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

System Requirements Specification
CSE 4316: Senior Design I
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Team UR5
Checkers-Playing UR5 Co-bot

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Revision History

Revision	Date	Author(s)	Description
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1.0	10.24.2022	NU, HH, PR, KV, JH	official release
1.1	05.09.2023	NU	final revisions
1.2	05.10.2023	NU, HH, PR, KV, JH	final revisions

CONTENTS

List of Figures

1 Product Concept

This section describes the purpose, use & intended audience for our programmed UR5 collaborative robot (co-bot). The UR5 co-bot will be programmed to be able to play the interactive & strategy-based game, checkers, against a human opponent. The robot will have an electropermanent magnetic attachment that will allow it to pick up and move the individual checkers pieces. The robot is not intended to beat the human opponent every time but rather just have the ability to play a full game of checkers against them.

1.1 Purpose and Use

Our project aims to showcase the UR5 co-bot's abilities as a means of promoting the UT Arlington College of Engineering to prospective students through the means of an interactive demonstration. Students visiting the College of Engineering are expected to be able to engage with the product in a game of checkers, which will provide the potential Mavericks with an enjoyable and educational experience.

1.2 Intended Audience

The intended audience of our product is the UT Arlington College of Engineering, Department of Computer Science & Engineering as well as the university as a whole to utilize the co-bot as a marketing strategy for prospective students. If this product were to be made commercially available it would be feasible and our primary customers would be other universities aiming to also recruit future engineers. Although the UR5 co-bot is intended to be operated by a student or faculty member of the university, the end user is a member of the public as the project is intended for general use.

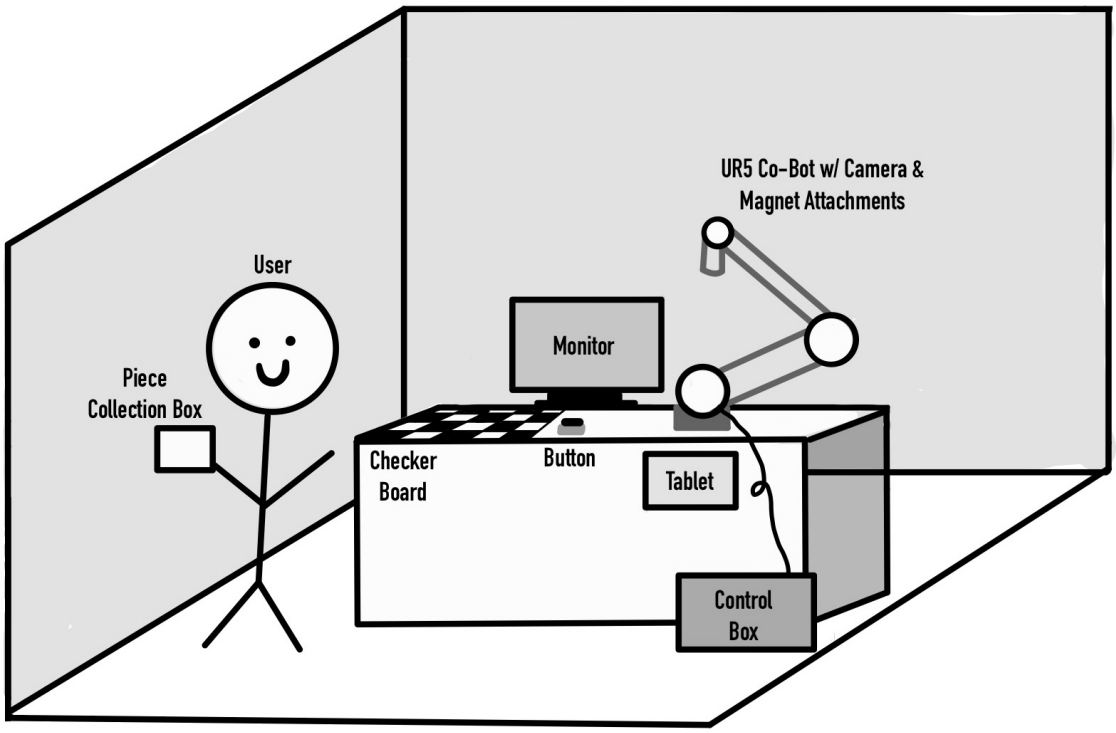

Figure 1: Conceptual Drawing

2 Product Description

This section provides the reader with an overview of our Checkers-Playing UR5 Co-Bot product. The primary operational aspects of the product from the perspective of end users & maintainers, are defined here. The key features & functions found in the product, as well as critical user interactions are described in detail.

