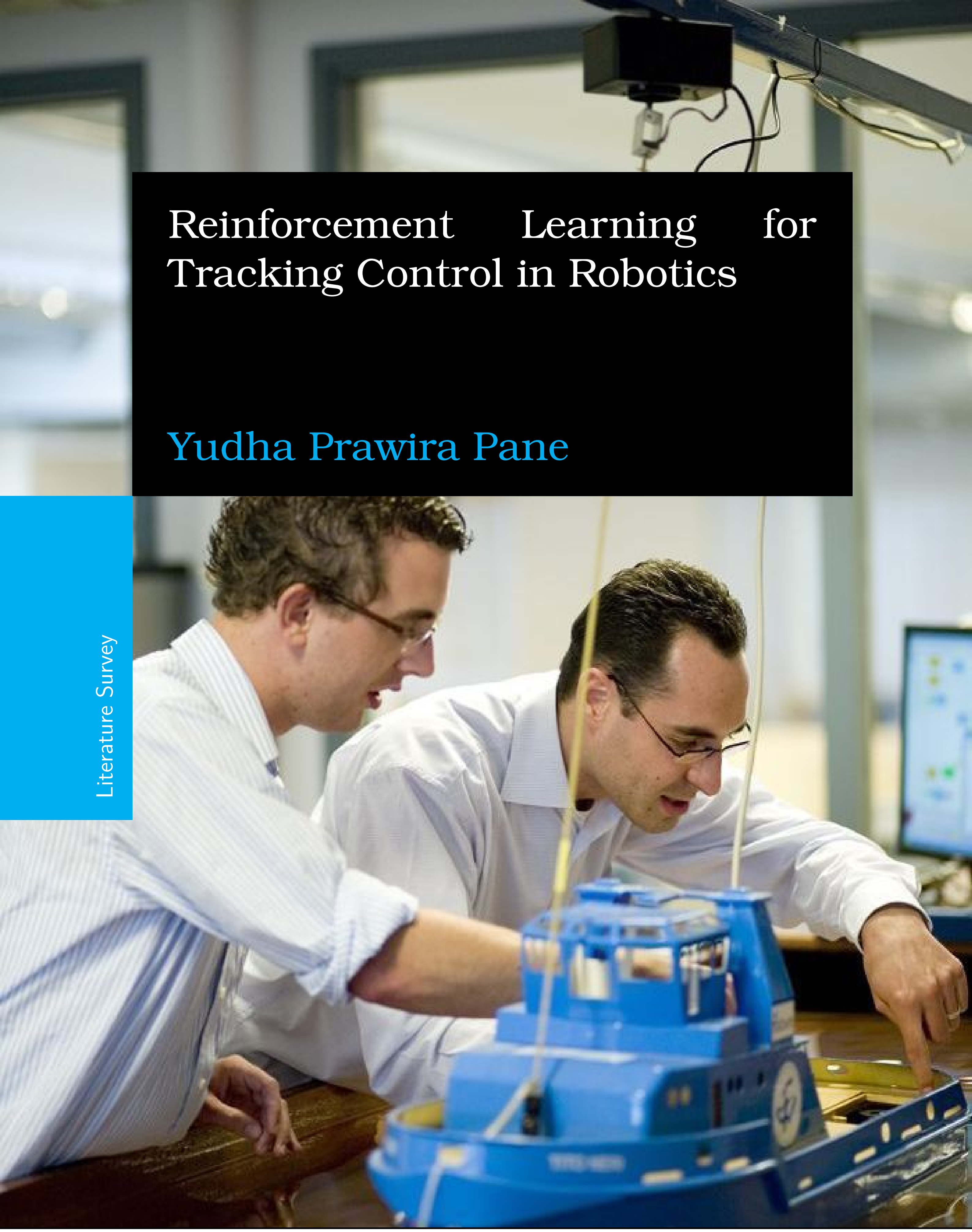

Reinforcement Learning for Tracking Control in Robotics

Yudha Prawira Pane

Literature Survey

TU Delft
Delft University of Technology

Delft Center for Systems and Control

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December 15, 2014

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The implementation work in this thesis was done at DCSC's robotics lab.

Abstract

This is an abstract.

