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

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0.1	09.24.2023	AP, AM, HK, KM, MA	Document creation

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1 Problem Statement

As technology rapidly evolves, devices with increasingly complex functionalities have become ubiquitous. Consequently, factors such as product weight, completeness, and precision have gained greater importance. Accommodating additional functions and sensors while simultaneously reducing weight demands smaller component sizes and intricate design solutions. In sectors where even minor errors can lead to significant consequences, particularly those involving human life, precision is of paramount importance. These complex tasks often push the limits of human capabilities. Furthermore, tasks requiring sustained concentration, such as repetitive actions or imitation that do not necessarily involve creativity, can be executed more efficiently and accurately by robots than by humans. Robot arms emerge as a compelling solution, offering efficiency, adaptability, and precision for executing intricate operations. The overarching goal of intelligent manufacturing is to enhance production efficiency, elevate product quality, and ensure production safety. Robot arms, with their inherent flexibility and precision, empower the execution of diverse and complex tasks. This project aims to further empower robot arms, enabling them to meet user objectives by addressing these multifaceted challenges. In doing so, it significantly contributes to the advancement of intelligent manufacturing practices, fostering innovation and excellence across various industries.

2 Methodology

In this project, our methodology revolves around harnessing the Mitsubishi Electric Industrial Robot, RV8, to execute precise tasks. Our priority is the enhancement of safety through the integration of innovative lighting systems, which provide visual progress representation, and the incorporation of multiple emergency stop mechanisms within the robot's controller, ensuring immediate halting of operations in unforeseen circumstances. We leverage the RV8's capabilities, notably its 8 controllable joints accessible via the Robot Teaching Box, enabling precise control over its movements. Furthermore, the robot's capacity to acquire manual movements through a teaching mode and its ability to manipulate objects by calculating distances and positions using a vision sensor are skillfully utilized. To enable intelligent task execution, we seamlessly integrate various algorithms into the robot's control system. Additionally, we have outlined future developments, including the attachment of an end-effector and the implementation of a rail system to expand the robot's workspace. These enhancements will enable the robot to adeptly grasp and manipulate a diverse range of objects. Throughout the course of these activities, our overarching concern remains centered on the preservation of safety and the optimization of operational efficiency, ensuring that the RV8 robot attains its maximum potential across a wide spectrum of tasks.

3 Value Proposition

In the era of rapid technological evolution and increasing industrialization, robot arms emerge as versatile and indispensable tools. These sophisticated machines are poised to reshape industries through a multitude of promising development trends. First, there is the exciting frontier of enhanced intelligence, where artificial intelligence and machine learning empower robot arms to engage in autonomous learning and decision-making. Equipped with advanced sensors and vision systems, these robot arms attain heightened environmental awareness and object recognition, thereby elevating their adaptability to dynamic scenarios. Furthermore, the surging demand for collaboration with humans necessitates robot arms' ability to perceive human movements and intentions, secure and seamless cooperation. In parallel, the realm of unmanned technology continues to advance, enabling robot arms to autonomously operate in specialized environments such as hazardous settings, space exploration, and deep-sea exploration. This newfound autonomy augments task safety, efficiency, and expands the scope of operations. Finally, an emphasis on integration, facilitated by modular and standardized designs, streamlines complexity, and enables swift configuration for diverse tasks. In summary, these trends position robot arms as indispensable catalysts for heightened productivity, efficiency, and safety across a multitude of 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, 2023
- System Requirements Specification - October 16, 2023
- Architectural Design Specification - November 6, 2023
- Detailed Design Specification - February 2023
- Demonstration of Initial Robot Movement - September 25, 2023
- Demonstration of Basic Program - October 16, 2023
- Demonstration of Linear Rail Movement - November 6, 2023
- Demonstration of E-stop Switch Configuration - November 27, 2023
- Demonstration of Gripper Configuration - February 2023
- Demonstration of Conveyor Belt Setup - February 2023
- Demonstration of Laser Safety Scanner Setup - March 2023
- Demonstration of Pick and Place Program - April 2023
- CoE Innovation Day poster presentation - April 2023
- Final Project Demonstration - May 2023