2.1 Features & Functions

Our programmed UR5 co-bot is intended to have the following features and functions as outlined in Figure 1:

- UR5 Robot Arm: core element of the product that is a programmable Universal Robots Arm with a 5 kg payload.
  - Camera: 3D camera that will be mounted to a tall tripod to view the board and analyze it.
  - Electropermanent Magnet Attachment: will allow the robot arm to pick up pieces individually by turning on the magnet & then place the pieces by turning off the magnet.
- Checker Board & Pieces: these game pieces will be fundamental to the product as they are what will allow the game-play between the UR5 bot and human user to take place.
- Tablet: UR+ Teach Pendant device that will be used to control the robot step by step
- Control Box: OEM Control Box that not only powers the UR5 co-bot but also allows for integration with external devices.
- Keyboard: Input from the keyboard that will allow the user to notify the robot when they have completed their turn.
- Piece Collection Box: Would ideally sit on the table next the the checkers board to allow both the human user and the co-bot to place pieces they have "won".
- Monitor: Will display the computerized version of the current state of the board.

2.2 External Inputs & Outputs

Given the nature of our project there is only a single external data flow. Our UR5 Co-bot is expected to receive input from end users via the keyboard input that they will press upon completion of their turn, thus signalling the robot to play their next move.

2.3 Product Interfaces

Our product will have a simple computerized version this is intended to show the current location of each players pieces.

3 Customer Requirements

The customers of the UR5 Checkers-Playing Co-bot include, but are not limited to, the project sponsor, the developers, peers, UTA College of Engineering, and prospective students. This section establishes what the end-user should expect with the product. The co-bot will come with a custom-made checkerboard and custom-made checkers pieces to ensure that the physical components of the game are large enough to be detected by the UR5 co-bot's magnetic electro-permanent gripper. The product will also include a collection box for both the user and robot to deposit the checkers pieces during the match. The user will have control over terminating or resetting the match.

3.1 The product shall have a custom-made checkerboard.

3.1.1 Description

The checkerboard will be constructed of a 18 inch by 18 inch wooden board and be custom-painted. It is custom-made to ensure that the size of the checkerboard and checkers pieces are large enough to be easily detected and grasped by the robot arm.

3.1.2 Source

Kevin Vu

3.1.3 Constraints

The custom board must be small enough to comfortably fit the UR5 stand base, and the squares must be large enough to fit the checkers pieces.

3.1.4 Standards

N/A

3.1.5 Priority

Critical

3.2 The product shall have custom-made checker pieces.

3.2.1 Description

These checker pieces will be 3D printed and will have a small magnet contained within them for the robot to grip the piece.

3.2.2 Source

Hoang Ho

3.2.3 Constraints

The checker pieces need to have a hole cut out for the washers to be inserted in them for easy pickup by the magnet in the robot arm.

3.2.4 Standards

N/A

3.2.5 Priority

Critical

3.3 The product shall have a piece collection box.

3.3.1 Description

The box will hold the checkers pieces that the robot arm picks up throughout a checkers match. Additionally, when storing away the game, the checkers pieces can go in here.

3.3.2 Source

Kevin Vu

3.3.3 Constraints

The box must be in reach of the UR5 robot arm during game play to drop off its checker pieces.

3.3.4 Standards

N/A

3.3.5 Priority

High

3.4 The UR5 robot arm shall have a magnetic electro-permanent gripper.

3.4.1 Description

This gripper will have the ability to turn on to grip, and turn off to ungrip. The gripper will be used by the robot arm to pick up checker pieces, and make its move.

3.4.2 Source

Hoang Ho

3.4.3 Constraints

Objects may need to have certain magnetic strength to be able to be picked up by the gripper. On the other hand, the gripper magnetic strength may be needed to take into account also, so that checker pieces relative to the one the robot arm is picking up is not picked up either. It may be that we may need to use a different type of gripper for the optimal object pick up motion. We may be limited by the different magnets we can buy whether it be size, strength, or budget. These limitations also apply to the gripper itself.

3.4.4 Standards

N/A

3.4.5 Priority

Critical

3.5 The system shall follow the rules of American checkers.

3.6 Description

The checkers engine should be programmed to know how to play by the rules of American checkers (English draughts) to avoid confusion.

