# Summer School on Risk

**Sunday 16th– Saturday 22nd August, 2015**

**Vienna University of Technology, Austria**

## Lecturers and programme

**Session 1**:
*Prof. Dr. Christian Bucher*
Institute of Building Construction and Technology, TU Vienna, Austria

**Opening and introduction: Elements of probability theory and statistics**
The lecture will first provide an overview of the fundamentals of probability theory such as conditional probabilities, types of distributions and models for random vectors. The second part will focus on elementary statistics and deals with estimation of means and variances, the uncertainty of estimates and confidence intervals.

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**Session 2**:
*Prof. Dr. Christian Bucher*
Institute of Building Construction and Technology, TU Vienna, Austria

**Introduction to the hands-on project**

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**Session 3**:
*Prof.dr.ir. S.N. (Bas) Jonkman*
Faculty of Civil Engineering and Geosciences, Delft University of Technology, Netherlands

**Recent developments in flood risk analysis**
This contribution will focus on methods for flood risk analysis. The general approach for risk analysis and the various steps (flood hazard analysis, levee reliability, flood modelling, damage and life loss analysis) will be highlighted. The various ways to express economic flood risks and risk to life will be introduced. Based on an example, participants will gain practical experience with flood risk analysis. Also, recent insights and advances from nationwide flood risk assessments in the Netherlands will be presented. The second part of the contribution will focus more in detail on methods for damage and life loss analysis. Based on information from actual floods (e.g. 1953 storm surge in the Netherlands, hurricane Katrina New Orleans) empirical relationships have been derived to assess economic damage, building vulnerability and life loss and evacuation that can also be applied to other regions. The final part of the presentation will highlight the relevance of flood risk analysis

based on lessons learned from field investigations and research on some major global flood events. Disasters that have been investigated include the flooding of New Orleans due to hurricane Katrina (2005), river floods in Thailand (2011) and Germany (2013). The lessons learned will focus on aspects such as the performance of the flood protection system, impacts of floods and risk reduction strategies.

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**Session 4**:

*Dr. Arash Lavasan and Mr. Kavan Khaledi*
Ruhr-Universität Bochum, Germany

**Part 1: Optimal experimental design for parameter identification** (Dr. Arash Lavasan)
In geotechnical engineering, the type of material or load are nature-given and their characteristics and physical-mechanical properties are initially unknown. Therefore, a proper in-situ or laboratory testing program is needed to investigate the hydro mechanical properties of soil prior to large construction projects. In the present research, the parameters of consolidation behavior in a soft clay from the Okoyama area in south Japan, were identified by a loading apparatus. The sensor set-up of this experiment was designed for measuring the pore water pressure and the vertical displacements without considering its possible influence on the precision of the measurements. However, due to the obtained experimental results, some uncertainties in the testing set up are observed. Accordingly, the objective of this work set to analyze the results gained from this initial set-up and to apply the philosophy of optimal experimental design. Optimal experimental design can show where the sensors should be positioned to get the best possible information for the following parameter identification. Global sensitivity analysis (GSA) is used to perform this localization. As this technique allows to identify which parameter has the most significant influence on a certain output, GSA technique is employed to investigate the positions in which this influence is maximized.

**Part 2: An introduction to meta-modeling and its application in engineering systems (**Mr. Kavan Khaledi)
During the past decades, along with the significant progresses in computer science, numerical simulation has been established as a powerful tool used practically in all fields of engineering and science. However, in a number of situations, engineering problems require computationally expensive simulations. Therefore, routine tasks such as design optimization, probabilistic studies of uncertainties, parameter identification, inverse problem or sensitivity analysis become impossible since they require thousands or even millions of simulations. A common practice for engineers to solve this problem is to develop simplified models to approximate the original model with high level of accuracy. The approximated model which can mimic the behavior of the original model is called meta-model or surrogate model. In this lecture, some existing meta-modeling techniques are introduced and their application in geotechnical engineering will be illustrated. Finally it is shown how solving computationally expensive problems such as parameter identification becomes more convenient if the original model is replaced by a reliable and robust meta-model.

