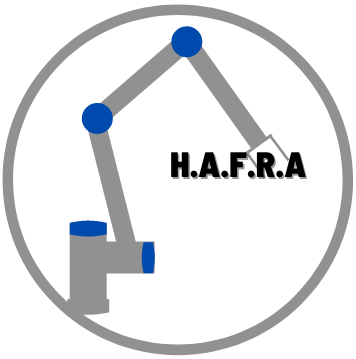
Department of Computer Science & Engineering
The University of Texas at Arlington

System Requirements Specification
CSE 4317: Senior Design II
Spring 2022



H.I.L Robot Team
H.A.F.R.A

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Revision History

Revision	Date	Author(s)	Description
0.1	10.15.2021	CR	document startup
0.2	10.20.2021	RA, KL, NP, CR, RT	complete draft
1.0	10.25.2021	RA, KL, NP, CR, RT	official release
1.1	05.10.2022	RA, KL, NP, CR, RT	final submission

CONTENTS

List of Figures

1 Product Concept

This section describes the purpose, use, and intended user audience for the Human Assistance For Robot Arm (HAFRA) product. HAFRA is an application that uses the UR5 robot and ArUco markers to pick up envelopes and place them into a bin. The robot will use human assistance in order to have a success rate of close to 100%. Industries will be able to use this robot in product lines to perform packaging or other tasks.

1.1 Purpose and Use

HAFRA should be helpful with tasks such as item pickup, and bin drop off. This application will include human assistance through helping the robot whenever it encounters a problem such as not being able to detect an arUco marker. Once implemented, the solution will increase overall productivity and ultimately reduce any errors or mistakes. It should be used in companies which have product lines.

1.2 Intended Audience

The intended audience of our product are companies who have product lines and would like to optimize their tasks with precision. Creating a robot that can mimic and perform human tasks efficiently and correctly and can be a great benefit to industries. The UR5 robot increases performance and reduces error to nearly 100% through human assistance. It would get rid of potential risks while still having a consistent worker. HAFRA is a profitable idea by replacing the cost of paying a human worker constantly to only a one time investment.

2 PRODUCT DESCRIPTION

This section provides the reader with an overview of HAFRA. 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