3.7 Source

Kevin Vu

3.8 Constraints

N/A

3.9 Standards

N/A

3.10 Priority

High

3.11 The system shall be able to abort and reset mid-match.

3.11.1 Description

For demonstration purposes, the checkers program should be able to abort mid-match to prepare for the next round of tourists/viewers to play or watch a fresh match.

3.11.2 Source

Kevin Vu

3.11.3 Constraints

N/A

3.11.4 Standards

N/A

3.11.5 Priority

High

3.12 The product shall show the state of the game to the player at all times.

3.12.1 Description

This will be used to provide a computerized version of the game.

3.12.2 Source

Nimita Uprety

3.12.3 Constraints

N/A

3.12.4 Standards

N/A

3.12.5 Priority

High

4 Packaging Requirements

This section covers the packaging requirements for the UR5 Checkers-Playing co-bot. The software components of the project will be consolidated through a GitHub repository, from which it can be downloaded and set up. The co-bot will be utilizing a CV Software package in conjunction with a camera for computer vision to perform tasks during the checkers game. Along with the robot arm, the product will include a checkers playing board, checkers pieces, and keyboard input to communicate the conclusion of a player's move to the robot.

4.1 The product source code will be publicly available in a GitHub repository.

4.1.1 Description

A link to the GitHub repository will be provided. As of now, the repository will contain a ReadMe file with instructions on setting up the robot arm.

4.1.2 Source

Hoang Ho

4.1.3 Constraints

N/A

4.1.4 Standards

N/A

4.1.5 Priority

High

4.2 The product shall also consist of the checkerboard and checker pieces.

4.2.1 Description

Alongside the UR5 robot arm, the checkerboard and checker pieces will be needed for the robot and player to play the game.

4.2.2 Source

Hoang Ho

4.2.3 Constraints

N/A

4.2.4 Standards

N/A

4.2.5 Priority

Critical

4.3 The product shall consist of a camera.

4.3.1 Description

The system will need to use a camera to gather data on the game state and utilize computer vision.

4.3.2 Source

Hoang Ho

4.3.3 Constraints

We will be able to utilize a camera that exists in previous years, thus saving our budget.

4.3.4 Standards

N/A

4.3.5 Priority

Critical

4.4 The product shall have player enter input from keyboard.

4.4.1 Description

The system will need input from keyboard to act as a way for the player to communicate they have finished their turn.

4.4.2 Source

Hoang Ho

4.4.3 Constraints

N/A

4.4.4 Standards

N/A

4.4.5 Priority

High

4.5 The system shall use a computer vision software package.

4.5.1 Description

The system will need to use a tool for computer vision such as OpenCV.

4.5.2 Source

Hoang Ho

4.5.3 Constraints

N/A

4.5.4 Standards

N/A

4.5.5 Priority

Critical

4.6 The system shall use Python 3.

4.6.1 Description

While programming the robot and implementing computer vision for the application, the Python 3 programming language will be used.

4.6.2 Source

Joanna Huynh

4.6.3 Constraints

N/A

4.6.4 Standards

PEP8 Guidelines will be followed for Python3.

4.6.5 Priority

High

4.7 The product shall come with an informative poster detailing the rules of American checkers.

4.7.1 Description

There should be a poster to display the checkers for players/tourists who are unfamiliar with the rules of American checkers rules to avoid confusion.

4.7.2 Source

Kevin Vu

4.7.3 Constraints

The poster should be large enough to be legible for a group of tourists to read. It should also be able to be easily attached and detached from the UR5 robot stand.

4.7.4 Standards

N/A

4.7.5 Priority

Moderate

4.8 The product shall have a storage box to store away its components and attachments when not in use.

4.8.1 Description

Since the robot arm has multiple uses, it will not always be used as a checkers-playing robot. The pieces and attachments for the robot arm should have a container for storage purposes in order to not lose any pieces.

4.8.2 Source

Kevin Vu

4.8.3 Constraints

N/A

4.8.4 Standards

N/A

4.8.5 Priority

High

4.9 The robot shall remain on its designated red toolbox.

4.9.1 Description

The robot will conduct all checkers games while stationed on the portable red toolbox.

4.9.2 Source

Joanna Huynh

4.9.3 Constraints

N/A

4.9.4 Standards

The toolbox must be transported to specific destinations for demonstrations.

4.9.5 Priority

High

4.10 The camera shall be mounted on a tall tripod and connected via a standard USB port.

4.10.1 Description

This camera will be used to capture the robot's movement.