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**Session 5:**

*Dr. Steffen Freitag*
Ruhr-Universität Bochum, Germany

**Simulation with polymorphic uncertain data in structural mechanics**

For numerical simulations of mechanized tunneling processes, only limited information of the input parameters, e.g. describing the local geology and the corresponding soil behavior, are available in the design stage of tunnel projects. Often, soil parameters obtained from borehole data are quantified as intervals by experts, whereas other parameters may be modeled as stochastic numbers. In this case, polymorphic uncertainty models are motivated taking epistemic and aleatoric sources of uncertainty into account for numerical simulations. In the lecture, approaches for computing with polymorphic uncertain data are presented combining stochastic and interval analyses. The approaches are applied to structural reliability analyses in structural mechanics.

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**Session 6:**

*Dr. Tom Lahmer*
Bauhaus-Universität Weimar, Germany

**Design of experiments (DoE) - Optimality criteria in frequency domain and DoE for model discrimination**

In order to make reliable prognosis of engineering systems, it is important to carefully synthesize the applied models and to update them w.r.t their model parameters according to given measurements. Techniques of model calibration may support the process of model updating. However, the generation of required data can still be considered as a costly process, so it should be organized effectively. Means of statistical designs of experiments have been transferred to the optimal design of experiments of technical structures or systems. There are various approaches to do so. Generally, a DoE can improve sensor locations, system excitations, choice of sensors and the minimal number of sensors required. In the first part of the talk we will concentrate on the latter and give an estimate of the number of measurements required for sinosoidally excited systems, i.e. how many different excitation frequencies need to be considered to get reliable parameter estimates. The derived theory is then applied to examples from poroelasticity and piezoelectricity. The second part of the talk treats the question, how to organize an experimental setup in order to distinguish between different model options in an effective manner. One example of a air pollutant proliferation is discussed where the presented criteria help to successfully discriminate between two models of different complexity.

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**Session 7:**

*Dr. Dmitrii Legatuik*
Bauhaus-Universität Weimar, Germany

**Coupling of models: theory and applications**

During modelling of different physical phenomena one has to deal with various models and methods which have to be coupled together in order to get a realistic model or a higher accuracy of results. The idea of this talk is to discuss some issues related to the coupling of different models and methods. We will start with an example of the coupling of different methods: complex function theory and the finite element method. This example will clearly indicate importance of additional studies of the coupling process, particularly for purposes of its assessment. After discussing such details we will propose a general theory, which can be used to describe a coupling of very different models, as a tool for an abstract description of a modelling process.

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**Session 8:**

*Prof. Dan M. Frangopol*
Department of Civil and Environmental Engineering, ATLSS Center, Lehigh University, Bethlehem, PA, USA

**Integration of reliability, optimization and SHM in life-cycle management of structures**

This lecture presents a brief overview of the role of probabilistic performance assessment, optimization and structural health monitoring (SHM) in the life-cycle assessment and management of deteriorating structures with emphasis on uncertainty. Life-cycle management is performed through an integrated probabilistic framework which provides the required information to achieve optimal decisions regarding future interventions for the structure under investigation. This framework includes modules for predicting the deteriorating structural performance in terms of the level of structural damage, or by using probabilistic performance indicators such as the reliability and redundancy indices. The proper description and estimation of the structural performance supports the next steps of the framework in which the inspection, monitoring, and/or maintenance actions are optimally scheduled. Different objectives of this scheduling process are discussed, in addition to the key achievements in developing the life-cycle framework and their associated results. Applications to highway bridges, highway networks, and naval ships are provided.

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**Session 9:**

*Prof. Antonina Pirrotta*
Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali (DICAM), Università degli Studi di Palermo, Palermo, Italy

