ENS4152 Project Development

Proposal and Risk Assessment Report

**Baxter Research Robot: Solving a Rubik’s Cube**

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**Abstract**

1. **Introduction**
   1. **Motivation**

Baxter Research Robot by Rethink Robotics is a dual arm robot, with seven degrees of freedom per arm, released in 2012. Developed to be affordable, flexible in its purpose, and above all else safe, Baxter includes three cameras, one on each wrist and the other on its head and a screen for displaying information relating to Baxter’s current task. The robot is designed to be a versatile research platform while containing the same hardware as its industry counterpart, allowing research to translate into industrial applications (Rethink Robotics, 2015).

Current research with Baxter has

* What is baxter
* What is baxter used for
* Current use of dual arm robots
* Current Problem solving robots
* Why undertake project
* Why important

This project is the development of an algorithm that combines the visual and actuator systems of the Baxter Research Robot with a solution scheme, allowing the robot to solve a problem. This will be demonstrated by using the Baxter to pick up, identify, solve, and then return a Rubik’s cube that is placed on a desk in front of it.

Research has been done, and an implementation using Baxter to solve a Rubik’s cube has been demonstrated. Initially the Rubi’s cube is put in the gripper of the Baxter, then using an external scanner they determine the colour placements. My research aims to differentiate itself by introducing object recognition and motion planning to initially pick up the cube, and the put it down after it has been solved. Also I strive to use only Baxter’s hardware to solve the cube.

* 1. **Objectives**

The overall objective of this project is to develop an algorithm that controls the vision and servos of the Baxter robot to allow it to pick up a Rubik’s cube, visually analyse the cube, find a solution and finally to allow the Baxter to manipulate the cube to solve it. As research has already been done on this, I will be aiming to use only the Baxter robot and no external hardware. This means that the project will require only the Baxter robot and a computer setup as a workstation to communicate to the robot.

The solving algorithm must allow any combination of a 3x3 Rubik’s cube to be solved. This requires a set of rules for solving the Rubik’s cube to be programmed, as opposed to using a database of solutions.

The vision must be able to recognise and determine placement of a Rubik’s cube placed in front of Baxter on a table, and to recognise the different colours on a Rubik’s cube with accuracy.

Movements made by Baxter will be mostly programmed in, such as the movements for analysing the cube and for manipulating it. Motion planning will be needed for retrieving the cube and placing it back. Ideally the cube will be placed on any spot in reach of Baxter.

As an extension the algorithm could also include the ability to solve a 4x4 Rubik’s cube. This will require additional research into a solving solution, and possible modification of the grippers. Additionally the vision software will also be required to identify the type of Rubik’s cube, and additional movements to manipulate the 4x4 cube will need to be defined.

* 1. **Significance**

1. **Proposed Approach**

The project can be broken down into a number of task that need to be completed sequentially and successfully for the objective to be achieved. All the programming will be done in Python using the Integrated Development Environment (IDE) Visual Studios. Python was decided as the Baxter robot has an Application Programing Interface (API) that allows direct python control of the Baxter robot. Additionally the Python programming language has been developed with emphasis on code readability allowing creation of well laid out code.

The majority of the work will be done on a computer of which I have two computers set up for programming with, and one will also have simulation software Gazebo (Open Source Robotics Foundation, 2014). This tool is designed for robot simulation capable of simulating detailed environments and multiple robots and allowing algorithm testing. The computers will be available at all times meaning work on the programming will not be limited by resource availability. For movement planning and manipulation MoveIt will be used (Sucan & Chitta, n.d.). This allows movement planning without having to interact with Baxter physically, reducing the impact of the robots unavailability.

When working with Baxter RViz will be used (Rethink Robotics, 2014). This tool allow the current configuration of Baxter to be displayed, along with camera vision and individual sensor values which will allow superior control and visualisation of Baxter’s movements.

Only one Baxter robot is available but there is multiple projects running on Baxter. A division of time to be spent testing and working with Baxter will need to be established to allow all the projects ample use of Baxter. However, use of the simulation software should allow some work to be done without working with Baxter directly and thus allowing work to continue at a similar pace.

First vision recognition will be used to identify a Rubik’s cube placed in front of Baxter. Then inverse kinematics will be needed to obtain the cube, given the relative positions of the gripper and the cube. The initial placement of the cube will need to be recorded for returning the cube. A vision system is already provided with Baxter but colour recognition will need to be added. This will require research on relevant software and to pick the optimal solution through a trade-off analysis.

