Engineering Risk Analysis Group
Prof. Dr Daniel Straub

MSc thesis or Study project proposal

Rare Event Probability Estimation: A New Energy Based Approach

Motivation and Objectives

Estimating the probability of rare events is a core challenge not only in engineering, but also in a wide range of other fields such as environmental science and finance. Although rare events occur infrequently, they are of critical importance because of the potentially severe consequences of their outcomes. Recently, the Energy-Based Model (EBM) approach has been introduced as an efficient method for estimating rare event probabilities, especially in inverse problem settings. In the EBM approach, the distribution of the quantity of interest is expressed by an energy density governed by a free energy function. Using principles from energy-based modelling, this free energy is estimated by optimizing a bias potential. Importantly, the EBM method cannot only be applied for inverse problems, but also in more conventional rare event scenarios, where the underlying variable has a known distribution. However, numerous estimation methods already exist for this setting. Thus, the question arises: How does the EBM approach compare to current state-of-the-art techniques for estimating the probability of rare events?

Methodology

- Understanding the EBM method
- Literature review on rare event probability estimation
- Implementation of the EBM method in Matlab or Python
- Comparison of the EBM method with other rare event estimation methods already available in the ERA Group software.

Requirements

- Good mathematical and programming skills (Matlab or Python)
- Lecture ‘Estimating Rare Events and Failure Probabilities’.

Starting date: Flexible, as soon as possible

Supervised by

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References

Friedli, L., Ginsbourger, D., Doucet, A., & Linde, N. (2025). An energy-based model approach to rare event probability estimation. SIAM/ASA Journal on Uncertainty Quantification, 13(2), 400–424, https://doi.org/10.1137/23M1605065 .


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