

University of Groningen

## Advanced non-homogeneous dynamic Bayesian network models for statistical analyses of time series data

Shafiee Kamalabad, Mahdi

**IMPORTANT NOTE:** You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

*Document Version*

Publisher's PDF, also known as Version of record

*Publication date:*

2019

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Shafiee Kamalabad, M. (2019). *Advanced non-homogeneous dynamic Bayesian network models for statistical analyses of time series data*. University of Groningen.

### Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

### Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

*Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.*

**Advanced non-homogeneous dynamic  
Bayesian network models for statistical  
analyses of time series data**

**Mahdi Shafiee Kamalabad**



The research for this doctoral dissertation has been carried out at the Faculty of Science and Engineering, University of Groningen, the Netherlands, within the Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence.

© Copyright 2018 M. Shafiee Kamalabad  
PhD Thesis, University of Groningen, the Netherlands

ISBN 978-94-034-1265-8 (printed version)  
ISBN 978-94-034-1264-1 (electronic version)

This thesis was typeset using  $\LaTeX$  template by Hildeberto Jordan Kojakhmetov.



university of  
 groningen

# Advanced non-homogeneous dynamic Bayesian network models for statistical analyses of time series data

**PhD thesis**

to obtain the degree of PhD at the  
 University of Groningen  
 on the authority of the  
 Rector Magnificus prof. dr. E. Sterken,  
 and in accordance with  
 the decision by the College of Deans.

This thesis will be defended in public on

14 January 2019 at 14:30 hours

by

**Mahdi Shafiee Kamalabad**

born on 21 September 1982  
 in Tehran, Iran

**Supervisor**

Prof. E. Wit

**Co-supervisor**

Dr. M. A. Grzegorzcyk

**Assessment committee**

Prof. D. Husmeier

Prof. C.J. Albers

Prof. J. Mulder

*To my parents*

*&*

*To my Mozhgan, Alicenna and Delina*



# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Static and dynamic Bayesian networks . . . . .	1
1.2	Network inference . . . . .	2
1.3	Non-homogeneous DBNs (NH-DBNs) . . . . .	2
1.4	Another conceptual problem . . . . .	5
1.5	The aim of this thesis . . . . .	5
1.6	Outline of thesis contribution . . . . .	6
<b>2</b>	<b>Partially sequentially segmentwise coupled NH-DBNs</b>	<b>9</b>
2.1	Methods . . . . .	10
2.2	Data . . . . .	22
2.3	Empirical results . . . . .	24
2.4	Discussion and conclusions . . . . .	28
<b>3</b>	<b>Generalized sequentially coupled NH-DBNs</b>	<b>31</b>
3.1	Methods . . . . .	31
3.2	Data . . . . .	49
3.3	Empirical results . . . . .	51
3.4	Discussion and conclusions . . . . .	58
<b>4</b>	<b>Partially edge-wise coupled NH-DBNs</b>	<b>61</b>
4.1	Methods . . . . .	62
4.2	Data . . . . .	76
4.3	Hyperparameter and simulation settings . . . . .	79
4.4	Empirical results . . . . .	79
4.5	Discussion and conclusions . . . . .	85
4.6	Appendix . . . . .	86
<b>5</b>	<b>Partially NH-DBNs based on Bayesian regression models with partitioned design matrices</b>	<b>89</b>
5.1	Methods . . . . .	90
5.2	Implementation . . . . .	97
5.3	Data and empirical results . . . . .	98
5.4	Discussion and conclusions . . . . .	104



---

5.5	Appendix . . . . .	105
<b>6</b>	<b>Comparative evaluation of various frequentist and Bayesian non-homogeneous Poisson counting models</b>	<b>111</b>
6.1	Methods . . . . .	112
6.2	Validation . . . . .	123
6.3	Data . . . . .	125
6.4	Simulation Details . . . . .	128
6.5	Comparative Evaluation Study . . . . .	129
6.6	Further model diagnostics . . . . .	138
6.7	Discussion and conclusions . . . . .	144
6.8	Appendix . . . . .	146
	<b>Summary</b>	<b>153</b>
	<b>Samenvatting</b>	<b>157</b>
	<b>Acknowledgments</b>	<b>161</b>
	<b>Bibliography</b>	<b>163</b>
	<b>Curriculum Vitae</b>	<b>169</b>