Bayesian Parameter Inference of Markov Population Model.

Master Thesis

Submitted by

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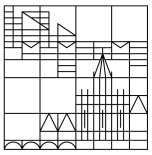

Modeling of Complex, Self-organising Systems

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Contents

Abstract

something

0.1 Introduction

- Brief introduction to Markov Chain
- Brief introduction to parameterization or Markov Chains
- Applications of parameter synthesis problem.
- Description of thesis structure.

We study the parameter synthesis problem of parametric Discrete-Time Markov Chain. Markov Chain is a probabilistic model to formalize stochastic processes.

Parameter synthesis is a relatively new research area [6]

This thesis is structured as follow.

- **Chapter 1** states the parameter synthesis problem and its applications.
- **Chapter 2** describes the most important definitions and theoretical background. In this chapter, we defines Discrete-Time Markov Chain formally. A brief introduction to Bayesian Inference is also included.
- **Chapter 3** reviews the state-of-the-art works of other researchers on the problem of parameter synthesis.
- **Chapter 4** describes the method.
- **Chapter 5** describes the benchmark.
- **Chapter 6** conclusion and future work.

Chapter 1

Preliminaries

- transition system
- markov property
- discrete-time markov chain and parametric dtmc
- continuous-time markov chain
- bayesian inference
- metropolis-hastings algorithm

1.1 Discrete-Time Markov Chain

1.2 Markov Decision Process

1.3 Probabilistic Model Checking

1.4 Bayesian Inference

1.4.1 Bayesian formula

1.4.2 Posterior conjugation

1.5 Metropolis-Hastings algorithm

1.6 Selection of prior distribution

The selection of prior distribution has strong effect on the result [what result specifically?] of a Bayesian inference [Citation needed].

Chapter 2

Literature review

- Probabilistic model checking: basic building blocks from Katoen and his fellas.
- Parameter synthesis: important papers and concepts
- Bayesian parameter synthesis: Polgreen paper
- Bayesian property checking: Jha paper
- Tools: mention PRISM and STORM

2.1 Probabilistic model checking

2.2 Parameter synthesis

2.3 Bayesian model checking

In the paper (Polgreen), the authors proposed an algorithm to decompose

In the paper (Jha) [], the authors proposed an algorithm to statistically check for (PB)LTL properties. The advantage of the algorithm is that The disadvantage of the algorithm is that it does

2.4 Tool

The definition and model checking of DTMC and pMC is studied by [1], [4], and [6].
Bayesian inference of pMC parameters is studied in [7] and [5]. In [7], the authors developed methods to synthesize parameters to satisfy a given set of PCTL properties. In [5], the authors presented methods to perform model checking of biological system using Bayesian statistic. The authors in [5] uses a Bayesian hypothesis test, where H_0 is the null hypothesis that the model satisfies a PCTL P, and alternative hypothesis H_1 is that the system does not satisfies P. Similar approach to the parameter estimation in this project is described by [3].
In this project, we use bee colony model semantics from [2]. The methods and implementation in this project is designed to extend the results of [2] and its tool *DiPS*.

Bibliography

[1] Christel Baier and Joost-Pieter Katoen. *Principles of model checking*. MIT press, 2008.

[2] Matej Hajnal et al. "Data-Informed Parameter Synthesis for Population Markov Chains". In: *International Workshop on Hybrid Systems Biology*. Springer. 2019, pp. 147–164.

[3] Faraz Hussain et al. "Automated parameter estimation for biological models using Bayesian statistical model checking". In: *BMC bioinformatics* 16.S17 (2015), S8.

[4] Lisa Hutschenreiter, Christel Baier, and Joachim Klein. "Parametric Markov chains: PCTL complexity and fraction-free Gaussian elimination". In: *arXiv preprint arXiv:1709.02093* (2017).

[5] Sumit K Jha et al. "A bayesian approach to model checking biological systems". In: *International conference on computational methods in systems biology*. Springer. 2009, pp. 218–234.

[6] Joost-Pieter Katoen. "The probabilistic model checking landscape". In: *Proceedings of the 31st Annual ACM/IEEE Symposium on Logic in Computer Science*. 2016, pp. 31–45.

[7] Elizabeth Polgreen et al. "Data-efficient Bayesian verification of parametric Markov chains". In: *International Conference on Quantitative Evaluation of Systems*. Springer. 2016, pp. 35–51.