Department of Computer Science & Engineering
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Architectural Design Specification
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Robo Crew
RV8 Workcell

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Revision History

Revision	Date	Author(s)	Description
0.1	11.06.2023	AM, MA, AP, HK, KM	Document Creation
0.2	05.04.2024	AM, MA, AP, HK, KM	Updating work cell task to painting

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1 Introduction

This product is a high level working prototype of an industrial level robot which serves the purpose of applying paint to automotive and aerial vehicle parts for various purposes, such as protection, aesthetics and branding. The paint will be sprayed using an airbrush. The air brush is connected to an air compressor which is being controlled by the PLC. This robot arm is set on a linear rail which serves as joint 7 (additional axis). There are two inductive switches placed on the ends of of linear rail signalling the end of the rail. These are also connected to PLC.

2 System Overview

This section outlines the architectural strategy for the flow of the RV8 work cell system, defining the top-level logical view of the design. The system is structured into three distinct layers: Input, Processing, and Output. Each of these layers serves a specific and vital function within the system, enabling the robot to perform fixed tasks based on the program. This section includes a high-level block diagram that visually illustrates the relationships and interactions between these layers, providing a comprehensive overview of the system's architecture.

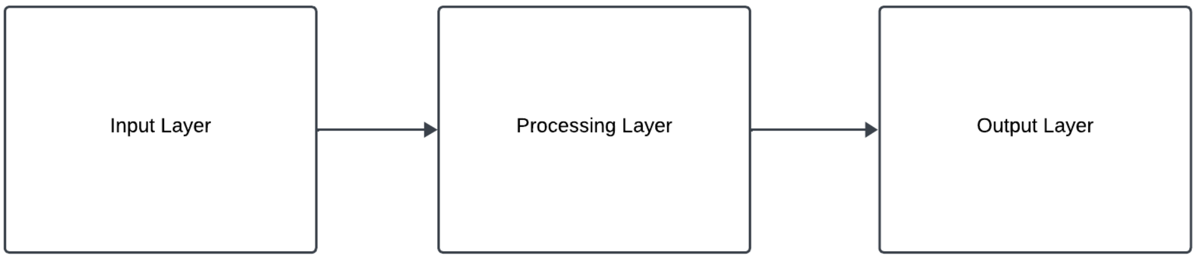

Figure 1: An overview of the higher level layers.

2.1 Input Layer Description

The input layer plays an important part in executing the spray painting task as per the programmed movement. The input in this system comes from the host PC and the sensors. The host PC acts as a centralized location to write programs for robotic movement, as well as control PLC logic. The sensors involved in the system are emergency stops (e-stops) and inductive switches. These inputs sends signals to the PLC on particular situations and scenarios to keep the safety measure intact. Inductive switches make sure that the robot arm is calibrated properly before it executes its task. Where as emergency stops immediately halt the robot's operation, ensuring the safety of personnel and preventing potential accidents.

2.2 Processing Layer Description

The processing layer comprises of connection and communication between the PLC and the robot controller primarily. In order to program the PLC to do the required tasks, GXWorks3 (software) and RTToolbox (software) are jointly used. A program written in ladder logic controls the logic for the air compressor and light tower. The program inside the PLC is written from the PC and executed. The instructions are passed onto the controller and directs the robot to move its joints according to the program.

2.3 Output Layer Description

The main component of output layer is the airbrush. Movement of joints and triggering air compressor enable the robot to spray paint in desired way or pattern. The PLC sends the signals to air compressor to control the air flow of the airbrush. Whereas, the robot arm adjust itself according to the programmed positions before the air brush sprays. In addition, there is a light tower which consist of 3 lights. Every color outputs different signal. Green light indicates the regular functioning of the robot. The yellow light is only visible when the robot is calibrating itself with the help of inductive switches. Red light indicates the error or e-stop status, which signals in the halt state of the robot.