Vision recognition will also serve the purpose of identifying the placement of the 6 different colours. As this system could have errors a check to ensure that there is 9 of each colour will be put in place to determine if any errors have occurred. If an error occurs, the colour will either be inferred or the cube will undergo a rescan. All of the colours will be saved either as strings or values in tables, each representing a face. Each colour will be determined by

Before the cube can be scanned, a set of movements must be defined that will scan all 6 sides of the cube one at a time. This will require programming in a set of movements for each arm to perform, with the colour recognition being used between each movement to scan the cube. MoveIt will be used to plan the motions for Baxter’s arms and then these motions will be converted into Python code.

The saved colour positions will serve as the inputs to a solving solution that will solve the Rubik’s cube and output a list of face rotations that will need to be performed. These rotations will be translated to sets of movements that are predefined within the code and then performed in order. As many programs have been written to solve a Rubik’s cube, research will be done into an efficient solution that requires the least time to solve, and the smallest number of movements. However the ability to integrate this program into python, and allow it to interact with the rest of the algorithm will be the most important criteria that will ultimately determine the solution used.

After the cube is solved, Baxter will then return the cube to its initial position and the algorithm will end. This will be achieved using reverse kinematics based on the saved initial position of the cube.

1. **Timeline**

A Gantt chart can be found as Attachment 2. This chart assumes that by week 12 of semester two, all project work should be completed for presentation in week 13. The chart also omits semester two assessments as dates cannot be determined at this time. Although the assessments will be worked on parallel to the project. The final report will require constant work and as such will run for most of semester two. The semester one report and presentation have been given two week each, and are assigned time parallel to task work.

As seen in the chart each task has been further broken into subtasks. Each task is defined as a section of the project that can be developed and tested by itself which allows for more targeted debugging. Each task for the project are completed sequentially as they are designed to be modules that will be combined after all project work related tasks are completed. Even though time for testing each module has been assigned, rigorous testing has been allowed for once all the tasks have been combined. This is for unseen issues that may arise. Additionally two weeks has been given no project work as this is exam time for other units.

Given the generous time allowed, and the various testing that occurs, this timeline is realistic and should allow for any unseen setbacks.

1. **Risk Assessment**

Majority of the project work is done on a computer, with testing the algorithm done by using the Baxter robot. This is reflected in the overall low risk rating shown by the risk assessment matrix as Attachment 1. The risks have all been assigned a three letter reference that fits in the following categories:

SUP - Supervisor

PER - Personal

ERG - Ergonomics

EQU - Equipment

CMP - Computer

SFT - Software

Many of the risks are inherently low due to low probability of occurrence or low impact on the project if they were to occur. The two medium risks are eye strain due to computer work and loss of project data. These risks required minimisation as they couldn’t be removed completely. For risk ERG\_03 the approach to reduce the risk is to require regular breaks from the computer, and to ensure ergonomic eye angles and screen distance are abided by. Risk CMP\_01 is medium because of its impact to the project. Losing project work can set back the project by weeks and as such must be minimised. By using cloud storage as an additional backup to having the files stored on multiple computers, this reduces the risk impact to low. Cloud storage also has the added benefit of allowing multiple computers to have access to the same version of project files.

1. **Progress to Date**

Current progress has been made to get the Baxter research robot ready to be used. A workstation installed with Ubuntu 14.04 with Robot Operating System (ROS) Indigo has been set up to allow a permanent connection to Baxter. The software on Baxter himself has also been updated to the latest version, 1.1. The arm configuration program has also been run to ensure correct sensor measurements and precise movements by Baxter. However the configuration program will need to be run every month as recommended by Rethink Robotics.

A personal Laptop has also been installed with Ubuntu 14.04 and ROS. This is for the purpose of simulating the Baxter robot when physical testing is unavailable. This laptop can also be setup to connect to Baxter, if the permanent workstation stops working.