5 Background

In the rapidly evolving landscape of warehousing and logistics, the conventional approach to material handling in warehouses contains several challenges. Palletizing and depalletizing boxes manually is a time-consuming task, which decreases productivity. Consequently, labor costs associated with manual palletizing and depalletizing are increased, encompassing wages, benefits, and additional expenditures associated with managing a workforce engaged in repetitive physical activities. Moreover, manual material handling poses inherent risks to the workforce. Accidents and injuries are a constant concern, impacting both employee well-being and company reputation. The physically demanding nature of tasks can also lead to reduced job satisfaction. Finally, with modern commerce continuing to grow, warehouses must adapt to higher volumes of goods and fulfill needs with efficiency. Manual processes often hinder the ability to meet customer demands effectively.

The integration of robotic arms for palletizing and depalletizing tasks is no longer a matter of 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 in robotic arms that demonstrate its ability to address these challenges effectively and revolutionize material handling in warehouses. Robotic arms excel at repetitive tasks requiring precision. The consistency of robot arms translates to significant improvements in efficiency, ultimately allowing faster order fulfillment and throughput rates. Robotic arms are also largely scalable. With a large rise in e-commerce, robotic arms can adapt to seasonal demand, and can shift workload to accommodate responsively in a dynamic marketplace. In addition to their agility in a demanding environment, robotic arms provide product integrity. In industries like food and pharmaceuticals, robotic arms are programmed to handle goods aligning with quality standards issued by the Occupational Safety and Health Administration (OSHA). This not only guarantees product integrity, but also compliance with industry-specific regulations.

The University of Texas at Arlington has 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 also is mounted to a linear rail, enabling its 7th axis. While the robot is operational, the work cell still needs several areas of integration completed. The laser safety scanners create virtual safety zones around the robot, monitoring the surrounding area for any human intrusion. These laser scanners are not implemented yet. There are two emergency stop (E-stop) switches in and around the work cell, providing immediate and highly visible means to shut down the robot in the case of an emergency. Currently, the emergency stops are functional but wired inefficiently. The linear rail was most recently installed with aims to enhance reach and flexibility of the robot. At present, the linear rail is not integrated with the RV-8 robot and is not functional.

The sponsor of this project, Dr. McMurrough, aims for this project to finish the integration of the work cell, with the hopes that it serves as an invaluable resource for both research and educational purposes at UTA. The robot is within a glass encasing shown to onlookers in the building. Thus, this project hopes to showcase the functionalities of the robot to a wider audience and spark interest at the consistent innovation within Computer Science and Engineering at UTA. The completed work cell will empower students with hands-on experience, allowing them to explore the frontiers of robotics, automation, and control systems.

6 Related Work

Warehouse robotics is emerging as a state-of-the-art technology. There are several current implementations of robotics that address the current challenges in logistics. Several companies offer robotic systems designed specifically for picking and placing (or picking and packaging). 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 food/beverage packaging, electronics, and pharmaceuticals.

Another notable robotic system in warehouse 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 material handling tasks in warehousing and 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 warehouse. 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 material handling and automation tasks in logistics. 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 material handling in warehouses. The Motoman MH series offers versatility and efficiency in material handling 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 warehouse environments.

As robots are becoming more technologically available, warehouses and logistics industries are adopting the technology with frequency. According to ABI Research, a global tech market advisory firm, worldwide commercial robot revenue in warehouses will have a Compounded Annual Growth Rate (CAGR) of over 23% from 2021 to 2030 and exceed $51 billion by 2030 [8]. This is seen with industry leaders Amazon, who in 2021 alone amassed 38 percent of total US warehouse automation investment within their fulfillment centers [9]. This comes after their $1 billion dollar commitment to Industrial Innovation Fund to support robotics firms, and the purchase of Kiva [9].