Table of Contents

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Preface

According to WIKIPEDIA, a preface (pronounced "*preffus*") is an introduction to a book written by the author of the book. In this preface I can discuss the interesting story of how this thesis came into being.

This is document is a part of my Master of Science graduation thesis. The idea of doing my thesis on this subject came after a discussion with my good friends Tweedledum and Tweedledee…

Acknowledgements

I would like to thank my supervisor for his assistance during the writing of this thesis. . .

By the way, it might make sense to combine the Preface and the Acknowledgements. This is just a matter of taste, of course.

Delft, University of Technology — Yudha Prawira Pane
December 15, 2014

“In the future, airplanes will be flown by a dog and a pilot. And the dog’s job will be to make sure that if the pilot tries to touch any of the buttons, the dog bites him.”

— *Scott Adams*

Chapter 1

Introduction

Reference or trajectory tracking is one of the building blocks to perform a complex task in robotics. Given a desired path/trajectory, the robot must be able to follow it as quickly as possible with minimum error. Capability to perform this precise tracking is crucial for robots that are to be deployed at manufacturing industries such as semiconductor, automotive, and recently, the emerging application of 3D printing.

Statistics by International Federation of Robotics (IFR) [1] shows that the global sales of industrial robots continues to increase steadily. In 2014, it is expected that the total number of industrial robots installed reaches 205,000 units, a rise of approximately 15 % from previous year. The survey points out that the mature markets such as automotive, electronics, and metal are responsible for such growth.

Meanwhile, there is also a growing interests in applying robots to relatively new applications such as 3D printing, architecture, and art. For instance, research done by Gramazio et. al [2] aims to push the capability of industrial robots to make the direct fabrication based on CAD model a reality. The advantage of using robots over conventional CNC machines lies on their flexibility, easy-to-adapt feature, and high degree of freedom (DOF) to enable execution of difficult configuration in 3D space. These aforementioned applications demands high precision since a minuscule of error could lead to a defect product or even worse, a disaster. Therefore, a precise, accurate reference tracking capability is inevitable.

In order to achieve this, a tracking controller is needed. However, robots are identical with non-linearities, noises, and external disturbances that are difficult to model, let alone compensate. This unknown properties hinders the controller to perform optimally, leading to poor tracking accuracy.

In order to

1-1 Problem Definition

The fundamental problem in this literature study concerns with the non-optimal performance of nominal controller with respect to reference tracking task. Therefore the research question can be raised as follows.

"Can we integrate Reinforcement Learning technique to a nominal controller in a certain structure such that reference tracking performance of the controlled system significantly improves?"

1-2 Goal of the Thesis

1-3 Literature Study Approach

1-4 Nomenclature

Chapter 2

Reinforcement Learning Preliminaries

2-1 Markov Decision Process

This chapter will cover figures and math.

2-2 Value and Policy Iteration

2-3 Reinforcement Learning for Continuous Space

2-3-1 Function Approximation

2-4 Actor-Critic Structure

Chapter 3

Reinforcement Learning for Tracking Problem: A Survey

This is real chapter for Delft Center for Systems and Control (DCSC), ok? We will use it as a demo for the different headings you can use to structure your text.

3-1 Dynamic Tuning via Reinforcement Learning

This is the first section .

3-1-1 Case Study: PI Tuning using Reinforcement Learning

This is the subsection of the first section.

3-2 Nonlinear Compensation for Tracking via Reinforcement Learning

This is second section.

3-2-1 Case Study: 1-DOF Robot Gravity Compensation

3-3 Reinforcement Learning for Optimal Tracking Control

This is third section.

3-4 Self-Proposed Controller [tentative]

Chapter 4

Simulation & Verification

4-1 Simulated Setup

This chapter will cover figures and math.

4-2 Simulation Result and Analysis

4-3 Discussion

Chapter 5

Future Work and Experiments Plan

5-1 Experimental Setup: UR5 Robot

Chapter 6

Conclusion

Appendix A

Appendix

Appendices are found in the back.

A-1 Simulation Program

A-1-1 A MATLAB listing

```
%
% Comment
%
n=10;
for i=1:n
    disp('Ok');
end
```

Glossary

List of Acronyms

DCSC Delft Center for Systems and Control