1. **Conclusion**
2. **References**

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**Attachment 1 – Risk Assessment Matrix**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Risk Reference** | **Risks** | **Consequences** | **Current Risk Treatments** | **Current Level of Risk** | | | | **Additional Risk Treatments** | **Residual Level of Risk** | | | |
| **Likelihood** | **Consequence** | **Risk Level** | **Ranking** | **Likelihood** | **Consequence** | **Risk Level** | **Ranking** |
| SUP\_01 | Supervisor is not contactable/unavailable for an extended period of time | Advice and guidance cannot be given, possibly allowing misinformation and a lack of help when needed. | The unit co-ordinator can be approached for general information. | 1 | 2 | 2 | L | None Required | 1 | 2 | 2 | L |
| PER\_01 | Sickness or unrelated injury | Reduced work progress or complete stoppage. Can set behind the whole project causing stress. | Computers available at residence has required software to work on much of the project, allowing work to continue, abet at a slower pace. | 2 | 2 | 4 | L | None Required | 2 | 2 | 4 | L |
| PER\_02 | Project work causes too much stress | Reduced ability to work on both project and other units. Can fall behind further increasing stress. | Maintain health level of commitment to work, while allowing for time spend outside of project and unit work. | 2 | 2 | 4 | L | None Required | 2 | 2 | 4 | L |
| ERG\_01 | Bad posture or sitting position | Sore back, shoulders and neck. Will reduce productivity and act as a distraction preventing focused work. | Adjustable chairs with movable seat angle and back position allowing an ergonomic seating position. | 2 | 2 | 4 | L | None Required | 2 | 2 | 4 | L |
| ERG\_02 | Repetitive Strain Injuries in hands or wrists | Computer work becomes painful impacting on both project work and unit work. | Regular breaks from computer work. | 2 | 2 | 4 | L | Implement regular wrist exercises. Use correct hand position according to ergonomic standards. | 1 | 2 | 2 | L |
| ERG\_03 | Eye strain/soreness | Work must be stopped to rest eyes. | Have regular breaks from computer work. | 3 | 2 | 6 | M | Correct ergonomic eye level and distance from screen. | 2 | 2 | 4 | L |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| EQU\_01 | Baxter robot breaks completely | Baxter cannot be used to test or demonstrate project. | Simulation software Gazebo can be used in place of Baxter for proof of concept. | 1 | 3 | 3 | L | None Required | 1 | 3 | 3 | L |
| EQU\_02 | Collision of Baxter robot with person | Affected area can have slight soreness. | Baxter's limited force application (lifting limit of 2kg) and slow motion ensures all collisions are low impact. | 2 | 1 | 2 | L | Area near Baxter to be clear of persons before and during use. | 1 | 1 | 1 | L |
| EQU\_03 | Some systems of Baxter stop working | All the main functions are needed, and as such this could completely eliminate using Baxter. | Use of Gazebo simulation software in place of Baxter may be required but will be sufficient to perform tests and present the project. | 1 | 3 | 3 | L | None Required | 1 | 3 | 3 | L |
| CMP\_01 | Loss of data | Time and effort wasted by losing data due to hard drive crashes or data corruption. | Copies of all project files are on different computers and backed up on USB's | 2 | 3 | 6 | M | Use of cloud storage to add another backup of project data and allow syncing between devices. | 1 | 1 | 1 | L |
| CMP\_02 | Workstation computer that connects to Baxter fails | Communication through workstation to Baxter and thus testing cannot be done. | Laptop is set up with required software and can be used instead of lab computer. Software can be reinstalled on a different computer in the lab. This would require a couple hours of work. | 1 | 3 | 3 | L | None Required | 1 | 3 | 3 | L |
| CMP\_03 | Either personal computer used for programming work fails | Limit personal computer work and therefore set back or slow down project work. | Multiple computers set up to work on. | 1 | 2 | 2 | L | None Required | 1 | 2 | 2 | L |
| SFT\_01 | Communication software becomes unsupported | Cannot communicate and thus use the Baxter robot. | Gazebo Simulation Software can be used in place of Baxter robot. | 1 | 3 | 3 | L | None Required | 1 | 3 | 3 | L |
| SFT\_02 | MoveIT software becomes unsupported | Motion planning cannot be done using the software. Can cause a large setback. | Motion planning will require test with the Baxter robot, or use of Gazebo simulation software. | 1 | 3 | 3 | L | None Required | 1 | 3 | 3 | L |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SFT\_03 | Rviz software becomes unsupported | Detailed information about Baxter cannot be displayed while testing. | Although less information can be obtained, tests can still be performed. Debugging of Baxter can be done by rqt\_console software. | 1 | 2 | 2 | L | None Required | 1 | 2 | 2 | L |
| SFT\_04 | Visual Studios IED becomes unsupported | Programming cannot be done using Visual Studios, stopping relevant work. | Another IDE can be used in place to allow programming work to recommence. | 1 | 2 | 2 | L | None Required | 1 | 2 | 2 | L |
| SFT\_05 | Gazebo Simulation software becomes unsupported | Accurate simulation of Baxter robot in an environment cannot be done. Can slow down project development. | Physical testing with Baxter must replace simulation tests. | 1 | 3 | 3 | L | None Required | 1 | 3 | 3 | L |

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| --- | --- | --- |
| **Activity Overall Risk Rating** | **0.00** | **Low** |

**Attachment 2 – Timeline Gantt chart**