**Stochastic and Fractional Calculus for overcoming closure scheme in the evaluation of nonlinear systems statistics**

Excitations such as ground motion, wind turbulence, sea waves, surface roughness, blasts and impacts loads being stochastic processes induce that structural responses are stochastic processes too. Thus, the analyst is concerned with the problem of the response statistical characterization. However, to consider a model closer to reality a nonlinear system has to be considered, then a complete statistical characterization of the response may be performed by solving the Fokker–Planck–Kolmogorov (FPK) equation, a partial differential equation whose solution is the joint probability density function (PDF) of the response variables. Unfortunately, the FPK equation admits analytical solution in very few cases, for this reason we resort to numerical methods. Among the numerical approaches, more attractive, from a computational point of view, is the moment equation (ME) approach, in which the response statistical characterization is given by the response moments. However, it is apparent that dealing with nonlinear systems that is considering the MEs form an infinite hierarchy in the sense that the equations for the moments of a fixed order, say j, contain moments of order higher than j. In order to overcome this difficulty, the so called closure methods were born. Thus, neglecting the terms beyond a given order ME is solvable. The moments of order higher than j are expressed in terms of moments of order equal or lower to j, but, this implies an approximation of the (j+1)th- and (j+2)th- order moments. While expressing the PDF in terms of fractional moments no closure scheme is required leading to accurate results. Numerical applications, introduced in class will assess the convenience of the use of fractional calculus into stochastic dynamics.

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**Session 10:**

*Dr. Mag. Stefan Hochrainer-Stigler*
IIASA – International Institute for Applied Systems Analysis, Laxenburg, Austria

**Estimation and Management of Extreme Risks: The CatSim Approach**

The lecture will focus on the Catastrophe Simulation model, CatSim, which was designed to illustrate the tradeoffs and choices a central or state government must make in managing the economic risks due to being exposed to natural hazards. While more developed countries usually are able to cope with the impacts and consequences of natural disasters, in less developed economies often a large proportion of the population is severely affected and a substantial strain is posed on a country's resources and ability to finance important social and economic programs. Currently, more and more emphasis is put on financial planning before events and in addition to mitigating potential losses and preparing for potential events, the financial planning and management of risk has become an important element of disaster risk management. CatSim can be helpful for developing disaster risk financing strategies by indicating the respective costs and consequences of alternatives on important indicators, such as economic growth. The model is equipped with a graphical interface that allows the user to change default parameters defining hazards, vulnerability, exposure and finally risk. There are two modules: the first one allows to assess risk, the second to study the costs and benefits of different risk management strategies. Since the user can interactively change important parameters and assumptions, the consequences can be studied in a transparent fashion. CatSim has been used on different occasions by countries severely exposed to natural hazards. We illustrate this model with an application to Madagascar, an island state with one of the highest cyclone risk worldwide. Furthermore, the lecture will be supported by presentations of latest state-of-the-art approaches for estimating extreme risks via copula approaches.

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## Venue

Vienna University of Technology
Karlsplatz 13, Vienna

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## Registration

Advanced registration is essential as places are limited.
For further information and registration please contact:
Gemma Carr, Centre for Water Resource Systems, Vienna University of Technology
Phone: +43 1 58801 406655; Email: carr@waterresources.at

| | Sun 16. Aug | Mon 17. Aug | Tue 18. Aug | Wed 19. Aug | Thur 20. Aug | Fri 21. Aug | Sat 22. Aug |
|---|---|---|---|---|---|---|---|
| **9:00 – 10:30** | | **Session 1**: Opening Elements of probability theory and statistics (Prof. Bucher) | **Session 4**: Parts 1 and 2 (Dr. Lavasan and Mr. Khaledi) | **Session 8**: Integration of reliability, optimization and SHM in life-cycle management of structures (Prof. Frangopol) | **Session 10**: Estimation and management of extreme risks: the CatSim approach (Dr. Hochrainer-Stigler) | **Group work** | Depart |
| **11:00 – 12:30** | | **Session 2**: Introduction to the project (Prof. Bucher) | **Session 5**: Simulation with polymorphic uncertain data in structural mechanics (Dr. Freitag) | | | | |
| **12:30 – 14:00** | | **Lunch** | **Lunch** | **Lunch** | **Lunch** | **Lunch** | |
| **14:00 – 15:30** | | **Session 3**: Recent developments in flood risk analysis (Prof. Jonkman) | **Session 6:** Design of experiments (DoE) - Optimality criteria in frequency domain and DoE for model discrimination (Dr. Lahmer) | **Session 9**: Stochastic and Fractional Calculus for overcoming closure scheme in the evaluation of nonlinear systems statistics (Prof. Pirrotta) | **Group work** | **Excursion** | |
| **16:00 – 17:30** | | | **Session 7:** Coupling of models: theory and applications (Dr. Legatiuk) | | | | |
| **Evening** | **Arrive** | | **Vienna city tour** | | | **18:00 “Heuriger” evening** | |