Department of Computer Science & Engineering
The University of Texas at Arlington

Project Charter
CSE 4316: Senior Design I
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Robo Crew
RV8 Robot Work Cell

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REVISION HISTORY

Revision	Date	Author(s)	Description
0.1	09.24.2023	AP, AM, HK, KM, MA	Document creation
0.2	05.05.2024	AM, MA, AP, HK, KM	Updating work cell task to painting

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1 Problem Statement

Devices with many features are now common. This means that things like how heavy a product is, how well it is made, and how exact it is have become more important. To add more functions and sensors while also making things lighter, we need smaller parts and very detailed designs. Even small mistakes can be really serious, especially if they involve people's lives, so being very exact is extremely important. These complicated tasks often need skills that humans might struggle with. Tasks that need a lot of focus, like doing the same thing over and over, are often done better and more accurately by robots than by people. Robot arms are a great solution for this, as they are efficient, adaptable, and very exact when doing complicated things. The main goal of smart manufacturing is to make production more efficient, improve the quality of products, and make sure that production is safe. Robot arms, because they are so flexible and exact, are great for doing all kinds of complicated tasks. This project aims to make robot arms even better at meeting the needs of users by tackling these complicated challenges. By doing this, it helps improve smart manufacturing practices, encouraging new ideas and high standards in many different industries.

2 Methodology

In this project, we focus on using the Mitsubishi Electric Industrial Robot, RV8, to perform precise tasks. Our main goal is to improve safety by integrating innovative lighting systems that show progress visually and by adding multiple emergency stop mechanisms in the robot's controller for immediate halting in emergencies. We make use of the RV8's capabilities, especially its 8 controllable joints that can be accessed through the Robot Teaching Box, allowing us to control its movements precisely. Moreover, we utilize the robot's ability to learn manual movements through a teaching mode. To make the robot execute tasks intelligently, we integrate various algorithms into its control system seamlessly. Additionally, we have plans for future developments, such as attaching an end effector and implementing a rail system to expand the robot's workspace. These enhancements will enable the robot to effectively grasp and manipulate a wide range of objects. Throughout these activities, our main focus is on ensuring safety and optimizing operational efficiency, so that the RV8 robot can perform at its best across a variety of tasks.

3 Value Proposition

In today's rapidly evolving technological landscape and increasingly industrialized world, robot arms are emerging as versatile and essential tools. These sophisticated machines are set to revolutionize industries through several promising trends in development. Firstly, there is the exciting frontier of enhanced intelligence, where artificial intelligence and machine learning empower robot arms to learn autonomously and make decisions. Equipped with advanced sensors and vision systems, these robot arms gain heightened environmental awareness and object recognition, making them more adaptable to dynamic scenarios. Additionally, the growing need for collaboration with humans requires robot arms to perceive human movements and intentions, ensuring secure and seamless cooperation. In parallel, advancements in unmanned technology allow robot arms to operate autonomously in specialized environments such as hazardous settings, space exploration, and deep-sea exploration. This autonomy improves task safety and efficiency and expands the range of operations. Finally, there is a focus on integration, facilitated by modular and standardized designs, which simplifies complexity and enables quick configuration for diverse tasks. In summary, these trends position robot arms as essential catalysts for increased productivity, efficiency, and safety across various industries. They will tackle complex challenges and unlock remarkable outcomes for the future.

4 Development Milestones

The following is a list of completion dates for all major documents, demonstrations, and associated deadlines:

- Project Charter first draft - September 25, 2024
- System Requirements Specification - October 16, 2024
- Architectural Design Specification - November 6, 2024
- Detailed Design Specification - February 12, 2024
- Demonstration of Initial Robot Movement - September 25, 2024
- Demonstration of Basic Program - October 16, 2024
- Demonstration of Linear Rail Movement - November 6, 2024
- Demonstration of E-stop Switch Configuration - November 06, 2024
- Demonstration of holder for paint brush - February 12, 2024
- Demonstration of GPIO 20-Pins Configuration - March 7, 2024
- Demonstration of Light Tower Setup - March 25, 2024
- Demonstration of Spray oil paint Program - April 15, 2024
- CoE Innovation Day poster presentation - April 16, 2024
- Final Project Demonstration - April 26, 2024
- Final Project Submission - May 08, 2024