3 Subsystem Definitions & Data Flow

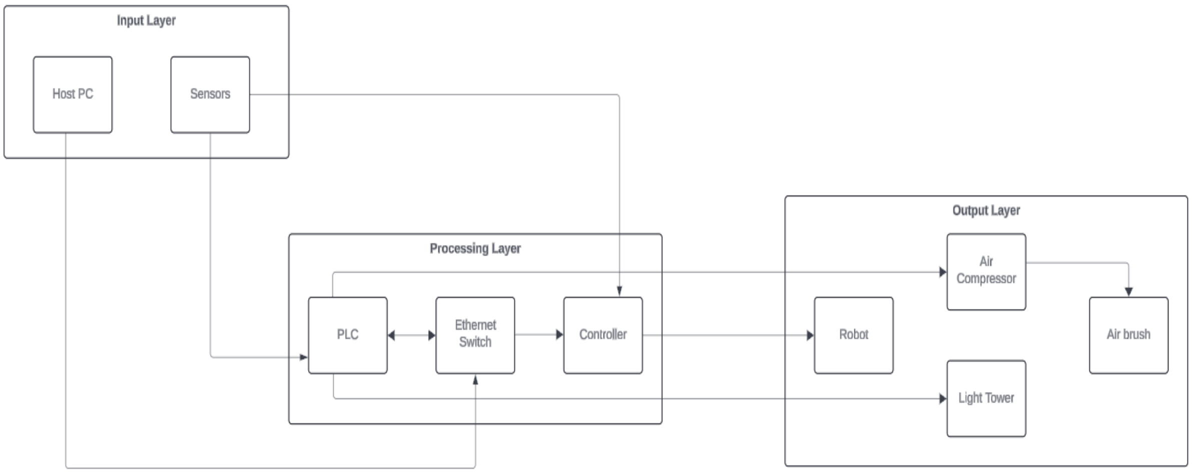

Figure 2: Data flow diagram of workcell.

4 Input Layer Subsystems

The input layer is comprised of various sensors, such as the E-stop switch and inductive limit switches. The input layer receives these inputs and directs them to the programmable logic controller for further processing. The host PC is also a component within the input layer, in charge of programming and writing to the system. We can configure the robot arm and the linear rail to execute a task, and in case of an emergency, the E-stop can halt our program instantly.

4.1 Host PC

The host PC acts as the centralized component for communication between the robot arm and the PLC. Comprised of software like RTToolbox and GXWorks3, the PC can program the different subsystems to accomplish the application task.

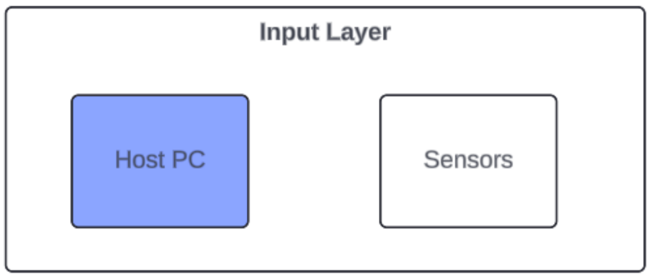

Figure 3: Host PC subsystem description diagram.

4.1.1 Assumptions

Host PC contains all the required software to program the movement of the robot. The program written in host PC will act as an input for our system.

4.1.2 Responsibilities

The program will contain logic behind the specific movement of the robot. The program will be written in a way that the robot only performs a fixed task.

4.1.3 Subsystem Interfaces

Table 2: Subsystem interfaces

ID	Description	Inputs	Outputs
#01	Write a robot movement program	-	sends program
#02	Write a logic program	-	sends program

4.2 Sensors

The sensors subsystem consists of emergency stops and inductive limit switches. E-stops serve as a safety feature, allowing users to halt the robot in the event of unexpected actions or when they desire. This sensor can stop the program, regardless of the current processing state. The inductive limit switches act as motion boundaries for the robot and aid with calibration.

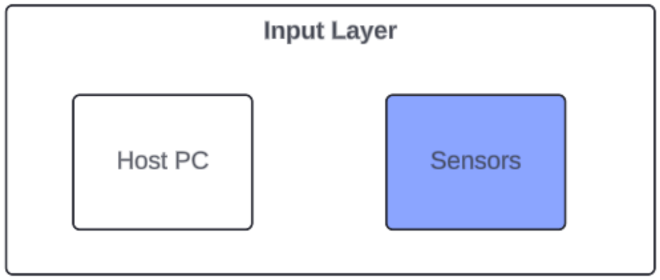

Figure 4: Sensors subsystem description diagram

4.2.1 Assumptions

E-stops can be pressed to immediately stop the robot in case of potential collisions, unexpected behavior, or excessive temperature increases. The emergency stops are used in emergency situations, and are not the normal standard for halting robot movement. The inductive limit switches send signals to the robot controller to indicate the robot is reaching its boundary limits. The program written by the PC must include a dynamic calibration sequence that references these limits.

