

## **PhD seminar on Bayesian networks and Bayesian hierarchical analysis in engineering**

Prof. Dr. Marc Maes, Prof. Dr. Michael Havbro Faber and Dr. Kazuyoshi Nishijima

Systems in engineering are typically complex systems comprised of geographically distributed and/or functionally interrelated components. These systems are designed to provide the desired functionality through the individual components as well as the way they are connected with other components; the functionality of the systems is described in aggregated terms of one or more attributes. Examples of such complex engineered systems include individual structures, infrastructure networks, geo- and environmental systems and industrial facilities.

As a part of the strategic management of engineered systems, the probabilistic modeling of the systems is one of the main technical issues. In general, the degree of the detail of these models should be determined in accordance with the use of the models in the management. In particular, in the management of engineered systems, due to the complexity of the systems, significant amounts of uncertainties are involved in the modeling of the systems. Consequently, the reduction of such uncertainties by efficient use of information available often constitutes a major step in the management; hence, dedicated probabilistic models are required such that information can be fully utilized to reduce the uncertainties.

For this purpose, the Bayesian interpretation of probability provides a philosophical basis for how such uncertainties can/should be reduced with information; i.e. the way for updating prior probabilistic models. Bayesian networks provide a practical scheme for representing and then updating the probabilistic models; once a Bayesian network representing the engineered system in consideration is developed, the calculation of any conditional/unconditional and marginal/joint probabilities as well as the expected values of quantities of interest is straightforward.

The present PhD seminar first presents the basic idea behind the Bayesian framework. Then, several software tools for Bayesian networks and Bayesian hierarchical analysis are introduced. Bayesian hierarchical modeling is investigated intensively, as it is especially useful for the modeling of complex systems. Throughout the seminar, a number of practical engineering applications are considered to facilitate the understanding of the techniques, their advantages and their shortcomings or limitations.

### Who should attend?

This seminar is open for Ph.D. students, post-docs, graduate students and researchers as well as practitioners interested in the probabilistic modeling of engineered systems and the applications to strategic management of the systems. No practical experience on the modeling of engineered systems is required. However, the participants should have the basic skills for probability calculations.

### Mode

The seminar will be conducted as a study group under the responsibility of Prof. Maes. All participants will in turn be responsible for presenting a part of the material and for developing the examples. Self study, presentations and discussions will constitute main components of the course.

### When and where?

Wednesdays, 16:45 – 18:00, ETH Hönggerberg, HIL E 6.

The seminar starts on 30 September 2009.

### Agenda (course plan)

Week	Date	Speaker	Topic
1	30.09.09		Introduction
2	07.10.09		BN* 1: model building
3	14.10.09		BN 2: decision making
4	21.10.09		Variability within multi-component systems (+ easy application using HBM**)
5	28.10.09		Spatial GLM*** networks and hierarchies (+ easy application in human error analysis)
6	04.11.09		Spatial discrete hazards using HBM (+ easy application in accident)
7	11.11.09		No course
8	18.11.09		Spatial variability: classical vs Bayesian kriging (+ easy application in simple geostatistics using HBM)
9	25.11.09		Hazard modeling using BN and HBM (+ easy application on earthquakes)
10	02.12.09		HBM for noisy/dirty data in integrity and lifetime extension assessment (+ easy application in pipeline deterioration)
11	09.12.09		HBM for environmental problems (+ easy application)
12	16.12.09		HBM for extremes (group exercise presentation)

(BN\*: Bayesian network, HBM\*\*: Hierarchical Bayesian model, GLM\*\*\*: Generalized linear model.)

Abstract	<p>During the course each student participates actively in the seminar through literature survey, presentations and discussions on the Bayesian networks. First, we will take a look at the basic mathematics underlying the Bayesian networks. The introduction of some software tools follow. Then, we will discuss on the Bayesian hierarchical modeling and its application to the modeling of engineered systems. Throughout the seminar, a number of practical engineering applications are considered.</p>
Objective	<p>The aim of the present course is to train the PhD and Msc students in their abilities to study existing literature together with the purpose of establishing the basic understanding of the Bayesian networks/Bayesian hierarchical modeling and the applications to engineered systems. Researchers, and post-docs interested in the modeling of complex engineered systems are welcome.</p>
Content	<p>Systems in engineering are typically complex systems comprised of geographically distributed and/or functionally interrelated components. These systems are designed to provide the desired functionality through the individual components as well as the way they are connected with other components; the functionality of the systems is described in aggregated terms of one or more attributes. Examples of such complex engineered systems include individual structures, infrastructure networks, geo- and environmental systems and industrial facilities.</p> <p>As a part of the strategic management of engineered systems, the probabilistic modeling of the systems is one of the main technical issues. In general, the degree of the detail of these models should be determined in accordance with the use of the models in the management. In particular, in the management of engineered systems, due to the complexity of the systems, significant amounts of uncertainties are involved in the modeling of the systems. Consequently, the reduction of such uncertainties by efficient use of information available often constitutes a major step in the management; hence, dedicated probabilistic models are required such that information can be fully utilized to reduce the uncertainties.</p> <p>For this purpose, the Bayesian interpretation of probability provides a philosophical basis for how such uncertainties can/should be reduced with information; i.e. the way for updating prior probabilistic models. Bayesian networks provide a practical scheme for representing and then updating the probabilistic models; once a Bayesian network representing the engineered system in consideration is developed, the calculation of any conditional/unconditional and marginal/joint probabilities as well as the expected values of quantities of interest is straightforward.</p> <p>The present PhD seminar first presents the basic idea behind the Bayesian framework. Then, several software tools for Bayesian</p>

	networks and Bayesian hierarchical analysis are introduced. Bayesian hierarchical modeling is investigated intensively, as it is especially useful for the modeling of complex systems. Throughout the seminar, a number of practical engineering applications are considered to facilitate the understanding of the techniques, their advantages and their shortcomings or limitations.
Literature	-
Notice	The seminar will be conducted in English.

ECTS credits	2 credits
Examiners	M. H. Faber
Type	Ungraded semester performance
Language of examination	English
Course attendance confirmation required	No
Repetition	Repetition only possible after re-enrolling for the course unit. If the course unit is part of an examination block, the credits are allocated for the successful completion of the whole block.