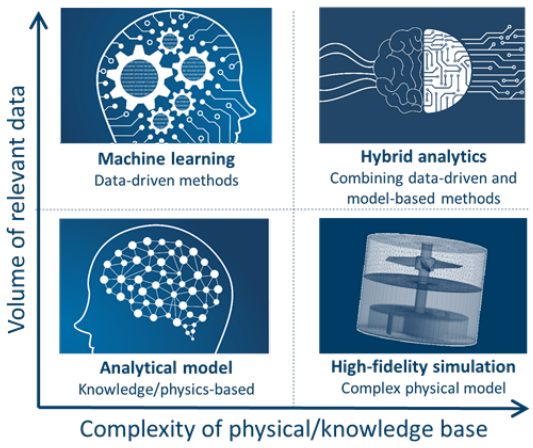
Uncertainty estimation in Neural Networks

Background



Artificial Intelligence (AI) has experienced a renewed interest in the last decade, which in particular can be credited the favourable results of deep learning in computer vision applications. The success of deep learning models stems from a combination of efficient learning algorithms and their huge parametric space [Arrieta et al., 2019]. However, the implementation of deep learning models in critical applications (e.g. autonomous vehicle transportation, data-based medical diagnosis, etc) is still limited due the harmful consequences of erroneous model outputs. The notion of eXplainable AI (XAI) is used as a collective term for learning techniques where the goal is to improve trustworthiness, transferability, confidence and uncertainty. This project focuses on the latter, as providing a measure of prediction uncertainty is a necessity to fully integrate deep learning algorithms in safety critical applications [Loquercio et al, 2020].

This topic is proposed in connection with the project "Towards autonomy in process industries: Combining data-driven and model-based methods for estimation and control (TAPI)". The goal of TAPI is to move Norwegian land-based process industries towards more autonomous processes by exploring the potential merge of artificial intelligence (AI) and more traditional model-based control methods in order to understand, control and optimise the production processes. Project partners are NTNU, SINTEF, Hydro, Elkem, Yara and Borregaard.

Assignment

The goal of this assignment is to test available methods for uncertainty estimation in deep learning:

- Survey the literature for proposed methods to estimate model uncertainty (e.g. Monte Carlo Dropout [Loquercio2020] or Approximated Variance Propagation [Postels2020]) and data uncertainty (e.g. Assumed Density Filtering [Loquercio2020]) in deep neural networks
- Implement at least one method for estimating model uncertainty and one method for estimating data uncertainty
- Evaluate the methods performance on simulated NNs for regression. We suggest to use neural networks representing (nonlinear) autoregressive with exogenous input ((N)ARX) models or nonlinear state-space models

[Arrieta2019] Arrieta et al, Explainable Artificial Intelligence (XAI): Concepts, Taxonomies, Opportunities and Challenges toward Responsible AI, arXiv:1910.10045, 2019

[Loquercio2020] Loquercio, A., Segu, M., and Scaramuzza, D., A general framework for uncertainty estimation in Deep Learning, arXiv:1907.06890 , 2020

[Postels2020] Postel, J., Ferroni, F., Coskun, H., Navab, N., Tombari, F., Sampling-free epistemic uncertainty using approximated variance propagation, https://arxiv.org/abs/1908.00598 , 2019

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