DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
THE UNIVERSITY OF TEXAS AT ARLINGTON

SYSTEM REQUIREMENTS SPECIFICATION
CSE 4316: SENIOR DESIGN I
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LJCJ
UR20

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Revision History

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0.1	10.01.2024	LC, JG, JD, CG	document creation

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1 Product Concept

This section describes the purpose, use and intended user audience for the UR20 arm. The UR20 arm is a system that performs palletizing. Users of UR20 will be able to automate the means for stacking cases of goods or products onto a pallet. This will be achieved by adding a vacuum gripper and a photo eye sensor.

1.1 Purpose and Use

The UR20 arm will palletize boxes sized 9"X12" onto a 48"X40" pallet. This will happen by feeding the boxes onto a conveyor belt, robot will wait until a box is in range of the arm and finally, the robot arm will put the box in the appropriate position on the pallet.

1.2 Intended Audience

The intended audience for a palletizing application encompasses various stakeholders within a manufacturing and logistics environment. This includes manufacturers seeking to automate their packaging and shipping processes to enhance efficiency and reduce labor costs. Warehouse managers focus on optimizing operations for better space utilization and inventory management. This application would be aimed at commercial use and implemented as the initial step in a conveyor system.

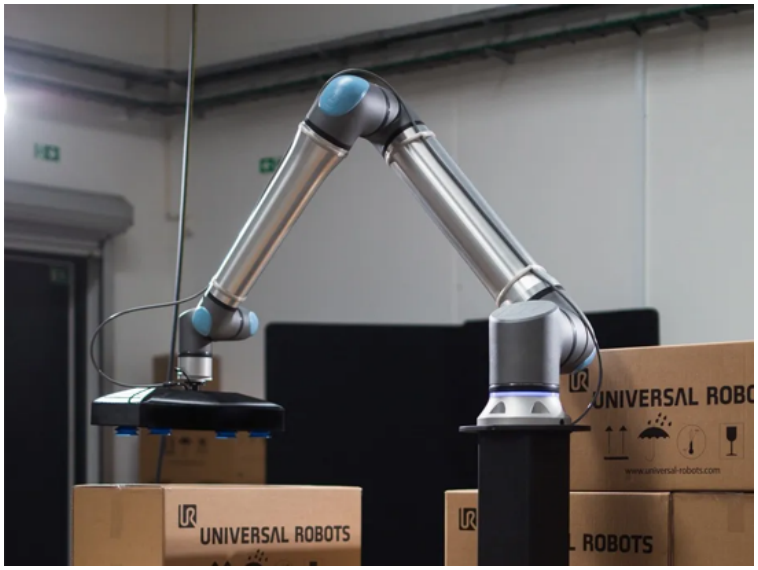

Figure 1: UR20 Palletizing concept image

2 Product Description

This section provides the reader with an overview of UR20. The primary operational aspects of the product, from the perspective of end users, maintainers and administrators, are defined here. The key features and functions found in the product, as well as critical user interactions and user interfaces are described in detail.

2.1 Features & Functions

The UR20 will perform a palletizing application using an added vacuum gripper to the end of the arm as well as a photo eye sensor. Once the data is processed, the arm will place the box according to its size. As seen in the system, the gripper will be made up of 20 bellow cup suction gripers attached to an air compressor

2.2 External Inputs & Outputs

The UR20 will perform a palletizing application with an added vacuum gripper at the end of the arm. This information will be processed by the robot arm's code, which will contain information such as the size and position of the box needed to be placed in the pallet. The vacuum gripper will be used to pick up the box. The UR20 will be used to move the object to the apparatus location. Once the data is processed, the arm will place the box accordingly.

2.3 Product Interfaces

The end user will have access to a Teach Pendant which is a tablet-like screen that can be used to do maintenance on the UR20. From this tablet, one can program the robot, run a program, or configure robot installation. This allows for easy adjustments to the UR20's behavior.

3 Customer Requirements

This section outlines the customer requirements for the UR20 robotic arm to palletize uniform sized boxes. The project also includes the design and implementation of a custom robotic gripper that incorporates bellow suction cups to handle the boxes effectivelty. The robot arm will maintain full functionality in waiting for a box on the conveyor belt and locating it, picking it up and placing on a pallet.

