Project II Report:

Networked Control System & Cyber Attacks

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**Course:** SY202 Cyber Systems Engineering

**Enclosures:** (a)PI Control mbed C++ code

(b) Cyber Attack mbed C++ code

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Metric** | **Weight** | **Quality** | | | | | **Max**  **Score** | **Midn**  **Score** |
| **0** | **1** | **2** | **3** | **4** |
| Use of Lab Template | 1 | No |  | Partially |  | Yes | 4 |  |
| Pre/Post Assessment | 2 | None |  | Only some members |  | All members completed it | 8 |  |
| Abstract | 1 | Not present or misleading |  | Incomplete |  | Clear synopsis | 4 |  |
| Introduction | 1 | Problem, purpose, and objectives are unclear |  | Problem stated but purpose/objectives unclear |  | Well discussed | 4 |  |
| Hardware Overview | 1 | Not listed |  | Incomplete list |  | Complete list with FBD | 4 |  |
| **Part I - Simulation** | | | | | | | | |
| Modeling | 1 | Simulink model is not included, components are not explained |  | Model included but incorrect or components are not explained |  | Correct Simulink model with components and functionalities explained | 4 |  |
| Results and Discussion (Robotic Arm Simulation) | 2 | Results are not presented or are poorly discussed, missing several observations |  | Result are presented, but missed some relevant observations, unsubstantiated claims |  | Results are well discussed; **short but cohesive**; trends and observations are well substantiated with data | 8 |  |
| Results and Discussion  (Disturbances) | 2 | Results are not presented, incomplete, or incorrect |  | Results are partially presented or some are incorrect; unsubstantiated claims |  | Results are complete and correct | 8 |  |
| Results and Discussion  (Cyber Attacks) | 3 | Results are not presented or are poorly discussed, missing several observations |  | Result are presented, but missed some relevant observations, unsubstantiated claims |  | Results are well discussed; **short but cohesive**; trends and observations are well substantiated with data | 12 |  |
| **Part II - Experiments** | | | | | | | | |
| Procedure | 2 | Wrong or vaguely described |  | Incomplete details or partially wrong |  | Well described and presented, yet cohesive | 8 |  |
| Proportional-Integral Control | 3 | Incorrect implementation and results |  | Missing information or minor mistakes, no discussion of results |  | Correct implementation, results are well-presented and discussed | 12 |  |
| Effects of Cyber Attacks  (Description) | 1 | Wrong or not introduced |  |  |  | Correct introduction/explained | 4 |  |
| Stealth Attack Results | 2 | Incorrect implementation and results |  | Missing information or minor mistakes, no discussion of results |  | Correct implementation, results are well-presented and discussed | 8 |  |
| Replay Attack Results | 3 | Incorrect implementation and results |  | Missing information or minor mistakes, no discussion of results |  | Correct implementation, results are well-presented and discussed | 12 |  |
| Resilient Control Solutions | 1 | Not listed or not explained |  | Vaguely analyzed/described |  | Well though and well described | 4 |  |
| Conclusions | 2 | Not included or poorly summarize main results |  | Included but inaccurate or vague |  | Included and cohesively summarize results | 8 |  |
| Enclosures | 1 | Not included |  | Partially |  | Included | 4 |  |
| Grammar, organization, & Professionalism | 1 | Poor grammar and use of slang, missing use of units |  |  |  | Professional engineering writing | 4 |  |
| Demo of your project | 5 | Not presented |  | Partially presented or wrong |  | Successful demonstration | 20 |  |
| **Total Points** | | | | | | | **140** |  |
| **Normalized Score (Total/140)x100** | | | | | | | **100** |  |

*Abstract*—Your abstract should be a single paragraph summarizing the entire document. Someone should be able to read your abstract and know exactly what to expect when they read the rest of the document. The abstract should also overview the objective of the laboratory assignment, its importance in context of the broader cyber-systems engineering landscape, and the final performance results.

# Introduction

**This should be in paragraph form (2-3 paragraphs)**. In this section you should discuss the following items.

Problem Statement and Objectives: Describe the purpose of the lab, the physical system being modeled or controlled, the problem, and the lab objectives. Motivation: Point out the importance of this lab with respect to your major and the Navy.

# Hardware Overview

Include a list of components and their function. Include a Functional Block Diagram and explain.

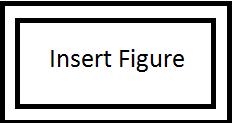


Figure 1. Functional Block Diagram

# Modeling of Networked Robotic Arm

Include a brief description of the system being modeled, mentioning the different components and their function within the system. Include (this is REQUIRED) a screen-shot or figure of your Simulink Model. If it too large, you may include it as an enclosure or Appendix but make sure to mention its existence within the text (otherwise, I might not see it).

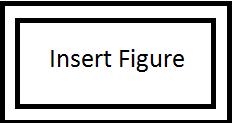


Figure 2. Simulink Model of NCS

# Simulation Results and Discussion

## Closed-Loop Control of Robotic Arm

Discuss the results and observations you obtained when using a proportional control (Kp only) and a proportional-integral control (Kp and Ki). Make comparisons. Provide the control gains and plots from step #14. Discuss your observations from step #15.

## Closed-Loop Control of Robotic Arm with External Disturbances

Discuss the results and observations from steps #16 and #17. Provide the requested plots.

## Closed-Loop Control of Robotic Arm under Cyber Attack

Discuss the results and observations from steps #18. Provide the table and plots being requested.

In addition, include ideas you may have that could protect the system or improve its performance (make the closed-loop system more resilience). There is no wrong answer to this question as long as you demonstrate some reasoning.

# Experimental Procedure

Describe the design and steps you used to complete the experimental part. Include the steps you used in your experimental part. Imagine someone not related to SY202 reading this report. He/she should understand what you did, how, and why.

# Proportional-Integral Control

Describe your proportional control. Include gains.

## Results and Discussion

Include a plot of the angular position of arm vs time when regulating the arm at 0 rad under rotation of the base (disturbance). Discuss any time response characteristics you are able to measure (such as Overshoot, settling time, peak time, and steady-state error). Include a plot of the PCM signal vs time.

Include a plot of angular position vs time and desired angular position vs time when following a cosine trajectory and discuss results.

Discuss possible sources of errors that might have affected your experiments.

# Effects of Cyber Attacks

Describe the difference in execution of both cyber-attacks.

## Stealth Attack: Results and Discussion

Include a plot of the angular position of arm vs time when the cyber attack error has a magnitude of 0.20 radians and a frequency of 2 attacks per second. Discuss your results. In addition, discuss how the size and frequency of the attack affected the response of the system.

## Replay Attack: Results and Discussion

Include a plot of the angular position of arm vs time when implementing the replay attack. Discuss your results.

## Resilient Control System Solutions

Include statements of how this lab relates to other control systems in the US Navy and describe potential effects of cyber attacks on those systems. Hypothesize measures (at least one) that you can implement in your control code, sensor code, or servo code that may protect these systems and explain.

# Conclusion

Summarize your final results here including observations and trends you observed. Among many other things, tell us if you consider your effort a success.

# Comments

Here you can feel free to provide constructive feedback on the project experience.