Project Deliverable C

Design Criteria and Project Specifications

Ani Preedom
Christy Lau
Paul Shedden
Claire Durand

GNG1103 Project Group 6
February 6, 2022

Abstract

On Halifax-class frigates, the Department of National Defence has a need for a robotic arm that uses inverse kinematics to paint surfaces. The robot must also scan and clean areas to identify and remove defects. To design the robot, a design process with several steps will be followed. Thus far, raw data about the product has been gathered from one of the users and interpreted to identify user needs. At this stage in the design process, the user needs must be used to establish a set of design criteria. This report presents a set of design criteria categorised into functional requirements, non-functional requirements, and constraints; presents results found from benchmarking thus far, and describes the next steps in the research process.

Table of Contents

1.0 Introduction

The Department of National Defence expressed the need for a robotic arm with three degrees of freedom to paint areas on Halifax-class frigates. Raw data was collected from the client and analysed to identify the needs of the user. The needs were then prioritised, and design criteria were produced from the interpreted needs.

2.0 Design Criteria

In this section, design criteria, including functional and non-functional requirements, and constraints are defined based on the user needs that were identified and categorised in Deliverable B.

2.1 Prioritised Design Criteria

Table 1. Prioritised Design Criteria from Interpreted Need

#	**Interpreted Need**	**Functional/ Non-Functional / Constraints**	**Design Criteria**	**Relative Importance (1-5, where 5 is most important)**
1	Transported and operated by a single user	Constraints	- Light for transport (maximum weight of 20 lb) - Ease of use	5
2	Arm is light and manoeuvrable for transport through the ship	Constraints	- Compact ($1m^2$) - Light for transport (maximum weight of 20 lb)	5
3	Arm can scan area for objects and people	Functional	- Safety sensors (detects movement or objects)	5
4	- Maintain stability with a heavy load - Maintains stability when system is pressurised	Functional	-Supports a maximum of 1 kg -Can withstand 8 bar of pressure	4
5	Operates using inverse kinematics	Functional Requirement	-Operates using inverse kinematics	5

6	Extends within a one metre radius	Constraint	-Maximum range of motion	4
7	Inexpensive	Constraint	- Budget of $100	4
8	Reproducible using 3D printing	Non-Functional	- Detailed documentation	4

3.0 Target Specifications

The design criteria were analysed and fitted with appropriate target specifications, such as values and units. These specifications will act as guidelines for the product. The specifications will be verified using appropriate methodology (testing, opinion board, analysis, planning, etc.).

3.1 Functional Requirements

Table 2. Design Specifications for Functional Requirements

Functional Requirements	Relation (=, < or >)	Value	Units	Verification Method
Supported Pressure	<	8	bar	Test
Operates using Inverse Kinematics	=	YES	N/A	Test

3.2 Non-Functional Requirements

Table 3. Design Specifications for Non-Functional Requirements

Non-Functional requirements	Relation (=, < or >)	Value	Units	Verification Method
Stability	=	YES	N/A	Test
Product life	>	6	months	Test
Maintainability	=	YES	N/A	Test
Reproducibility	=	YES	N/A	Test
Aesthetics	=	YES	N/A	Opinion board

Ease of Use	=	YES	N/A	Test
Safety Sensors	=	YES	N/A	Test

3.3 Constraints

Table 4. Design Specifications for Constraints

Constraints	Relation (=, < or >)	Value	Units	Verification Method
Maximum Load	=	1000	g	Test
Minimum Range of Motion	=	100	cm	Test
Maximum Weight	=	20	lb	Analysis
Compactness	<	1	m^2	Analysis
Maximum Cost	=	100	$	Planning

4.0 Benchmarking

4.1 Technical Benchmarking

	Robot 1	Robot 2	Robot 3	Robot 4	Robot 5
Name	Arduino Braccio Robotic Arm	Drawing Robot Arm	Lynxmotion 3-DoF	Lynxmotion AL5D + BotBoarduino	AL5A+ BotBoarduino
Dimensions	52 cm high 14 cm wide base	N/A	N/A	N/A	N/A
Degrees of Freedom	4	3	3	4	4

Maximum reach (cm)	80	10x10	38x21	42x48	29x14
Software	N/A	Arduino	LSS Flowarm	Arduino	Arduino
Interface	N/A	None	LSS Adapter	Arduino	Arduino
Cost (CAD)	305.20	N/A	510.24	396.50	348.54
Mass (g)	792	N/A	634	N/A	N/A
Electronics	Arduino	Arduino UNO	N/A	N/A	Arduino
Maximum Load (g)	400	N/A	N/A	275	100
Motors used	2 x SR 311, 4 x SR 431	Bosch AHC 24V SERVO DMN29BA-002 24V	Smart Servo	Hitec Servo	Hitec Servo

Note: Red = worst specification, Yellow = intermediate, Green = best specification

4.2 User Benchmarking

Robot Name	**Points from Review**	**Interpretation from Review**
Universal Robots e Series	1) User friendly and easy to implement, good user interface 2) High precision movements and strong safety features 3) Has weight and adaptability limitations to different projects	1) Ensure user friendly interface and simple/easy implementation of robot 2) Test for stability of robot and ensure low error in movement 3) Ensure robot can handle large loads (maybe larger than given constraint to account for unknown situations)
Arduino Braccio Robotic Arm	1) Small, yet strong and reliable 2) Robot moves in unpredictable ways when input does not make sense 3) User had a problem calibrating the	2) For error handling, the code must handle invalid inputs and prompt the user for a valid input to ensure that the robot

	range of motion 4) Robot still deserves a five-star review because the setup requires little effort and time	functions correctly 3) User interface could allow users to change parameters easily 4) Users appreciate a fast and easy setup: ensure robot has this quality
Lynxmotion AL5D+ BotBoarduino	1) Difficult to assemble 2) Motor was powerful and easy to command 3) User friendly	1) Easy to assemble/disassemble 2) Motor should be able to handle required task with ease 3) User friendly

5.0 Required Research to Complete

Although some research has been done to improve the benchmarking for this project, additional research is still required. Benchmarking has been done for many physical properties and qualitative feedback from users, but an area which has not been benchmarked sufficiently is the code for robots that use inverse kinematics. Open-source code will be researched because for this project, approximately 80% of the code will be recycled from developers who have already written foundational code. Additionally, the 20% that will be specifically written to achieve the functionality required for this project will also be researched with the aim of finding coded solutions of functions similar to the functions performed.

Other knowledge gaps will be filled by reading literature found on the internet and the Omni online library. One such knowledge gap is theoretical knowledge of inverse kinematics, which is required to program a robot to use inverse kinematics. Other resources such as the laboratory session on February 9 will act as supplements to the ongoing learning process.

6.0 Conclusion

The Department of National Defence has a need for a robotic arm that uses inverse kinematics to paint surfaces. In this deliverable, user needs identified in Deliverable B were used to formulate a list of prioritised design criteria. Technical and User benchmarking were also completed in order to determine target specifications. Moving forward with the project, more research will need to be completed to incorporate inverse kinematics into the design of the robot. In the next stages of the project, the design criteria and benchmarking will be used to create numerous conceptual ideas for the design and operation of the robotic arm.