4.10.2 Source

Nimita Uprety

4.10.3 Constraints

N/A

4.10.4 Standards

N/A

4.10.5 Priority

High

5 Performance Requirements

This section covers the performance requirements for the UR5 Checkers-Playing co-bot. This includes how the system will recognize the checkers pieces, recognize its magnetic gripper, complete its turn within a certain time, calculate certain moves ahead, how it will use frames from the webcam, and the way points setup for the robot.

5.1 The system shall accurately recognize the checkers pieces.

5.1.1 Description

The robotic arm should be able to recognize the custom-made checkers pieces and be able to distinguish between its piece and player's piece to select and grip pieces that are within its domain.

5.1.2 Source

Joanna Huynh

5.1.3 Constraints

Requires a camera that can detect location.

5.1.4 Standards

N/A

5.1.5 Priority

Critical

5.2 The UR5 robotic arm shall recognize when the magnetic gripper should be activated.

5.2.1 Description

The robotic arm's magnetic gripper should only activate once it is its turn in the game, it has decided which piece should be moved, and it has decided on the end location on the checkers board.

5.2.2 Source

Joanna Huynh

5.2.3 Constraints

N/A

5.2.4 Standards

N/A

5.2.5 Priority

High

5.3 Both the UR5 robotic arm and human user shall complete their turns without a set time limit.

5.3.1 Description

The robotic arm and the player should be able to efficiently complete their turn without a set time limit.

5.3.2 Source

Joanna Huynh

5.3.3 Constraints

N/A

5.3.4 Standards

N/A

5.3.5 Priority

Moderate

5.4 The system shall calculate at least three moves ahead.

5.4.1 Description

This will be used to find the accurate move for the robot arm.

5.4.2 Source

Kevin Vu

5.4.3 Constraints

N/A

5.4.4 Standards

N/A

5.4.5 Priority

High

5.5 The product will have detect ArUco markers detection.

5.5.1 Description

The ArUco markers are used on all Checkers pieces for the program to detect their state on the board.

5.5.2 Source

Nimita Uprety

5.5.3 Constraints

N/A

5.5.4 Standards

N/A

5.5.5 Priority

High

5.6 The UR5 robotic arm shall be able to place checkers pieces in a specific location.

5.6.1 Description

The robotic arm should be able to accurately place the checkers piece within a square cell at its center point on the board.

5.6.2 Source

Joanna Huynh

5.6.3 Constraints

N/A

5.6.4 Standards

N/A

5.6.5 Priority

Critical

5.7 The system arm shall be able to make the most optimal decision.

5.7.1 Description

The system should be able to decide on a move that is most optimal to the robotic arm's victory.

5.7.2 Source

Joanna Huynh

5.7.3 Constraints

How the system decides on the most optimal move may be limited by the algorithm used or how many moves ahead is anticipated.

5.7.4 Standards

N/A

5.7.5 Priority

High

5.8 The product shall communicate with the computer to make a particular move.

5.8.1 Description

The computer will be used to issue commands to the robot to make these moves.

5.8.2 Source

Nimita Uprety

5.8.3 Constraints

N/A

5.8.4 Standards

N/A

5.8.5 Priority

Critical

5.9 The product shall perform as many test games as needed.

5.9.1 Description

The product will perform as many games needed to calculate success and failure rates before being handed to the customer.

5.9.2 Source

Nimita Uprety

5.9.3 Constraints

N/A

5.9.4 Standards

N/A

5.9.5 Priority

High

5.10 The robot arm shall be programmed to be able to move to designated squares on the board.

5.10.1 Description

The program will be used to move the robot arm to precise cells on the board on command.

5.10.2 Source

Nimita Uprety

5.10.3 Constraints

N/A

5.10.4 Standards

N/A

5.10.5 Priority

High

6 Safety Requirements

This section covers the safety precautions surrounding the Checkers-Playing UR5 Co-bot. While working in the laboratory, the team will be following LOTO procedures and NEC wiring compliance. More specific to the robotic arm are standards related to having a designated area for any robotic manipulators, functions that automatically stop the movement of the robotic arm in the case of a collision, and a physical emergency stop button which also halts movement.

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 [1]

6.3.5 Priority

Critical

6.4 The system shall stop upon collision.

6.4.1 Description

When someone collides with the robot arm while it is in motion, the robot arm will automatically stop upon collision rather than continuing its motion. The system keeping track of the game state will also be paused, until explicitly told to resume.

