Autonomous Navigation – SLAM, Frontier Exploration & A* Path Planning

At the core of the robot's autonomous navigation system is a 2D LiDAR sensor, which continuously scans its surroundings to generate a real-time occupancy grid map via SLAM (Simultaneous Localization and Mapping). This dynamic map serves as the foundation for both exploration and navigation. The robot employs a frontier-based exploration strategy, which identifies boundaries between explored and unexplored space ("frontiers")and prioritizes movement toward these regions to maximize map coverage efficiently. Once a frontier goal is selected, the A* path planning algorithm is used to compute an optimal route through free space, balancing path length and obstacle avoidance. This high-level planner interfaces with local control modules to generate velocity commands, enabling the robot to maneuver safely around static walls and dynamic obstacles while progressing toward its mission objectives. The integration of SLAM, frontier detection, and A* ensures reliable, efficient, and intelligent navigation within unknown and complex maze environments.

Launcher Mechanism – Flywheel System

This system operates by rapidly spinning a pair of opposing wheels using JGB37-250 motors, generating sufficient tangential velocity to propel lightweight projectiles such as ping pong balls. When a projectile is fed into the flywheel gap, frictional contact with the rotating surfaces accelerates it forward at high speeds.We make use of a gear train to increase RPM with the bigger gear connected to the motor and the smaller gear connected to the flywheel axle. This is paired together with our ball loading system to create our flare mechanism.

Rack and Pinion - Ball Loading System

To support automated and repeatable firing, the robot integrates a rack and pinion-based loading mechanism. This system uses a linear actuator where rotational motion from a servo-driven pinion gear is converted into linear displacement of the rack. Each stroke of the rack pushes a single projectile from a pipe into the flywheel launching chamber. This mechanical design ensures consistent alignment and loading of the projectile, minimizing jams while enabling controlled reloading cycles synchronized with the firing sequence. The servo timing was adjusted using code to ensure it loads the balls at 2-4-2 intervals. The pipe rests on a pipe holder and the pipe is at an angle such that the gravitational force causes the balls to roll into the holding area before it is fed into the flywheel.

Heat Detection

The AMG8833 heat sensor creates an 8x8 array of temperatures. When the temperature value and temperature count exceeds a threshold, the launching mechanism is activated.

Power Consumption, Operation time and battery specification

Battery specification: 11.1V, 1800 mAh
Total time for which the system can operate: 92.3 min