5 BACKGROUND

In the rapidly evolving landscape of manufacturing, particularly in sectors like automotive, industrial painting plays a crucial role in ensuring product quality and aesthetics. However, the conventional approach to tasks such as painting within factories and industrial settings presents several challenges. Manual painting processes are often time-consuming and prone to errors, leading to decreased productivity and increased labor costs. Moreover, manual painting poses inherent risks to the workforce, with exposure to hazardous chemicals and fumes. Accidents and injuries are constant concerns, impacting both employee well-being and company reputation. Additionally, the physically demanding nature of manual painting tasks can lead to reduced job satisfaction among workers.

The integration of robotic arms for painting tasks is no longer just a convenience but a necessity. The shift towards automation is driven by the pitfalls of manual labor listed above, as well as several compelling factors consistent with robotic arms that demonstrate their ability to address these challenges effectively and revolutionize painting processes in industries like automotive manufacturing. Robotic arms excel at repetitive tasks requiring precision, leading to significant improvements in efficiency and higher quality finishes. They are also scalable, allowing adaptation to fluctuating production demands, particularly vital in dynamic manufacturing environments. Additionally, robotic arms provide a safer working environment by reducing workers' exposure to hazardous materials and fumes.

The University of Texas at Arlington possesses a Mitsubishi Electric RV-8CRL Robot housed in room 335 of the Engineering Research Building. Previous teams of students and Dr. Christopher McMurrough have worked on the hardware setup of the work cell, including the MELSEC Programmable Logic Controller (PLC). The RV-8 is also mounted on a linear rail, enhancing its reach and flexibility. While the robot is operational, the work cell still requires several areas of integration to be completed, including the implementation of safety sensors like inductive limit switches, door sensors, etc. Also, the efficient wiring of emergency stop (E-stop) switches must be accomplished to ensure a fully safe work cell environment. Additionally, the linear rail needs integration with the RV-8 robot to become fully functional. Lastly, a painting application will be installed into the work cell.

Sponsored by Dr. McMurrough, the project aims to complete the integration of the work cell, serving as a valuable resource for both research and educational purposes at UTA. The project also seeks to showcase the functionalities of the robot to a wider audience and spark interest in the consistent innovation within Computer Science and Engineering at UTA. Once completed, the work cell will empower students with hands-on experience, allowing them to explore the frontiers of robotics, automation, and control systems.

6 RELATED WORK

Factory automation, including robotic painting systems, is emerging as a state-of-the-art technology in manufacturing. There are several current implementations of robotics that address the current challenges in factory automation. Several companies offer robotic systems designed specifically for painting applications. A pioneer in these types of robots is ABB's Delta line of robots, most notably the FlexPicker IRB 360 [6]. The first prototype was designed by a research group led by Professor Reymond Clavel at EPFL, Switzerland [2]. The groundbreaking robot was based on the concept of parallelograms, where three parallelograms restricted the mobile platform's orientation to three purely translational degrees of freedom. The robot's actuation involves rotating levers with revolute joints, which can be actuated using rotational motors or linear actuators. Its lightweight construction and base-mounted actuators make it ideal for light objects between 10 grams to 1 kilogram [2]. Covered by over 30 patents, the robot's success is seen in several industries including automotive manufacturing, electronics, and aerospace.

Another notable robotic system in factory automation from ABB's product line is the IRB 6700 Series. Similar to the RV-8CRL, an IRB 6700 robot is a vertical robotic solution with six degrees of freedom.

The series has an impressive payload range between 150 to 300 kilograms, with a max reach of 3.2 meters [7]. The line even includes variants available as floor mounted and inverted versions, matching the orientation of UTA's RV-8CRL. Other series designed by ABB include the IRB 2600 line, IRB 140 line, and YuMi robots.