3.1 Box Palletizing by UR20 Robot

3.1.1 Description

The UR20 will be used to palletize boxes, process data, and stack boxes in an effective manner. The system will handle boxes of the same size, ensuring precise and efficient stacking.

3.1.2 Source

CSE Senior Design project specifications

3.1.3 Constraints

Environment is suitable for operation of collaborative robot in a safe manner.

3.1.4 Standards

ISO 10218-1 Robots and robotic devices â Safety requirements for industrial robots ensuring protective measures. ISO 10218-2, Robots for industrial environments â Safety requirements to minimize hazards associated with robots and end effectors.

3.1.5 Priority

Critical The priority of this requirement relative to other specified requirements. Use the following priorities:

3.2 Custom Gripper with Vacuum and Bellow Cups

3.2.1 Description

The gripper design will feature bellow cups and a vacuum to securely handle and move the boxes during the palletizing process. It will be designed to fit the size of the boxes and ensure firm grasping to prevent slippage during handling. The vacuum will be generated using an air compressor and an attachment along the tubing line that utilizes the Bernoulli principle.

3.2.2 Source

CSE Senior Design Project specifications

3.2.3 Constraints

The strength and durability of the bellow cups that support the box's weight, and the selection of materials on a limited budget.

3.2.4 Standards

ISO/TR 20218-1:2018 Robotics â Safety design for industrial robot systems, ensuring safety measures for design and integration of end-effectors. ISO 10218-2, Robots for industrial environments â Safety requirements to minimize hazards associated with robots and end effectors.

3.2.5 Priority

High

4 Packaging Requirements

The packaging requirements for the UR20 robot and custom-designed gripper will include pre-installed control software. Additionally, the custom gripper will be fully assembled and contained in a single package. The requirements focus on making the product easily deployable and ready for use in palletizing operations.

4.1 Pre-Installed Software

4.1.1 Description

The control software for operating the UR20 robot will be pre-installed on the system before delivery to the customer. The robot can immediately perform palletizing application upon arrival without complex installation procedures.

4.1.2 Source

CSE Senior Design Project Specifications

4.1.3 Constraints

The software must be compatible with the UR20 system and ensure reliable functionality. Limited modifications will be needed by customer post-installation.

4.1.4 Standards

ISO/IEC/IEEE 12207:2017 Systems and software engineering â Software life cycle processes - proper installation and support for future updates

4.1.5 Priority

High

4.2 Gripper Assembly and Packaging

4.2.1 Description

The gripper mechanism, including vacuum suction cups, will be delivered pre-assembled and tested for immediate use with the UR20 robot. All components will be securely packaged to avoid damage during transportation.

4.2.2 Source

CSE Senior Design Project Specifications

4.2.3 Constraints

The packaging must ensure the safe transport of the assembled gripper, sourcing of packaging material will be the responsibility of the engineering team.

4.2.4 Standards

ISO 3676:2012 Packaging â Complete, filled transport packages and unit loads â Unit load dimensions ensuring products arrive safely from their origin to their destination.

4.2.5 Priority

High

5 Performance Requirements

This section defines the preformance requirements that the UR20 will need to meet.

5.1 palletizing speed

5.1.1 Description

The UR20 will be able to place boxes in a timely manner while being fed boxes through a conveyor belt

5.1.2 Source

LJCJ Team Decision

5.1.3 Constraints

Pallet size restriction of 40"X48"

5.1.4 Standards

GMA pallet standards

5.1.5 Priority

High

5.2 Box Size

5.2.1 Description

The UR20 will be able to pick up boxes of size 9"X12"

5.2.2 Source

LJCJ Team Decision

5.2.3 Constraints

Maximum payload of 20kg

5.2.4 Standards

NO standard applicable

5.2.5 Priority

Moderate

5.3 Successful box placement rate

5.3.1 Description

Boxes should not be dropped or misplaced under expected operation conditions

5.3.2 Source

LJCJ Team Decision

5.3.3 Constraints

Gripper must have a clear working area, proper alignment, and enough force to pick up boxes

5.3.4 Standards

NO standard applicable

5.3.5 Priority

High

6 Safety Requirements

This section defines the safety standards that will taken when the UR20 is operating. The UR20 is a collaborative robot, commonly known as a Cobot, meaning that human collaboration with the Cobot is possible when safety guidelines are followed. Although this robot is deemed 'collaborative', it is not entirely safe for humans. Injuries from electrical shock, impact, or compression can still occur if proper safety measures are not taken. In this use case, the UR20 will be transporting cardboard boxes of a consistent weight between a pallet and a conveyor belt, which could impact or crush the human user not taking proper precautions.