6.4.2 Source

Hoang Ho

6.4.3 Constraints

N/A

6.4.4 Standards

Safety-related functions and interfaces built into the UR5 robots are monitored in accordance to EN ISO13849-1:2008 [1]

6.4.5 Priority

Critical

6.5 The system shall have an emergency stop.

6.5.1 Description

The UR5 robotic arm has a controller which provides an emergency stop button to immediately stop all robot motion.

6.5.2 Source

Joanna Huynh

6.5.3 Constraints

N/A

6.5.4 STANDARDS

Safety-related functions and interfaces built into the UR5 robots are monitored in accordance to EN ISO13849-1:2008

6.5.5 PRIORITY

High

7 Maintenance & Support Requirements

After the delivery of our checkers-playing program for the UR5 robotic arm, the customer will need to maintain the hardware and software in case our product were to ever fail. Since we will be using Commercial Off The Shelf components such as the UR5 robotic arm itself, we will include official documents for those components along with our own source code, documentation, and contact information.

7.1 The product source code documentation will be available.

7.1.1 Description

Documentation for the source code will be accessible for the customer in case of technical issues or modifications needed.

7.1.2 Source

Hoang Ho

7.1.3 Constraints

Most of the programming done for the robot arm's movements may be done on the UR5 controller box interface. The programs made here may not be able to be exported.

7.1.4 Standards

N/A

7.1.5 Priority

High

7.2 The official UR5 user manual will be available.

7.2.1 Description

The official user manual for the UR5 robot arm will be provided to the customer.

7.2.2 Source

Hoang Ho

7.2.3 Constraints

N/A

7.2.4 Standards

N/A

7.2.5 Priority

High

8 Other Requirements

To ensure the robot arm can be reconfigured to execute our checkers-playing program, here are some additional requirements not covered in the previous sections. These requirements are important in case the customer would want to port our project to other platforms or would like to temporarily remove its modules to re-purpose the UR5 robot, and then reconfigure the robot to play checkers again in the future.

8.1 The control computer shall run on Ubuntu 22.04.

8.1.1 Description

The computer that will drive the checkers-playing program will run on Ubuntu 22.04.

8.1.2 Source

Joanna Huynh

8.1.3 Constraints

N/A

8.1.4 Standards

N/A

8.1.5 Priority

High

8.2 The system shall use existing checkers engine.

8.2.1 Description

This engine will be used to implement the game and dictate the robot's move decisions.

8.2.2 Source

Nimita Uprety

8.2.3 Constraints

N/A

8.2.4 Standards

N/A

8.2.5 Priority

High

8.3 The program shall use mini-max algorithm.

8.3.1 Description

Mini-max algorithm will be used to provide an optimal move for the robot arm assuming that player is also playing optimally.

8.3.2 Source

Nimita Uprety

8.3.3 Constraints

N/A

8.3.4 STANDARDS

N/A

8.3.5 PRIORITY

High

9 Future Items

This section covers the future requirements for the UR5 Checkers-Playing co-bot. These are the further developments that will be potentially made on the project which include but are not limited to having difficulty level setting, UR5 automatically resetting the board, and option to play other regional variations of the robot.

9.1 The system shall have a difficulty level setting.

9.1.1 Description

The user should be able to select an easier or a harder opponent to face. The difficulty of the opponent could be defined by how many moves ahead the system takes into account, or a particular algorithm.

9.1.2 Source

Kevin Vu

9.1.3 Constraints

N/A

9.1.4 Standards

N/A

9.1.5 Priority

Future

9.2 The system shall be able to automatically reset the board and replace the checkers pieces.

9.2.1 Description

After completing a match or aborting a match, the UR5 robot arm should automatically reset the board and its checker pieces to prepare for the next match.

9.2.2 Source

Kevin Vu

9.2.3 Constraints

N/A

9.2.4 Standards

N/A

9.2.5 Priority

Future

9.3 The system shall have the option to play other regional variations of checkers that use an 8x8 squares board.

9.3.1 Description

Since there are many different variations of checkers played around the world (Russian draughts, Turkish draughts, etc.), there is a possibility to program the robot to play by slightly different rules.

9.3.2 Source

Kevin Vu

9.3.3 Constraints

N/A

9.3.4 Standards

N/A

9.3.5 Priority

Future

REFERENCES

[1] UR5 User Manual. ver 3.0 https://www.usna.edu/Users/weaprcon/kutzer/_-files/documents/User%20Manual,%20UR5.pdf, 2009.