FANUC's M-20 series of robots represent a versatile solution for medium payload painting tasks in manufacturing. This line of robots have a payload capacity of 35 kilograms and a max reach of 1,811 millimeters [3]. The robot is strong, yet reasonably light. The 6-axis machine's design incorporates a hollow upper arm, and is ideal for multi-material handling. Its compact footprint allows it to work efficiently in confined spaces, optimizing space utilization within the factory. FANUC's dedication to reliability is reflected in the M-20 series, as it boasts an industry leader long Mean Time Between Failures (MTBF) figure, up to 11 years [1]. Other series designed by FANUC include the CR series and R-30iB series.

KUKA, a German robotics company, offers a range of robots suited for painting and automation tasks in manufacturing. Their KR AGILUS series, for example, provides high-speed and precise handling capabilities for small and medium payloads [4]. On the other hand, Yaskawa Motoman, a subsidiary of Yaskawa Electric Corporation, specializes in industrial robots for various applications, including painting in manufacturing. The Motoman MH series offers versatility and efficiency in painting tasks [4]. Additionally, companies like Universal Robots and MiR (Mobile Industrial Robots) have gained prominence for their collaborative and autonomous mobile robots that can work alongside human workers in factory environments.

As robots are becoming more technologically available, manufacturing industries are adopting the technology with frequency. According to ABI Research, a global tech market advisory firm, worldwide commercial robot revenue in factories will have a Compounded Annual Growth Rate (CAGR) of over 23

Locally, companies are building factories with an aim at reducing human labor. Companies like Tesla have been researching with their robotic painting systems, which have capabilities of painting and coating various automotive parts. Operating at a facility in Dallas, Texas, these systems are capable of handling a significant portion of the painting process [5]. As these companies continue to innovate and invest in automation solutions, the manufacturing industry is poised for a transformative shift marked by increased efficiency, reduced operational costs, and improved product quality.

7 System Overview

The Mitsubishi RV8-CRL robot an 8-axis industrial robotic system with 6 main joints and 2 additional axes has been chosen for this project. Its payload capacity of 8 kg makes it suitable for the task at hand. The goal is to program the robot to demonstrate how industrial robots are utilized in the automotive industry, specifically for painting various automotive and air vehicle parts.
Key features of the RV-8CRL robot include:

- Rotational Axes: The robot's rotational axes allow for precise motion and coordination during painting.
- Versatility: With its 8-axis composition, the robot offers freedom and flexibility in its actions.
- Trajectory Control: Each axis contributes to accurate task execution.
- Safety Sensors: The robot is equipped with integrated inductive sensors along its linear rail. These sensors identify end points and enhance safety.
- Emergency Stop Buttons: An additional sensor ensures protection by allowing the robot to halt its movements instantly to prevent injuries.

- Programming Sequence: The RV-8CRL robot's programming involves a predefined sequence of stages for efficient paint spraying. It calibrates itself, moves its joints according to the program, and sprays when needed.
- Linear Rail (7th Axis): The linear rail enables the robot to move precisely and perform the required tasks.

8 Roles & Responsibilities

Our key stakeholder is Dr. Christopher McMurrough, the project sponsor and the designated point of contact from the sponsor side. Mitsubishi RV-8CRL Robot and essential project materials will be provided by the project sponsor, facilitating the project's implementation. The project team includes five undergraduate students from the Computer Science and Engineering (CSE) department at the University of Texas at Arlington (UTA). The software engineer on the team is Ameen Mahouch. Additionally, there are three team members with a background in Computer Science: Akshay Paluri, Muhammad Anas, and Hyun Ho Kim. With a Computer Engineering background, Kundan Singh Mahato is also part of the team. The workload within the group will be distributed equally among all team associates to provide efficient improvement and successful task fulfillment. The team will decide that each team member will have reasonable support in responsibilities and duties.

9 Cost Proposal

The project aims to program the robot for precise and accurate painting. To create a fully functional system, we require additional components. These include an air compressor and an airbrush, which must be attached to the robot. Additionally, inductive sensors are necessary to enable the robot to operate on the additional linear rail axis.

9.1 Preliminary Budget

For the project's future development, several additional components are being considered to enhance the capabilities and efficiency of the Mitsubishi RV-8CRL robot in its paint spraying application the will be added in future documents.