Locally, companies are building warehouses with an aim at reducing human labor. Amazon has been researching with their Sparrow robot, which has capabilities of picking up and sorting unpackaged items. Operating at a facility in Dallas, Texas, Sparrow is capable of picking up and sorting roughly 65% of inventory [5]. Walmart, FedEx, and Tesla are also prototyping several picking-and-sorting robots in their respective domains [5]. As these companies continue to innovate and invest in automation solutions, the warehousing and logistics industries are poised for a transformative shift marked by increased efficiency, reduced operational costs, and improved service delivery.

7 System Overview

The Mitsubishi RV-8CRL robot, an 8-axis industrial robotic system with a payload capacity of 8 kg and 6 degrees of freedom, has been selected for pelletizing stacks of boxes in a warehouse. The purpose is to program the robot to efficiently handle and collect boxes in response to human input, using its rotational axes for precise motion and coordination. The RV-8CRL robot exhibits an 8-axis composition, allowing much freedom and versatility in action. Each axis of trajectory is leveraged for careful handling of boxes during pelletization. With an 8 kg load capacity, the robot is capable of lifting and managing standard containers normally encountered in storage environments. Integrated detectors are employed to monitor and detect human activity within the workspace. These sensors are essential in ensuring protection by allowing the robot to adjust its movements and avoid bodily injuries during function. The programming of the RV-8CRL robot involves developing a predefined sequence of stages for pelletizing packages. The series includes motions like identifying the target container, picking it up, deciding the optimal placement, and unleashing the box in the preferred pellet arrangement. In the context of box pelletizing, the RV-8CRL robot's programming enables it to handle stacks of boxes seamlessly. It picks up individual boxes, aligns them according to the chosen pellet configuration, and precisely places them, optimizing the pelletized stack's stability and organization.

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 focuses on programming the Mitsubishi RV-8CRL robot for efficient box pelletizing in a warehouse setting, and several major expenses are expected. The investment of a software license for programming the robot is required, ensuring that the RV-8CRL's capabilities are fully utilized and seamlessly melded into the preferred pelletization process and investment in a Mitsubishi Gripper, tailored to the specifications and requirements of the RV-8CRL robot, is essential to enable the precise handling of boxes during the pelletization task. Functional units necessary for the robot's seamless operation, including sensors for safety and coordination and any customized fixtures to optimize the pelletizing process, are crucial components of the project's expenditure.

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 box pelletizing application the will be added in future documents.

Items	Price
Gripper	400

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 gripper 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 coded with the MELSEC PLC controller and in the host PC

13 Risks

Risk description	Probability	Loss (days)	Exposure (days)
Availability of gripper due to delay in shipping	0.50	20	10
Gripper, 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 gripper 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. Although this document will be altered and updated as required. Since the team has not started working on this project physically things might be added or updated or removed.

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 following the agile methodology this document will be modified as required for certain specifications. This will be delivered by the end of sprint 3 (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 requirement or plan. This will be delivered by the end of sprint 3 (November 6, 2023).

14.1.4 Detailed Design Specification

Detailed design specifications will also be delivered by the end sprint 3. The document would be altered if the team finds a necessary change.

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.

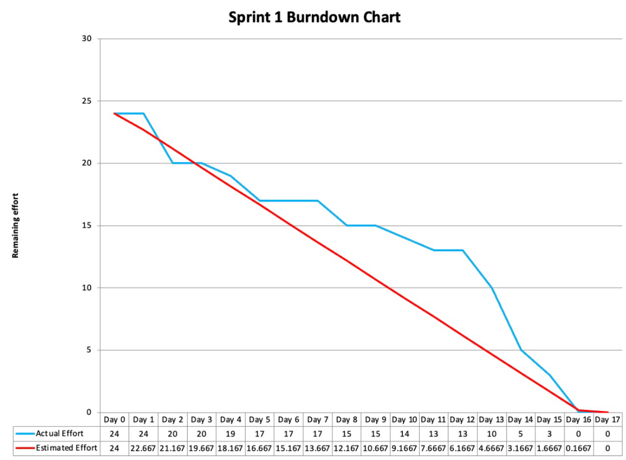

Figure 1: Example sprint burn down chart

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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