4.2.2 Responsibilities

If users press any of the E-stops, the system stops by transmitting the changed input value to the controller. When any of the emergency stop switches are pressed, the switch is closed and the electric signal is outputted, and this value is then relayed to the controller to halt the system. Similarly, any time the robot travels over the limit switch, the contact is closed and sends a signal to the PLC.

4.2.3 Subsystem Interfaces

Table 3: Subsystem interfaces

ID	Description	Inputs	Outputs
#03	E-stop signal	button status	closed or open
#04	Inductive switches	closed or open	0 or 1

5 Processing Layer Subsystems

In this section, the processing unit layer is described in some detail in terms of its specific subsystems. The processing unit comprises three primary components: the PLC, the Ethernet switch, and the robotic controller. This layer plays a crucial role in the robotic system by acquiring input data from sensors and processing it before transmitting the processed data to the robotic arm and air compressor.

5.1 PLC

Programmable Logic Controller (PLC) is an industrial automation device used for controlling and automating various processes in manufacturing, production and other industrial applications.

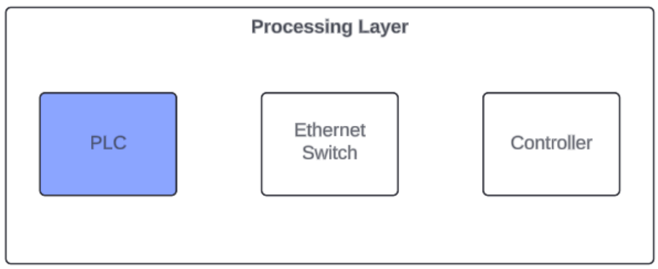

Figure 5: PLC subsystem.

5.1.1 Assumptions

PLC is like a central processing unit of this product. The input comes from the input layer and is written onto to the PLC since the primary purpose of using a PLC is to automate the process.

5.1.2 Responsibilities

The responsibility of the PLC being used in this project is to save the logical program and movement program, and to continuously process the state of the work cell. The PLC is written with a logic-based program that receives input signals from the input layer and manipulates them according to the program specification. PLC is also responsible to send output signals to other components within the system such as the air compressor and light tower to conclude the process. The output signals are computed via the logic written in the PLC. It also receives input signals from inductive switches for calibration purposes.

Table 4: Subsystem interfaces

ID	Description	Inputs	Outputs
#01	Programmable Logic Controller	Logic Program	Send to different devices
#02	Programmable Logic Controller	Movement Program	Send to Controller
#03	Programmable Logic Controller	Inductive switches	Light Tower

5.2 Ethernet Switch

The Ethernet switch bridges communication between 3 crucial components: the host PC, the robot controller, and the PLC. The Ethernet switch is located within the control cabinet and insures consistent and instantaneous communication over the network.

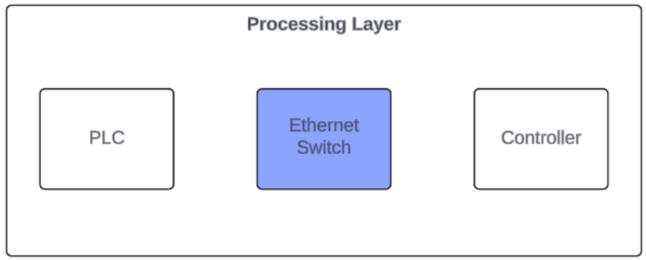

Figure 6: Ethernet subsystem

5.2.1 Assumptions

A stable Ethernet connection is assumed for consistent data transfer. The components are configured to be on the same sub-network to communicate. Additionally, the robot controller and PLC must be configured with Mitsubishi's CC-Link IE Field Network to ensure signal transfer.

5.2.2 Responsibilities

The Ethernet switch is responsible for routing and forwarding data packets between the robot controller, PLC, and other networked devices. The switch must be consistent to ensure precision and fast transmission. Without the Ethernet switch, the robotic work cell cannot function properly and errors will arise from a lack of communication.

5.2.3 Subsystem Interfaces

Table 5: Subsystem interfaces

ID	Description	Inputs	Outputs
#04	Data input from PC	CAT6 Ethernet Cable	CC-Link processed packets
#05	Data input from PLC	CAT6 Ethernet Cable	CC-Link processed packets
#06	Data input from CR-800 Controller	CAT6 Ethernet Cable	CC-Link processed packets

5.3 Controller

Controllers are designed to seamlessly integrate with robots. These sophisticated devices serve as the brain of robots, governing their actions and enabling precise control.

