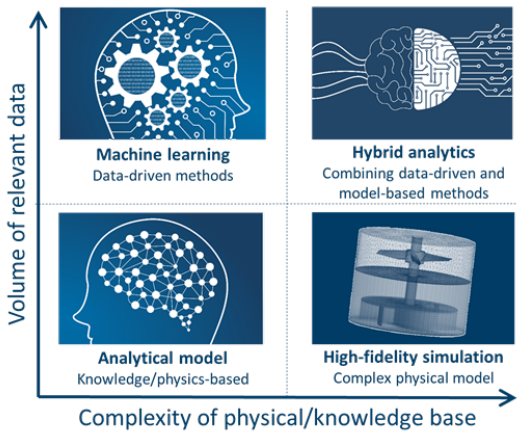
**Closed-loop Subspace Identification in Machine Learning**

## Background




Machine learning can be a useful tool to identify and improve models for many industrial control applications. However, because many industrial systems are tightly regulated to follow reference trajectories and setpoint values, the information in the process measurements is often insufficiently rich to train deep neural networks. Recently, there has been a renewed focus on identifying linear dynamical models to capture the closed-loop system dynamics in a small region around the setpoint values using subspace methods [van der Veen et al., 2013]. Several new methods have been proposed (see e.g. [Lee and Lamperski, 2020] and [Tsiamis and Pappas, 2019]) for which error bounds have been derived based on the amount of available data. This project is to get a deeper understanding of the differences between the various subspace methods for closed-loop identification in terms of data requirements, implementation and error bounds, and to investigate possible directions for improvements.

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 get an overview of the recent advances in subspace methods for closed-loop identification and to evaluate the performance of these methods:

- Survey the literature for classical and newly developed subspace methods for closed-loop identification;
- Implement at least three subspace methods for closed-loop identification on one or two chosen test-cases;
- Evaluate and compare the methods' performance in terms of data requirements, made assumptions and magnitude of identification errors.

[van der Veen et al., 2013] van der Veen, G., van Wingerden, J.-W., Bergamasco, M., Lovera, M. and Verhaegen, M., Closed-loop subspace identification methods: an overview, IET Control Theory and Applications, 2013.

[Lee and Lamperski, 2020] Lee, B. and Lamperski, A., Non-Asymptotic Closed-Loop System Identification using Autoregressive Processes and Hankel Model Reduction, CDC, 2020.

[Tsiamis and Pappas, 2019] Tsiamis, A. and Pappas, G. J., Finite Sample Analysis of Stochastic System Identification, CDC, 2019.

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