6.1 Laboratory equipment lockout/tagout (LOTO) procedures

6.1.1 Description

Any fabrication equipment provided used in the development of the project shall be used in accordance with OSHA standard LOTO procedures. Locks and tags are installed on all equipment items that present use hazards, and ONLY the course instructor or designated teaching assistants may remove a lock. All locks will be immediately replaced once the equipment is no longer in use.

6.1.2 Source

CSE Senior Design laboratory policy

6.1.3 Constraints

Equipment usage, due to lock removal policies, will be limited to availability of the course instructor and designed teaching assistants.

6.1.4 Standards

Occupational Safety and Health Standards 1910.147 - The control of hazardous energy (lockout/tagout).

6.1.5 Priority

Critical

6.2 National Electric Code (NEC) wiring compliance

6.2.1 Description

Any electrical wiring must be completed in compliance with all requirements specified in the National Electric Code. This includes wire runs, insulation, grounding, enclosures, over-current protection, and all other specifications.

6.2.2 Source

CSE Senior Design laboratory policy

6.2.3 Constraints

High voltage power sources, as defined in NFPA 70, will be avoided as much as possible in order to minimize potential hazards.

6.2.4 Standards

NFPA 70

6.2.5 Priority

Critical

6.3 RIA ROBOTIC MANIPULATOR SAFETY STANDARDS

6.3.1 DESCRIPTION

Robotic manipulators, if used, will either housed in a compliant lockout cell with all required safety interlocks, or certified as a "collaborative" unit from the manufacturer.

6.3.2 SOURCE

CSE Senior Design laboratory policy

6.3.3 CONSTRAINTS

Collaborative robotic manipulators will be preferred over non-collaborative units in order to minimize potential hazards. Sourcing and use of any required safety interlock mechanisms will be the responsibility of the engineering team.

6.3.4 STANDARDS

ANSI/RIA R15.06-2012 American National Standard for Industrial Robots and Robot Systems, RIA TR15.606-2016 Collaborative Robots

6.3.5 PRIORITY

Critical

6.4 COLLABORATE ROBOT INDUSTRIAL SAFETY REQUIREMENTS

6.4.1 DESCRIPTION

Collaborative robots remain dangerous, and collaborators entering the work area of a Co-bot shall adhere to specific safety requirements in order to prevent bodily harm.

1. The movement path of the collaborator(s) must be kept free of tripping or other movement hazards while the Cobot is powered on.
2. A collaborator shall not enter the workspace with dangling jewelry, loose clothing, or long loose hair.
3. Collaborator(s) must not enter the marked Cobot operating space while the Cobot is active.

6.4.2 SOURCE

International Organization for Standardization

6.4.3 CONSTRAINTS

Those not adhering to the safety requirements listed in ISO/TS 15066 shall be prohibited from collaboration with the Cobot until adherence to the requirements resumes.

6.4.4 STANDARDS

ISO/TS 15066:2016

6.4.5 PRIORITY

Critical

6.5 Collaborate robot workspace clearance requirements

6.5.1 Description

The collaborative robot workspace should be clear of hazards that could impede the movement of the collaborator(s) or the Cobot itself.

1. The collaborative space of the Cobot, where humans are safe to interact, must be visibly delineated from the operating space of the Cobot.
2. The Cobot shall function with reduced force when a human is present. In calculating these reduced forces, the weight of the payload must be considered.
3. The workspace of the Cobot must be kept free of blockages or other movement hazards while the Cobot is powered on.
4. Possible locations of quasi-static contact (where a human may be clamped between any part of the Cobot and the working environment, including another part of the Cobot) must be identified and removed where possible.
5. Possible locations of transient contact (where the Cobot or the environment may collide with a human) must be identified and removed where possible. The force of contact should also be considered.