5.3.1 Assumptions

The primary role of a robot controller is to receive instructions from a PLC and external sensors.

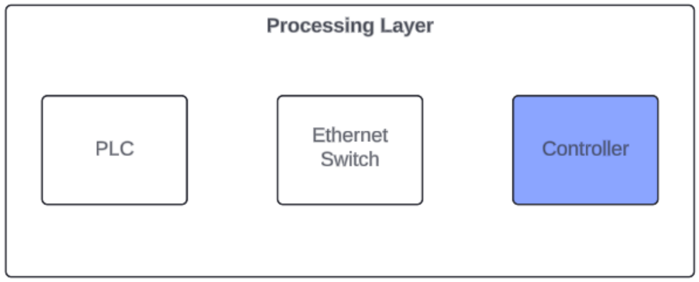

Figure 7: Controller subsytem

5.3.2 Responsibilities

Responsibilities of controller is to precisely manipulate the robot's joints according to a specific sequence or pattern. In addition, it also receives signals from E-stops which halts the robot functionality.

5.3.3 Subsystem Interfaces

Table 6: Subsystem interfaces

ID	Description	Inputs	Outputs
#07	Controller	signals	movement of joints
#08	Controller	Emergency stops	Halting the robot movement

6 Output Layer Subsystems

This section discusses the output layer of the work cell system and how each component is going to interact with data inputs to perform the task of industrial painting. The primary goal of this layer is to receive signals from the processing layer and perform the necessary operations like moving the robotic arm/linear rail, execute the painting task, and illuminate the safety light tower.

6.1 Robot

This layer consists of the robot subsystem, which includes the Mitsubishi RV-8CRL robotic arm and the additional axis linear rail.

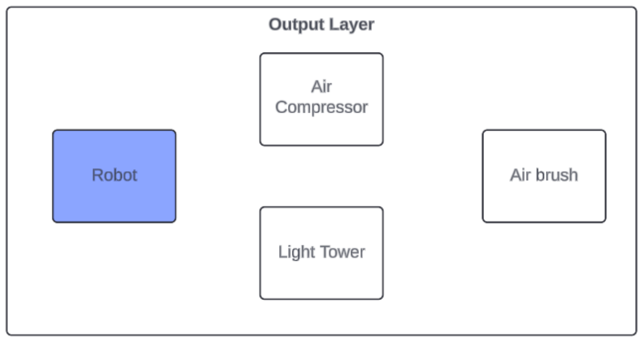

Figure 8: Robot subsystem

6.1.1 Assumptions

The robotic arm provided by Mitsubishi is functional and abides to its specifications as provided by Mitsubishi documentation. We also assume the CR-800 controller is compatible with the robot and linear rail, and communication between the components is ensured through the RT Toolbox software stored on the host PC.

6.1.2 Responsibilities

The robot is responsible for movement and engaging in painting. Movement can be achieved through the robotic arm's 6 joints, as well as the additional 7th axis linear rail. The robot receives movement commands from the host PC and/or the robot controller's 'Operation Panel' (OP). The robot also houses the pneumatic line.

6.1.3 Subsystem Interfaces

Table 7: Subsystem interfaces

ID	Description	Inputs	Outputs
#01	Joint control	RT Toolbox program Operation Panel	Robot movement
#02	Robot errors	Internal signals	CR-800 controller
#03	Pneumatic line	Base air hose	Forearm airhose

6.2 Air Compressor

An air compressor is a machine that takes ambient air from surroundings and discharges it at a higher pressure.

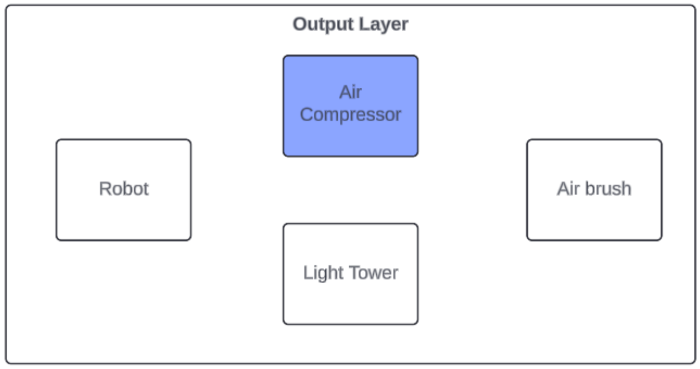

Figure 9: Air Compressor subsytem

6.2.1 Assumptions

The primary role of an air compressor is to provide sufficient air pressure for spraying purposes.

