Master's thesis proposal

Technische Universität München

E R A

Ingenieursfakultät Bau Geo Umwelt
Engineering Risk Analysis Group
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# Network reliability assessment with advanced sampling methods

## Background

Infrastructure networks, such as power grids and water supply systems, deliver essential services to society. Failures of such networks can have severe consequences. Quantification of the probability of survival or, conversely, the probability of failure of such systems is essential in understanding and managing their reliability; this is the main purpose of network system reliability assessment.

Historically, there are two main concerns about the network performance, the connectivity and the functionality [1]. Although connectivity can be regarded as a basic functionality of networks, the connectivity reliability and the functionality reliability of networks are two different concepts no matter in terms of the assessment object or the analysis method. In connectivity-based problems, one evaluates the probability that a given set of nodes are connected mainly based on the principles of the graph theory and the probability theory. However, in functionality-based problems, one focuses on whether the demand of the customer can be satisfied and expert knowledge of the specific field is often required to model complex network dynamics. As a result, the research on connectivity reliability is more 'mathematical', while the investigation of functionality reliability typically relates to a specific engineering context.

A set of non-sampling and sampling based methods has been proposed for the above two kinds of problems [2]. For most non-sampling based approaches, the computational cost grows exponentially with the dimension of the network making these methods inefficient even infeasible in reliability assessment of a real-world infrastructure network. Therefore, we will focus on the sampling based methods in this thesis. In particular, we are going to combine the stratified sampling and the cross entropy method to achieve accurate and efficient analysis of the infrastructure networks. The method will then be tested on three provided engineering models (with matlab code):

(1) Connectivity-based model of the water supply system in Mianzhu, China.
(2) Graph efficiency model of IEEE 39/118 power grid.
(3) Direct current flow model of IEEE 39/118 power grid.

We expect that the student has successfully completed the course *Estimation of rare events and failure probabilities* (or a similar course) and is familiar with advanced sampling techniques. Good mathematical and programming skills will certainly prove helpful in this project.

## Objectives

The student conducting the proposed MSc thesis will learn:

- Basic concepts of water supply systems and power transmission networks.

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- The state of art sampling based methods for network reliability assessment.

**Methodology**

The suggested work flow is as follows:

- The student will first do the literature review of the sampling based methods especially the stratified sampling and cross entropy method.
- The student will try to find a proper way of choosing the sample size of each stratum.
- (Possible extension): The student will try to find a reasonable way to divide the strata.
- The student will perform the cross entropy method to get the conditional failure probability in each stratum.
- In the final stage, the student will implement the proposed method in three provided engineering models.

**Supervised by**:

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**Starting date**: As soon as possible

**References**

[1] J. Li and W. Liu, *Lifeline Engineering Systems: Network Reliability Analysis and Aseismic Design*. Springer, 2020.

[2] G. Rubino and B. Tuffin, *Rare event simulation using Monte Carlo methods*. John Wiley & Sons, 2009.