

ROBUST CONTROL OF CONTACT-RICH ROBOTS VIA NEURAL
BAYESIAN INFERENCE

by

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CONTENTS

LIST OF FIGURES	vii
LIST OF TABLES	viii
1 BACKGROUND	1
1.1 Contact Modeling with Linear Complementarity Problem	1
1.2 Passivity-Based Control (PBC)	1
1.2.1 Neural PBC	1
1.2.2 Neural Interconnection and Damping Assignment PBC	1
1.3 Bayesian Learning	1
2 SWITCHING CONTROL WITH DEEP-NET MIXTURE OF EXPERTS	2
2.1 Introduction	2
2.2 Learning Deep-Net MOE Controllers	2
2.3 Experimental Results	2
2.3.1 Stable Switching Between Unstable Systems	2
2.3.2 Cartpole with Wall Contacts	2
2.4 Conclusion	2
3 UNCERTAINTY HANDLING VIA NEURAL BAYESIAN INFERENCE	3
3.1 Introduction	3

3.2	Theoretical Justification of Robustness	3
3.3	Learning Robust Stochastic Controllers	3
3.3.1	Bayesian Neural PBC	3
3.3.2	Bayesian Neural Interconnection and Damping Assignment PBC . . .	3
3.4	Experimental Results	3
3.4.1	Simple Pendulum	3
3.4.2	Inertia Wheel Pendulum	3
3.4.3	Rimless Wheel	3
3.5	Conclusion	3
	REFERENCES	3
	APPENDICES	4

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1:

BACKGROUND

1.1 Contact Modeling with Linear Complementarity Problem

1.2 Passivity-Based Control (PBC)

1.2.1 Neural PBC

1.2.2 Neural Interconnection and Damping Assignment PBC

1.3 Bayesian Learning

CHAPTER 2:

SWITCHING CONTROL WITH DEEP-NET MIXTURE OF EXPERTS

2.1 Introduction

2.2 Learning Deep-Net MOE Controllers

2.3 Experimental Results

2.3.1 Stable Switching Between Unstable Systems

2.3.2 Cartpole with Wall Contacts

2.4 Conclusion

CHAPTER 3:

UNCERTAINTY HANDLING VIA NEURAL BAYESIAN INFERENCE

3.1 Introduction

3.2 Theoretical Justification of Robustness

3.3 Learning Robust Stochastic Controllers

3.3.1 Bayesian Neural PBC

3.3.2 Bayesian Neural Interconnection and Damping Assignment PBC

3.4 Experimental Results

3.4.1 Simple Pendulum

3.4.2 Inertia Wheel Pendulum

3.4.3 Rimless Wheel

3.5 Conclusion

BIBLIOGRAPHY

APPENDIX

Expectation of the performance index

Proof of Lemma ??. Substituting the solution (??) of the SDE (??) expression into the performance measure (??) yields

$$\begin{aligned} \mathcal{J} = & -\frac{1}{4} \frac{q + r\theta^2}{p + \theta} (1 + e^{2T(p+\theta)}) + (q + r\theta^2)\theta\sigma \int_0^T e^{(p+\theta)t} \int_0^t e^{(p+\theta)(t-s)} dW_s dt + \\ & \frac{1}{2}(q + r\theta^2)\theta^2\sigma^2 \int_0^T \left(\int_0^t e^{(p+\theta)(t-s)} dW_s \right)^2 dt \end{aligned}$$

The conditional expectation of this quantity given the system parameter p under the distribution induced by the Wiener process may be computed in closed-form using Itô calculus:

$$\begin{aligned} \mathbb{E}_W [\mathcal{J} \mid p] = & -\frac{1}{4} \frac{q + r\theta^2}{p + \theta} (1 - e^{2T(p+\theta)}) + (q + r\theta^2)\theta\sigma \int_0^T e^{(p+\theta)t} \mathbb{E}_W \left[\int_0^t e^{(p+\theta)(t-s)} dW_s \mid p \right] dt + \\ & \frac{1}{2}(q + r\theta^2)\theta^2\sigma^2 \int_0^T \mathbb{E}_W \left[\left(\int_0^t e^{(p+\theta)(t-s)} dW_s \right)^2 \mid p \right] dt \\ = & -\frac{1}{4} \frac{q + r\theta^2}{p + \theta} (1 - e^{2T(p+\theta)}) + \frac{1}{2}(q + r\theta^2)\theta^2\sigma^2 \int_0^T \left(\int_0^t e^{2(p+\theta)(t-s)} ds \right) dt \\ = & -\frac{1}{4} \frac{q + r\theta^2}{p + \theta} (1 - e^{2T(p+\theta)}) + \frac{1}{2}(q + r\theta^2)\theta^2\sigma^2 \int_0^T -\frac{1}{2(p+\theta)} (1 - e^{2T(p+\theta)}) dt \\ = & -\frac{1}{4} \frac{q + r\theta^2}{p + \theta} \left[\theta^2\sigma^2 T + (1 - e^{2T(p+\theta)}) \left(1 + \frac{1}{2} \frac{\theta^2\sigma^2}{p + \theta} \right) \right]. \end{aligned}$$

□