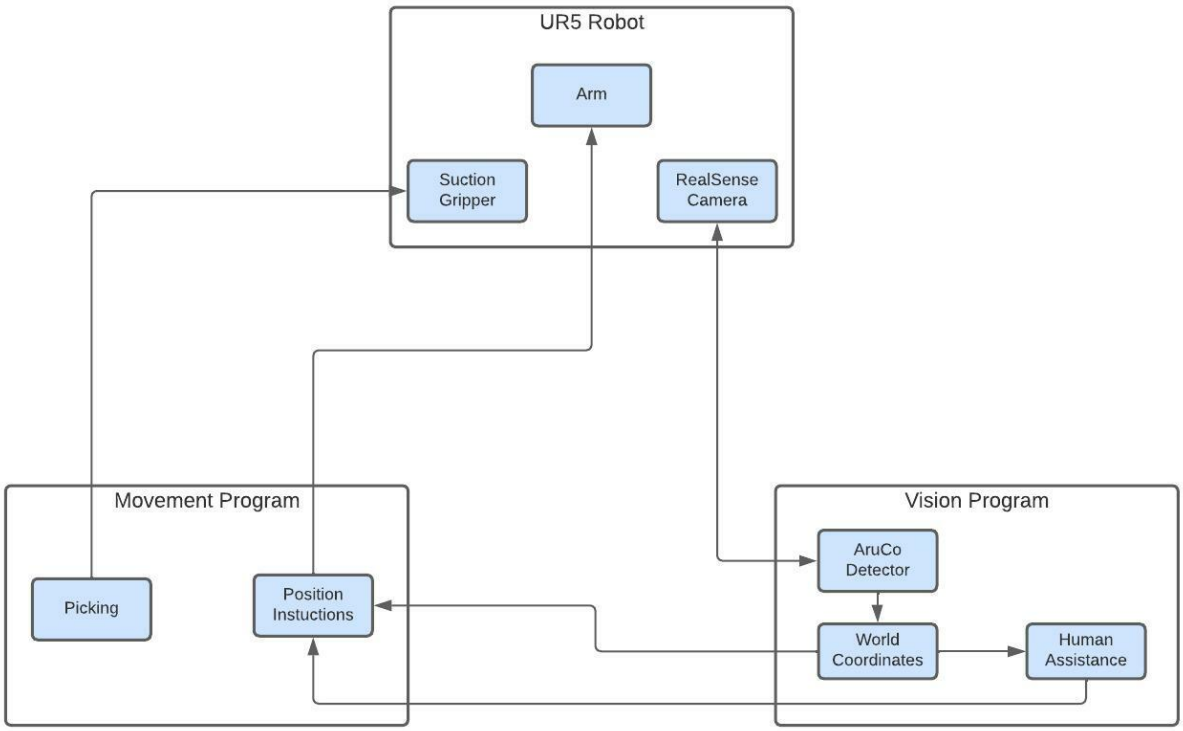

Figure 1: System Overview

The UR5 project has three major components, the movement program, vision program, as well as the UR5 robot. The movement program will hold the functionality of how the robot will be moving as well as how the vacuum will be activated. The vision program is where the RealSense camera will be utilized to take an image of the work space. This workspace is where the robot will search for arUco markers. If no markers are detected, then an image will be taken and the user can find coordinates to enter into the program for the robot to move to manually. Otherwise, the robot will go to the detected marker and pick it up normally. Lastly, the UR5 robot contains two other pieces of hardware, the vacuum to pickup the envelopes, as well as the RealSense camera to work with vision.

2.2 External Inputs & Outputs

Name	Description	Use
Python Program (Input)	Python program will contain the code and instructions for the UR5 robot to pick up objects and calling for human assistance when it reaches a problem	This will give the robot its base success rate and its ability to perform its main task.
Human Assistance (Input)	When robot encounters a problem, call for human assistance. Human will help the robot solve the problem by choosing where to pick.	This will increase the robots overall success rate and reduce the error rate.
UR5 Robot Asking for Assistance (Input)	The UR5 will notify the human for assistance when it encounters an item that doesn't fit a certain criteria. In our case, when an image is taken and there are no detected arUco markers.	To reduce its error rate, the robot will attempt to solve these errors with human help.
Overall Increased Success Rate (Output)	With HAFRA's focus on eliminating robot error with human assistance, the robot will have an overall increase in its success rate.	Industries and companies will be able to utilize this problem with the reduce need for human workers while also decreasing human risks in work settings.

2.3 Product Interfaces

The administrator of HAFRA will have a user interface to be able to assist the robot. The interface will have a window pop-up that contains an image of the current workspace, user will be able to get real time coordinates, and can enter in coordinates in an x y format to tell the robot where to go. The user will also be able to exit the human assistance functionality if needed as well.

3 Customer Requirements

The customer requirements address items that our customer has stated are needed for our project. Our customer will be Professor McMurrough, he will be overseeing our project each sprint and will be our point of contact for any questions we may encounter.

3.1 Robot Requires Continuous Human Support

3.1.1 Description

The robot will be able to perform efficiently and do its tasks successfully most of the time, but the goal of our project is to have a worker be able to remotely assist the robot to fix the tasks the robot fails at. A worker should be available for contact during the performance of the robot to execute human assistance when needed.

3.1.2 Source

Richard Tran

3.1.3 Constraints

Requires human availability for efficient performance

3.1.4 Standards

N/A

3.1.5 Priority

Critical

3.2 Error Fixing with Human Support

3.2.1 Description

When the robot encounters a problem that it does not know what to do, it will notify the worker that it needs help. For this project, the robot will be picking up envelopes with arUco markers, so situations like a damaged marker, or a missing marker will warrant a call for human assistance. With the provided sensor, an image will be given to the human, and then the human will then send coordinates to the program to tell the robot where to go to. The user will also have the opportunity to exit this functionality as well and have the robot continue to pick.

3.2.2 Source

Richard Tran

3.2.3 Constraints

Requires human availability and attention to execute.

3.2.4 Standards

N/A

3.2.5 Priority

Critical

3.3 Develop an application

3.3.1 Description

The application should provide a software solution for envelope picking by a human operator. The user interface should be user friendly.

3.3.2 Source

Katia Lopez

3.3.3 Constraints

N/A

3.3.4 Standards

N/A

3.3.5 Priority

Critical

3.4 Pick Envelopes from Workspace

3.4.1 Description

The robot should be able to pick envelopes from the workspace with a suction and drop it into a bin.