6.5.2 Source

International Organization for Standardization

6.5.3 Constraints

Not all possible locations of contact will be removeable. To account for this, dangerous areas must be delineated as part of the Cobot operating space. Risk of injury at these locations shall be minimized by calculating the reduced force used by the Cobot according to ISO 10218-1:2011.

6.5.4 Standards

ISO/TS 15066:2016 and ISO 10218-1:2011

6.5.5 Priority

High

6.6 Force adjustment according to dynamic item weight

6.6.1 Description

The collaborative robot will adjust the force it uses dynamically according to the weight of the item, as opposed to assuming a uniform weight for all items.

6.6.2 Source

International Organization for Standardization

6.6.3 Constraints

Judging the weight of the item would be difficult, and somewhat out of scope for this project. A weighing system would have to be implemented, either negatively accounting for weight leaving the conveyor belt or implemented directly in the robot arm itself.

6.6.4 STANDARDS

ISO/TS 15066:2016 and ISO 10218-1:2011

6.6.5 PRIORITY

Future

7 Security Requirements

This section defines the security standards that will be taken to avoid malicious tampering involving the hardware or software of the Cobot. In the event that the Cobot's security is confirmed to be compromised, continued use will be halted until approval is given by the course instructor.

7.1 Physical Security

7.1.1 Description

The Cobot, including the programming tools and control systems, shall be located in an area that only approved persons may access. In the event that an unapproved person gains access to the Cobot, the possibility of tampering should be ruled out for both the hardware and software of the Cobot.

7.1.2 Source

LJCJ Team Decision

7.1.3 Constraints

The Senior Design lab is frequently used by a large number of students. As it would be impossible work in the case that all of those students were considered a safety concern, these students and their guests shall be considered approved persons.

7.1.4 Standards

N/A

7.1.5 Priority

High

7.2 Cyber Security

7.2.1 Description

In the event that network access is necessary, the Cobot should not be connected to insecure or unknown networks. When connection is no longer needed, the Cobot should be disconnected from the network.

Similarly, the Cobot should not be connected to insecure or unknown devices.

Removeable media shall only be used when its contents are completely known and approved of by at least one member of the team. Do not insert removeable media of dubious origin into the Cobot.

7.2.2 Source

LJCJ Team Decision

7.2.3 Constraints

The Cobot may need to be connected to UTA Wi-Fi and our team's computers, which are not very secure. However, it is unlikely that the course instructor will fund alternatives, so these must be used regardless.

7.2.4 Standards

N/A

7.2.5 Priority

Low

8 Maintenance & Support Requirements

Maintenance and support requirements define the necessary measures to ensure that the UR20 robotic palletizing system remains fully functional after deployment. Effective support includes troubleshooting guides and accessible source code for any required modifications. Additionally, maintenance teams must be equipped with appropriate tools to service the robot system.

8.1 Maintenance Procedures for UR20 and Conveyor System

8.1.1 Description

Routine maintenance must be performed on the UR20 robot and the conveyor system to ensure proper functionality. This included for wear and tear on the bellow cups, the end effector itself, the robot arm, and conveyor belt mechanism.

8.1.2 Source

LJCJ Team

8.1.3 Constraints

Constraints include the availability of spare parts and in case of gripper needing full repair the design schematics will be provided.

8.1.4 Standards

ISO 9283:1998 Manipulating industrial robots â Performance criteria and related test methods for industrial robots ISO 10218-1:2011 Robots and robotic devices â Safety requirements for industrial robots

8.1.5 Priority

High

8.2 Support Documentation and Troubleshooting Guides

8.2.1 Description

Detailed troubleshooting manuals and user guides will be provided based on the team's experience when working with the UR20. This will include known issues that may arise and step-by-step instructions on how to resolve them. Digital access to the resources will be available.

8.2.2 Source

LJCJ Team

8.2.3 Constraints

Documentation must be kept up to date with any changes to the system. such as software updates or any change in hardware.

8.2.4 Standards

IEEE 1063-2001 IEEE Standard for Software User Documentation - content on the software will be provided to the user and meets proper documentation practices

8.2.5 Priority

High

8.3 Source Code availability

8.3.1 Description

The source code for the UR20 control system will be available to maintainers for debugging and future updates. A version control system will be utilized to track changes in the software and maintain organization.