Items	Price
Air compressor with airbrush	120

9.2 Current & Pending Support

$800, the default funding given to the Senior Design Project by CSE department.

10 Facilities & Equipment

The RV8 Robot Work Cell project will be situated in ERB 335, a designated laboratory area. This lab area will include the electrical infrastructure to accommodate the power requirements of the RV8 robot, MELSEC, and PLC controllers. Safety measures are of paramount importance, and as such, emergency stop systems, safety barriers, and warning signs have been implemented and will be modified to create a secure working environment for both operators and equipment. Additionally, the layout of workstations within ERB 335 will be configured to optimize workflow efficiency, allowing operators to interact with the RV8 robot and associated equipment.

In terms of equipment, the RV8 Robot Work Cell will feature essential components. The RV8 robot itself will be the central robotic arm, equipped with advanced technology to provide precision, speed, and versatility in performing a wide range of tasks. The project will also incorporate a Mitsubishi Electric MELSEC controller as the central control unit, facilitating coordination and synchronization of the robot's actions. Programmable Logic Controllers (PLCs) will be positioned to manage auxiliary equipment and processes within the work cell Furthermore, to complement the RV8 robot's capabilities, a gripper will be outsourced from a reputable supplier, selected based on its compatibility and suitability for handling various materials and objects within the work cell. Additionally, the work cell will incorporate a linear rail with a motor attached to it, a key feature for controlled and precise linear movement of the RV8 robot. This motor will be connected to the PLC controller, allowing for precise control over the linear motion of the robot along the rail. The linear rail will be provided in the laboratory as well and will require reading of several manuals from Mitsubishi to configure the movement of the linear rail.

11 Assumptions

- ERB 335 will provide all equipment needed to program the movement for the robot arm
- The Engineering Research Building will provide for reliable internet connection and ample power connectivity
- Security measures such as emergency stop will work as intended and will stop the movement of robot arm once pressed
- Once the air brush arrives, it will work as intended and will meet the quality standard needed with the robot arm
- The development team will be notified of any problems that may occur in the Engineering Research Building (ERB)

12 Constraints

- Final prototype demonstration must be completed by the beginning of Q2, 2024
- The programming and movement shall only happen in ERB 335a.
- LOTO or Lockout Tagout procedure must be used to prevent unauthorized personnel to access the robot arm.
- Total development costs must not exceed $800.
- The robot arm should only be programmed via the host PC and any wiring shall be connected via the PLC.

13 Risks

Risk description	**Probability**	**Loss (days)**	**Exposure (days)**
Availability of air brush due to poor 3D printing	0.80	5	4
Air brush, along with robot arm could damage its environment	0.30	15	4.5
Internet delays that may cause delay in the program of the robot arm	0.30	9	2.7
Mishandling of electrical components and/or the PLC	0.05	30	1.5
Poor integration of the air brush with robotic arm and linear rail	0.30	10	3

Table 1: Overview of highest exposure project risks

14 Documentation & Reporting

14.1 Major Documentation Deliverables

The major documentation deliverables for this project are project charter, System requirement specification, detailed design specification. Sprint 1 will cover project charter document. The duration for each sprint in this project is 2-weeks long (default length for any new team when assigned the project). The first half of the project is consisting of total number of 4 sprints. First sprint will deliver the project charter. System requirement specification will be delivered the second sprint. Third and fourth sprint will consist of Architectural design specification and detailed design specification including Phase I demo.

14.1.1 Project Charter

This document will be completed by the end of first sprint. As the team makes more progress into the project and adds more components, this document will be altered and updated as required.

14.1.2 System Requirements Specification

This document is planned for sprint two. The requirements specifications will be written by the end of second sprint. Since we are following the agile methodology, this document will be modified as required by our sponsor to meet our latest updates. This will be delivered by the end of sprint 2 (October 16, 2023).

14.1.3 Architectural Design Specification

Architectural Design will be initiated in sprint 3. This will be maintained and modified as per the change in the components and the robot arm. This will be delivered by the end of sprint 3 (November 6, 2023).

14.1.4 Detailed Design Specification

Detailed design specifications will be initiated during sprint 5. The document would be altered if the team finds a necessary change. The document will be delivered in the end of sprint 5 (February 12, 2024).