3.4.2 Source

Katia Lopez

3.4.3 Constraints

N/A

3.4.4 Standards

N/A

3.4.5 Priority

Critical

3.5 Cases that require Human Assistance

3.5.1 Description

A robot will require human assistance whenever it encounters a situation it's not programmed to solve. This will typically be if it encounters an image without any arUco markers. This could be due to the marker being damaged or an envelope not having a marker.

3.5.2 Source

Richard Tran

3.5.3 Constraints

N/A

3.5.4 Standards

N/A

3.5.5 Priority

Critical

3.6 Working in different Environments

3.6.1 Description

The UR5 robot should not be limited to working only in one area. With enough time and effort, the UR5 robot should be able to work in many different environments.

3.6.2 Source

Cesar Rea

3.6.3 Constraints

N/A

3.6.4 Standards

N/A

3.6.5 Priority

Future

3.7 Pick different objects

3.7.1 Description

The UR5 robot may be able pick different objects of different sizes and shapes with the help of human assistance.

3.7.2 Source

Katia Lopez

3.7.3 Constraints

N/A

3.7.4 Standards

N/A

3.7.5 Priority

Future

4 Packaging Requirements

Packaging requirements are those requirements that identify how the delivered product will be packaged for delivery to the end-user. The UR5 robot and the software component, which will be a Python program, will be delivered. The software will be available via download on our project website.

4.1 Demo & Python Code Delivery

4.1.1 Description

Our final product will be a zip file containing the following: final demo, all python files, and all professional documentation. The final demo will be a short video that displays exactly what the UR5 robot will be doing, picking envelopes and dropping it off inside a bin, and also displaying the human assistance functionality. Python files will be the vision program and the movement program. Finally, all the documentation will be the documentation worked on throughout the semester that will contain detailed information on HAFRA.

4.1.2 Source

Richard Tran

4.1.3 Constraints

Will require internet access for download

4.1.4 Standards

N/A

4.1.5 Priority

Critical

4.2 Accessories & Tools Delivery

4.2.1 Description

We will be giving the stickers used for arUco markers as well as the specific marker we used for our project. Envelopes as well as the hardware used will be given to our sponsor as well. These items can be used for project execution or for personal testing. Our project will be specific about picking up arUco markers on an envelope and dropping it off in a bin.

4.2.2 Source

Richard Tran

4.2.3 Constraints

May require contact with project members for specific layout or setup of the workspace and how items will be placed.

4.2.4 Standards

N/A

4.2.5 Priority

Moderate

5 Performance Requirements

Performance Requirements will address the numeric aspects of our project. Any numbers such as timing, success rates, error rates, recovery, and response. All aspects of performance with our robot and program will be explained in detail here.

5.1 Success Rate Without Human Assistance

5.1.1 Description

The UR5 should already be performing at above a 50 percent success rate without the help of human assistance functionality.

5.1.2 Source

Richard Tran

5.1.3 Constraints

N/A

5.1.4 Standards

N/A

5.1.5 Priority

Critical

5.2 Success Rate With Human Assistance

5.2.1 Description

The UR5 robot should successfully pick envelopes 95 percent of the time with the help of human assistance.

5.2.2 Source

Katia Lopez

5.2.3 Constraints

N/A

5.2.4 Standards

N/A

5.2.5 Priority

High

5.3 Time Required for Decision Making

5.3.1 Description

Once the sensor detects a marker, the robot should be able to make a decision on whether it can perform the task itself or if it needs human assistance to continue in under 30 seconds

5.3.2 Source

Richard Tran

5.3.3 Constraints

N/A

5.3.4 Standards

N/A

5.3.5 Priority

High

5.4 Quick and Intuitive Human Response

5.4.1 Description

Our human assistance functionality should be quick and simple, when the robot requires assistance the human should be able to assess the problem quickly and give the robot a solution in less than a minute.

5.4.2 Source

Richard Tran

5.4.3 Constraints

N/A

5.4.4 Standards

N/A

5.4.5 Priority

High

5.5 Base Success Rate Without Human Assistance Increased

5.5.1 Description

The UR5 base success rate of 50 percent can be increased to a higher percentage.

