advantage Actor-Critic) , Deep Q-Learning, among others. The software stack for development and simulation will include ROS Noetic, Gazebo, Rviz, Python, and Linux.

In addition to the mentioned RL algorithms and software stack, the project can also incorporate Federated Learning (FL) as a part of the Multi-Agent Reinforcement Learning (MARL) setup for optimising intra-warehouse package delivery.

Problem Statement:

The current intra-warehouse package delivery system faces challenges in terms of efficiency and coordination. The aim is to develop a MARL setup that addresses the following key problems:

- Task Scheduling:
  Design an algorithm that allows wheeled robots to schedule package delivery tasks among themselves effectively. The MARL setup should enable autonomous decision-making, considering factors such as package priority, robot availability, and proximity to the destination.

- Deadlock Avoidance:
  Implement mechanisms to prevent deadlock situations where robots block each other's paths, leading to a halt in package delivery. The MARL setup should incorporate intelligent decision-making and coordination strategies to ensure smooth and continuous operation.

- Efficient Package Transportation: Develop algorithms that optimise the transportation of packages by enabling wheeled robots to choose the most efficient routes. This includes avoiding obstacles and dynamically adapting to changes in the warehouse environment.

Sensors and Controllers :

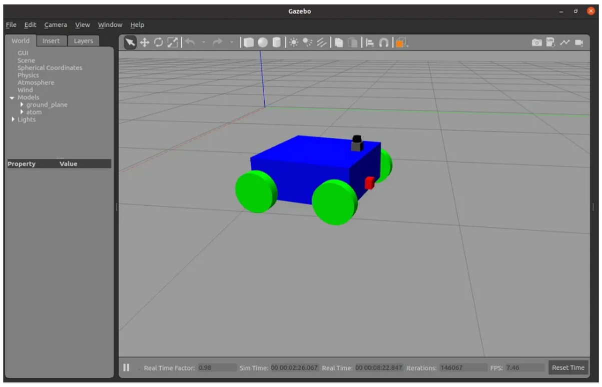
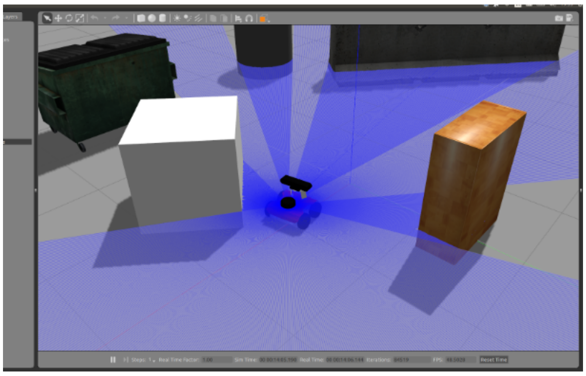
The wheeled robots in the MARL setup will be equipped with the following sensors and controllers :

- Camera: Cameras will be used for visual perception, enabling the robots to perceive the environment, identify package locations, and detect obstacles or other robots in their vicinity.
- Lidar: Lidar sensors will provide depth information and 3D mapping capabilities, allowing the robots to accurately navigate the warehouse environment, avoid collisions, and plan efficient paths.
- PID Controller: A PID (Proportional-Integral-Derivative) controller is an integral part of the control system and is responsible for regulating the output of the motors based on feedback from sensors. It uses the difference between the desired state and the current state to adjust the control signals, ensuring accurate and precise movement control of the wheeled robots.

URDF Model:

The wheeled robots in the MARL setup will be based on the Atom URDF model. The Atom model provides a suitable representation for the robots, allowing for accurate simulation and interaction within the ROS and Gazebo environments.

The model can be found here : https://github.com/harshmittal2210/Robotics_ws/tree/main

Software Stack:

The software stack for development and simulation of the MARL setup will include the following:

ROS Noetic: ROS (Robot Operating System) provides a framework for building robotic systems. ROS Noetic will be used to develop the communication infrastructure and coordination mechanisms for the wheeled robots.

Gazebo: Gazebo is a widely-used robot simulation environment that allows for realistic and customizable simulations. Gazebo will be utilised to simulate the warehouse environment and the behaviour of the wheeled robots.

Rviz: Rviz is a powerful visualisation tool provided by ROS. It will be used to visualise and analyse the sensor data, robot positions, and package locations during the MARL setup development and testing phases.

Python: Python programming language will be used to implement the MARL algorithms, develop the control logic, and integrate the different components of the system.

Linux: The project will be developed and executed on a Linux-based operating system, leveraging the advantages of open-source software and compatibility with ROS.

Conclusion:

This project aims to design a MARL setup using wheeled robots for intra-warehouse package delivery. By employing advanced reinforcement learning algorithms, effective task scheduling, deadlock avoidance, and efficient package transportation can be achieved. A combination of cameras, lidar, and motors as sensors will enable the robots to perceive the environment, navigate accurately, and transport packages. The software stack comprising ROS Noetic, Gazebo, Rviz, Python, and Linux will provide the necessary tools and infrastructure for the development, simulation, and evaluation of the MARL setup.

The development of a MARL setup using wheeled robots for intra-warehouse package delivery demonstrates the potential of robotics in solving complex logistical problems. The integration of sensors, advanced algorithms, and the software stack provides a robust foundation for achieving efficient task scheduling, deadlock avoidance, and optimised package transportation. As the field of robotics continues to advance, future scope includes further refinement of the MARL algorithms, incorporation of more sophisticated perception capabilities, and integration with real-world warehouse systems.

By incorporating Federated Learning, the project can benefit from the advantages of collaborative learning across multiple wheeled robots while respecting data privacy and maintaining the distributed nature of the system. The use of Federated Learning in MARL can enhance the robots' coordination, decision-making, and overall efficiency in delivering packages within the warehouse environment

This project serves as a stepping stone towards the realisation of intelligent and autonomous robotic systems for efficient intra-warehouse package delivery, with implications extending to broader applications in logistics and automation.