8.3.2 Source

LJCJ Team

8.3.3 Constraints

Constraints include ensuring the version control system is maintained properly, only allowing authorized users to modify code.

8.3.4 Standards

ISO/IEC/IEEE International Standard - Software engineering - Software life cycle processes - Maintenance (maintain software)

8.3.5 Priority

High

9 Other Requirements

The UR20 in a palletizing application will require a conveyor belt, vacuum gripper attachment, and E-stop button. These components must be configured to work with the UR20 and each other for each new environment and job (with the exception of the E-stop button, which will always perform the same task in every situation).

9.1 E-stop peripheral integration

9.1.1 Description

Along with UR20 movement, the E-Stop will completely halt all operation of the conveyor belt and vacuum generator.

9.1.2 Source

LJCJ Team Decision

9.1.3 Constraints

Some components may not take kindly to having the power cut unexpectedly. This should be considered during implementation.

9.1.4 Standards

N/A

9.1.5 Priority

Low

9.2 Vacuum Gripper Attachment

9.2.1 Description

A vacuum gripper must be constructed in order for the UR20 to fulfill its basic purpose. Once built, it shall provide appropriate suction power in order to securely transport a box, and a release of that suction in order to deposit the box.

9.2.2 Source

LJCJ Team Decision

9.2.3 Constraints

The vacuum gripper's completion date is dependent on shipping times and the success of prototypes.

9.2.4 Standards

N/A

9.2.5 Priority

Critical

9.3 Conveyor Belt

9.3.1 Description

The conveyor belt must be configured to operate at a suitable speed, one that can keep up with the UR20's max speed while not spilling over when the UR20 slows down to accommodate a human presence. It must be placed in a location that is marked, as if its position significantly changes the UR20 may have difficulty recognizing the boxes.

9.3.2 SOURCE

LJCJ Team Decision

9.3.3 CONSTRAINTS

This is dependent on the conveyor belt's adjustability. In the case that a variable speed cannot be achieved, the UR20 may be forced to operate at a low speed at all times.

9.3.4 STANDARDS

N/A

9.3.5 PRIORITY

Moderate

10 Future Items

10.1 Force adjustment according to dynamic item weight

10.1.1 Description

The collaborative robot will adjust the force it uses dynamically according to the weight of the item, as opposed to assuming a uniform weight for all items.

10.1.2 Source

International Organization for Standardization

10.1.3 Constraints

Judging the weight of the item would be difficult, and somewhat out of scope for this project. A weighing system would have to be implemented, either negatively accounting for weight leaving the conveyor belt or implemented directly in the robot arm itself.

10.1.4 Standards

ISO/TS 15066:2016 and ISO 10218-1:2011

10.1.5 Priority

Future

10.2 Depalletizing application of the UR20

10.2.1 Description

The collaborative robot will implement a depalletizing application with the same hardware. The addition would be undoing the palletization done originally, which will demonstrate further usage capabilities of the arm and will be extremely convenient on SD II demonstration day.

10.2.2 Source

LJCJ Team Decision

10.2.3 Constraints

Not enough time available to implement this.

10.2.4 Standards

CoaXPress â Hosted by JIIA; release date 2010; current version 2.1 Camera Link HS â Hosted by A3; release date 2012; current version 1.2 IIDC2 â Hosted by JIIA; release date 2012; current version 1.1.0 USB3 Vision â Hosted by A3; release date 2013; current version 1.2

10.2.5 Priority

Future

10.3 Palletizing with computer vision

10.3.1 Description

The collaborative robot will have implement computer vision to determine box placement

10.3.2 Source

LJCJ Team Decision

10.3.3 Constraints

Insufficient time to implement a computer vision algorithm for palletizing

10.3.4 Standards

No applicable standards

10.3.5 Priority

Future

10.4 Palletizing boxes of varying size

10.4.1 Description

The collaborative robot will implement a computer vision algorithm to place different items onto the same pallet

10.4.2 Source

LJCJ Team Decision

10.4.3 Constraints

Insufficient time and resources to implement

10.4.4 Standards

no applicable standards

10.4.5 Priority

Future

References