5.5.2 Source

Cesar Rea

5.5.3 Constraints

N/A

5.5.4 Standards

N/A

5.5.5 Priority

Future

5.6 Adaptation by Machine Learning

5.6.1 Description

The human assistance provided to the Robot can be recorded for machine learning, robot should learn from previous failures in order to make the robot work without human assistance in case it encounters similar situations in future. Robot will show gradual progress on similar tasks.

5.6.2 Source

Resha Adhikari and Nishan Pathak

5.6.3 Constraints

N/A

5.6.4 Standards

N/A

5.6.5 Priority

Future

5.7 Distance constraint of the item from the robot arm

5.7.1 Description

Once stationed, UR5 robot has a working radius of 33.5 inch radius, so all the objects to be picked should be within that reach, or else the arm will not reach the object.

5.7.2 Source

Resha Adhikari

5.7.3 Constraints

N/A

5.7.4 Standards

N/A

5.7.5 Priority

Critical

6 Safety Requirements

Safety requirements will address any situations or occurrences that could affect the physical well-being of users or team members. Anything here will address any precautions that need to be taken in order to execute our program, deal with wiring, and use the UR5 robot without any injuries.

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 SAFETY DISTANCE FROM ROBOT

6.4.1 DESCRIPTION

Person working on the robot should maintain a distance of at least two feet for their safety. It is to prevent any accidents to befall on the worker if the UR5 robot falls onto the ground

6.4.2 SOURCE

Resha Adhikari

6.4.3 CONSTRAINTS

While robot is active, people will stay at least 2 feet away

6.4.4 STANDARDS

N/A

6.4.5 PRIORITY

Critical

6.5 SPECULATION OF MECHANICAL PARTS

6.5.1 DESCRIPTION

Before working on the machine, we should make sure that there are no wear and tear of any mechanical parts. Though the UR5 is a simple robot, it should be regularly inspected for any sign of damage.

6.5.2 SOURCE

Resha Adhikari

6.5.3 CONSTRAINTS

N/A

6.5.4 Standards

N/A

6.5.5 Priority

Critical

6.6 Restriced Access for Unauthorized People

6.6.1 Description

Anyone who is not related with the project should not be allowed to do any unwanted test on robot which can create error in the project.

6.6.2 Source

Nishan Pathak

6.6.3 Constraints

Will require secure access to location of robot.

6.6.4 Standards

N/A

6.6.5 Priority

High

6.7 Use of Necessary Protective Gear

6.7.1 Description

Any team member who is working close with robot should wear some protective gear such as safety glass to avoid any unnecessary movement from the robot that may injure eyes.

6.7.2 Source

Nishan Pathak

6.7.3 Constraints

Will require instructor for access.

6.7.4 Standards

N/A

6.7.5 Priority

Moderate

6.8 Weight Constraint of UR5 Robot

6.8.1 Description

UR5 robot is designed only to hold/pick items up to 5 kgs. No object heavier than the maximum capacity of the robot is used in the project to ensure the safety of robot. [1]

6.8.2 Source

Resha Adhikari

6.8.3 Constraints

No object will surpass the weight of 5kg.

6.8.4 Standards

N/A

6.8.5 Priority

Critical

7 Security Requirements

Security of our project will only have to do with the UR5 robot as our program will be free-to-access for all. Access to the UR5 robot should be limited, and only programmers using it should have access.

7.1 Security of UR5 Robot

7.1.1 Description

The security of the program and the robot should be ensured so that it is not tampered with. It is ensured, as the lab where robot is kept requires UTA NetID authentication to enter.

7.1.2 Source

Resha Adhikari

7.1.3 Constraints

Will require secure access to location of robot.

7.1.4 Standards

N/A

7.1.5 Priority

High

8 Maintenance & Support Requirements

Maintenance and Support requirements address items specific to the ongoing maintenance and support of our product after delivery. Anything that the user or customers should know or will need after we have delivered our project.

8.1 Documentation & Manuals Availability

8.1.1 Description

All our documents and files will be available for access online after delivery for any technical or high-level related questions about the project. Such as any bugs or strange occurrences we may have encountered and how to fix it. In-depth explanations on features and functions of our project will also be provided to clarify any questions.

8.1.2 Source

Richard Tran

8.1.3 Constraints

User will need internet access to download our documentation.

8.1.4 Standards

N/A

8.1.5 Priority

Moderate

8.2 Potential Hotfixes

8.2.1 Description

There may be an error in a situation not accounted for, so fixes in the python code should distributed on the project web page.