14.2 Recurring Sprint Items

14.2.1 Product Backlog

Items will be added to backlog based on SRS. These items will be prioritized by the complexity and necessity to reach the goal of the sprint and progress towards end result. Team will use excel to track the backlog. These backlogs will be discussed in meetings.

14.2.2 Sprint Planning

Each sprint will be planned after the termination of previous sprint. There are going to be a total of 8 sprints (Senior Design I has 4 sprints and Senior Design II has 4).

14.2.3 Sprint Goal

The team will decide collaboratively about the sprint goal.

14.2.4 Sprint Backlog

The teams will determine which task or tasks will make it to backlog.

14.2.5 Task Breakdown

Different tasks will be assigned to team members. The task can have a sub team of 2-3 members working on it or it can also be assigned to an individual team member depending upon the complexity of the task.

14.2.6 Sprint Burn Down Charts

The team will decide the burn down charts. This will use MS-Excel.

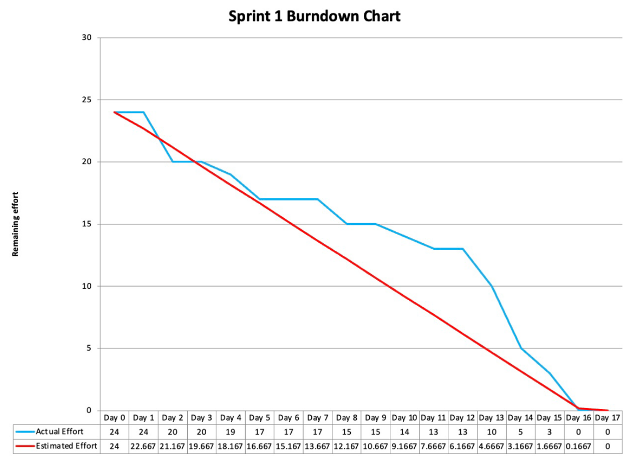

Figure 1: Example sprint burn down chart

14.2.7 Sprint Retrospective

The retrospective will be handled after carrying out a conversation regarding the previous sprint. Individuals are required to report any sort issues and inconvenience before the sprint end so that important measure can be taken before the sprint ends. Lastly, next sprint goals and previous sprintś incompletion (if any) will be discussed before the start of new sprint.

14.2.8 Individual Status Reports

An individual must report the progress that was being through the sprint which will also be recorded. Peer Review will ensure that the team is in the best possible way of communications and are good aware of the other members strengths and weaknesses regarding this project.

14.2.9 Engineering Notebooks

Engineering notebooks will not be used.

14.3 Closeout Materials

14.3.1 System Prototype

The final system prototype will include a working RV8 robot arm with a linear rail. This will be demonstrated through a video as well as in the lab where it is setup.

14.3.2 Project Poster

The project poster will discuss the system overview of the project. The overview will include the design and architectural details. It will be delivered after the system prototype is ready.

14.3.3 Web Page

The project webpage will be public and provide access to the documentation associated with the prototype such as project charter, SRS and ASD. This webpage will be updated throughout the project as the sprints will be put to finish.

14.3.4 Demo Video

The demo video will be a source to display the use of the prototype and the purpose the prototype.

14.3.5 Source Code

GitHub will be used as the repository to maintain and store code for this project. All the changes made will be pushed to GitHub. Using GitHub will give us the option to revert if any complication arises. Since the prototype is designed for specific purpose only, the code will be implemented.

14.3.6 Source Code Documentation

The documentation will be provided in a PDF format.

14.3.7 Hardware Schematics

This will be decided during ASD.

14.3.8 CAD files

The prototype will contain a gripper. The team will try to obtain from external retailer. In case of unavailability of the part or if it is unsuited then the teams will use Inkscape to generate CAD files for the gripper and will use it to generate the gripper as designed.

14.3.9 Installation Scripts

The customer will not be required to deploy any software as the team will deploy the software for them. There will be no updates in future for this project. Because this project is only required to fulfill certain task only.

14.3.10 User Manual

The customer will be provided with a digital (PDF) and a printed manual for the project.

References

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