Inspection Robot for Confined Spaces

Requirements Specifications

Moataz SEGHYAR

Document Purpose

This document serves as the Project Requirements Specifications for the Inspection Robot for Confined Spaces. It outlines the technical requirements, design parameters, and functional specifications necessary to ensure the robot meets its operational objectives. While the complementary justification document provides detailed analytical and engineering rationale for component selection, this document focuses on defining the key performance criteria, operational constraints, and system requirements that guide the design and development process.

Purpose

This project aims to develop an **inspection robot** for OCP, capable of operating in **60 cm high confined spaces** within phosphate extraction machinery. The robot will:

- Detect **toxic gases**.
- Monitor **temperature** and **humidity**.
- Create a **3D map** of the environment using LiDAR and depth cameras and **navigate autonomously**.

The robot addresses challenges such as **limited accessibility**, **hazardous conditions**, and the need for **real-time data collection**.

Stakeholders

Key stakeholders include:

- **OCP Engineers and Operators**: Use the robot for machinery inspections.
- **Safety Personnel**: Ensure compliance with safety regulations.
- **Maintenance Teams**: Identify potential issues early.
- **Project Managers**: Oversee deployment and integration.

Scope

The robot will:

- Operate in **60 cm high confined spaces** with autonomous navigation and remote control options.
- Collect and transmit real-time data on gases, temperature, humidity, and 3D mapping.
- Withstand harsh industrial environments (e.g., dust, moisture, corrosive gases).
- Comply with **IP65** safety standards.

Project Overview

The inspection robot will:

- Use a tracked propulsion system for mobility.
- Navigate using LiDAR and a depth camera.
- Collect and transmit environmental data (temperature, humidity, gas concentrations).
- Operate in both manual remote control and autonomous modes.
- Feature a modular expansion port for additional components.
- Be designed to withstand harsh industrial environments (IP65-rated).

System Architecture

The robot system consists of the following key components:

- **Propulsion:** Tracked system powered by two DC motors.
- **Processing Unit:** Jetson Nano for sensor data processing.
- **Microcontroller:** STM32 for motor and sensor control.
- **Power System:** 24V battery providing at least 1.5 hours of operation.
- **Sensors:** Industrial-grade sensors for temperature, humidity, and gas levels.
- **Communication:** Wireless connectivity for real-time data transmission and remote control.

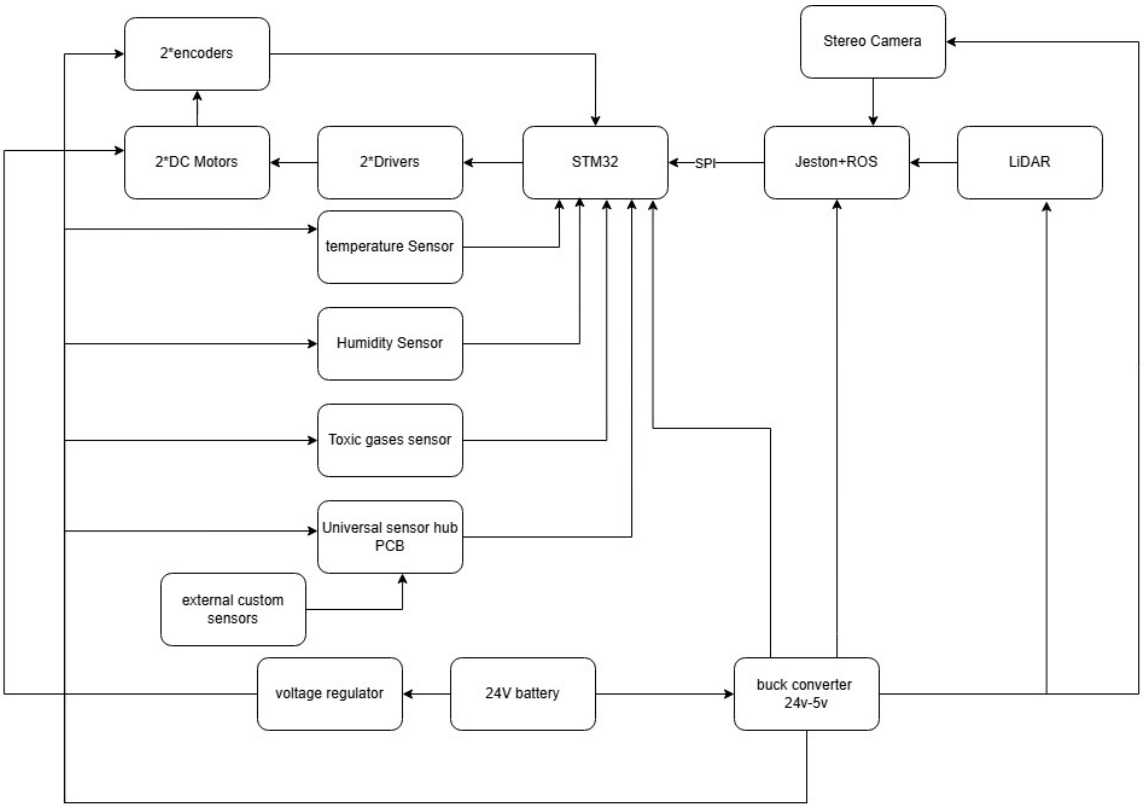

Figure 1: System Architecture

Requirements

Functional Requirements (FRs)

ID	Requirement
FR-01	The robot shall use a tracked propulsion system powered by two DC motors.
FR-02	The robot shall navigate autonomously using LiDAR and depth camera data.
FR-03	The robot shall support manual remote control via a wireless interface.
FR-04	The robot shall collect and transmit environmental sensor data.
FR-05	The robot shall enable real-time data transmission.
FR-06	The robot shall include a modular expansion bay for additional components.
FR-07	The robot shall provide an emergency stop function for safety.

Non-Functional Requirements (NFRs)

ID	Requirement
NFR-01	The robot shall achieve a maximum speed of at least 20 cm/s.
NFR-02	The robot shall operate continuously for a minimum of 2 hours on battery power.
NFR-03	The robot shall be IP65-rated for dust and moisture resistance.
NFR-04	The robot shall function in ambient temperatures between $-20°$C and 50°C.
NFR-05	The robot's communication latency shall not exceed 500 ms.
NFR-06	The battery system shall support a minimum of 500 charge cycles.
NFR-07	The modular expansion bay shall enable easy integration of additional sensors or tools.
NFR-08	The robot shall weigh less than 20 kg for ease of transportation.