8.2.2 Source

Cesar Rea

8.2.3 Constraints

User will need internet access to download

8.2.4 Standards

N/A

8.2.5 Priority

Moderate

8.3 Ease of Access for Tools

8.3.1 Description

Project webpage will provide links to the specific items (Sensor, objects) used for execution. The web-page will also include a description of the UR 5 Robot and will provide a link to Universal Robots.

8.3.2 Source

Cesar Rea

8.3.3 Constraints

User will need internet access

8.3.4 Standards

N/A

8.3.5 Priority

Low

8.4 Friendly User Installation

8.4.1 Description

Goal is to provide steps on executing/installing the code into the UR5 robot so that users will have minimal confusion. Steps can be provided online or in a little pamplet upon delivery.

8.4.2 Source

Cesar Rea

8.4.3 Constraints

User will need internet access

8.4.4 Standards

N/A

8.4.5 Priority

Low

8.5 Updating Webpage

8.5.1 Description

Iterations of the Python Code will be posted on the webpage.

8.5.2 Source

Cesar Rea

8.5.3 Constraints

User will need internet access to download our documentation

8.5.4 Standards

N/A

8.5.5 Priority

Moderate

9 Other Requirements

This section contains requirements that don't fit into any of the other categories but is still required for the H.A.F.R.A project to be considered complete and able to be delivered.

9.1 Neat Web Page

9.1.1 Description

Project webpage should be neat, simple and organized. Users should not have to struggle to find what they are looking for.

9.1.2 Source

Cesar Rea

9.1.3 Constraints

N/A

9.1.4 Standards

N/A

9.1.5 Priority

Low

9.2 Transition into the Industrial Work Environment

9.2.1 Description

With the extreme success rate, it has huge potential to replace many human tasks in the industrial sector.

9.2.2 Source

Nishan Pathak

9.2.3 Constraints

N/A

9.2.4 Standards

N/A

9.2.5 Priority

Future

9.3 Resistance to any kind of Power related problem

9.3.1 Description

While working on robot, if any kind of power outage occur which can shut down the system then it should have the ability to save all the work that have already been done before power down.

9.3.2 Source

Nishan Pathak

9.3.3 Constraints

N/A

9.3.4 STANDARDS

N/A

9.3.5 PRIORITY

High

10 Future Items

In this section, requirements that are considered and discussed but are NOT implemented will be placed here. The requirements here will not be addressed in the delivery of of our prototype due to constraints of budget, time, skills, technology, feasibility analysis, etc.

10.1 Working in different Environments

10.1.1 Description

The UR5 robot should not be limited to working only on conveyor belts. With enough time and effort, the UR5 robot should be able to work with many types of environments such as bin picking.

10.1.2 Source

Cesar Rea

10.1.3 Constraints

N/A

10.1.4 Standards

N/A

10.1.5 Priority

Future

10.2 Base Success Rate Without Human Assistance Increased

10.2.1 Description

The UR5 base success rate of 50% can be increased to a higher percentage.

10.2.2 Source

Cesar Rea

10.2.3 Constraints

N/A

10.2.4 Standards

N/A

10.2.5 Priority

Future

10.3 Adaptation by Machine Learning

10.3.1 Description

The human assistance provided to the Robot can be recorded for machine learning, robot should learn from previous failures in order to make the robot work without human assistance in case it encounters similar situations in future. Robot will show gradual progress on similar tasks.

10.3.2 Source

Resha Adhikari/Nishan Pathak

10.3.3 Constraints

N/A

10.3.4 Standards

N/A

10.3.5 Priority

Future

10.4 Transition into the Industrial Work Environment

10.4.1 Description

With the extreme success rate, it has huge potential to replace many human tasks in the industrial sector.

10.4.2 Source

Nishan Pathak

10.4.3 Constraints

N/A

10.4.4 Standards

N/A

10.4.5 Priority

Future

10.5 Pick Different Objects

10.5.1 Description

The UR5 robot may be able pick different objects of different sizes and shapes with the help of human assistance.

10.5.2 Source

Katia Lopez

10.5.3 Constraints

N/A

10.5.4 Standards

N/A

10.5.5 Priority

Future

REFERENCES

[1] Universal Robots. Automation. optimized.