6.2.2 Responsibilities

The electrical connection between the air compressor and the PLC ensures their communication. Additionally, the pneumatic lines run through the robot arm, maintaining the connection between the air brush and the air compressor.

6.2.3 Subsystem Interfaces

Table 8: Subsystem interfaces

ID	Description	Inputs	Outputs
#04	Sprays paint	PLC	air pressure to air brush

6.3 Light Tower

An industrial light tower system, typically used in a working cell or industrial setting, serves several essential responsibilities to ensure the efficient and safe operation of the workspace. The specific responsibilities of an industrial light tower system may vary depending on the application. For our system, it serves as an inference to the work environment as it indicates different modes with colored LEDs as get input from the controller and outputs as LEDs.

6.3.1 Assumptions

The "Light tower" subsystem assumes that it will receive status information from the PLC about the working status of the robot arm. It is assumed that this will be a reliable signal or interface to indicate the status of the working cell.

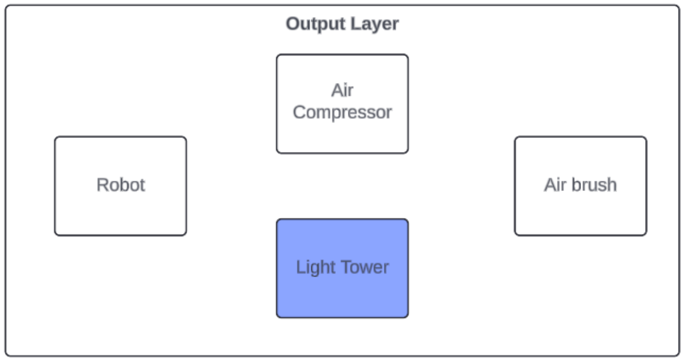

Figure 10: Light tower subsystem

6.3.2 Responsibilities

Signaling and Alerts: Industrial light tower systems often include signal lights or beacons. These lights can be used to convey information or alerts to workers or nearby personnel. Common signals include indicating when a machine is running, signaling the need for maintenance or repair, or warning of specific hazards or emergencies. Status Indication: The light tower system can provide status indications for machines or equipment within the working cell. Safety: Ensuring the safety of workers is a primary responsibility. Light towers can be programmed to flash or change colors to draw attention to potential safety hazards, such as moving equipment or areas that require caution.

6.3.3 Subsystem Interfaces

Table 9: Subsystem interfaces

ID	Description	Inputs	Outputs
#05	Stop Operation	E stops	red led signal
#06	Calibrating	PLC	yellow led signal
#07	Regular operation	PLC	green led signal

6.4 Air brush

An airbrush is a versatile tool used by artists, creators, and hobbyists to apply color to various surfaces

6.4.1 Assumptions

Air brush expects air pressure from air compressor as per the pattern requirement.

6.4.2 Responsibilities

The airbrush's role is to apply paint while the robot moves in a predetermined pattern as per its programming.

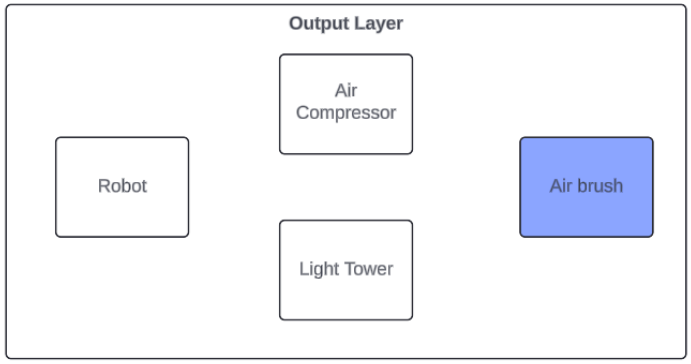

Figure 11: Air brush subsystem

6.4.3 Subsystem Interfaces

Table 10: Subsystem interfaces

ID	Description	Inputs	Outputs
#08	Tool for spraying	Air compressor	sprays paint

References