To meet with urgent demands of advanced batch process control technologies and performance assessment methods required for implementation of Industry 4.0 concept, this project aim is to develop advanced control methods and algorithms for industrial batch processes that can accommodate for sensor and actuator limitations, account for complex, uncertain, and unpredictably process dynamics, and robustly operate in the presence of disturbances and delays. The promise of learning-based control methods is the ability to account for all of these effects with less or even without plant or system model knowledge and therefore, are a key element to cope with increasing demands on the production accuracy and productivity. Specifically, the main contribution of this project will be the development of learning-based methods that can achieve control performance beyond the reach of classical feedback control. As commonly known, a successful application of classical feedback control, even when feedforward action is used to increase the resulting control performance, depends foremost on proper representation of the plant or process dynamics. In contrast, learning-based control attempts to learn about the plant dynamics during system operation, so as to overcome the influence from repeatable process uncertainties and disturbances. Moreover, plants or systems that are inherently difficult to model and/or control with classical methods can potentially be effectively controlled with learning-based methods. Therefore, the project tries to apply learning methodologies to produce control laws of a high performance for industrial batch processes. To satisfy project objectives it is required to develop the following tasks:

1. **Design of iterative learning schemes with two-dimensional/repetitive setting**.
   As known, it is possible to formulate the iterative learning control problem as two-dimensional control problem. Within this formulation, the finite time domain behavior and discrete batch number domain behavior are easily captured. Furthermore, control design can incorporate both time and batch number domain objectives. Therefore, it is important to investigate and develop this control problem setting. Additionally, deep insight into limitations that result in safe operation requirements (good transients and stability) is performed to predict the achievable performance of a learning control algorithm.

2. **Development of data-driven methods for control of industrial batch processes**.
   A powerful aspect of data-driven (or data-based) approaches for controller synthesis is that there is no need for a plant model or assumptions regarding the dynamical structure of the process other than standard ones (e.g. linear time invariance or causality). Therefore, data-driven methods can strongly contribute to iterative learning control strategies for industrial batch processes. Motivated by these facts we will investigate the underlaying phenomena and principles that are associated with the design of learning based control systems from data samples and cope with them by proposing the conditions for stability and monotonic convergence. This also means that we investigate the gap between a finite number of samples and process properties such as closed-loop stability and monotonic convergence of the proposed control scheme.

3. **Synthesis of learning-based control schemes for batch processes with input delays**.
   It is well known that, together with the increasing expectations of process dynamic performances, the input delays information in industrial batch processes should not be neglected. Specifically, due to mass transportation or/and energy exchange input delay phenomenon pervasively exists in batch processes and leads to a very challenging control problem. Especially when input delay is variant along batch direction, the convergence of tracking error in iteration domain may not be guaranteed due to the mismatch of control update. Additionally, to obtain an acceptable closed-loop performance within one batch, predictor-feedback should be adopted to compensate input delay along time direction, which will bring difficulties in robust stability analysis and iterative learning control law design when two-dimensional setting is applied.

4. **On-line quality prediction methods for multi-phase and/or multi-grade batch processes**
   It is of great significance to design a control system to ensure the process input(s) is within the allowed operation range and the output(s) reaching or close to the desired set-point value(s). Since the allowed process input range and desired output value(s) are known in advance, proper cost functions could be established with respect to the errors between the real-time measured system operation data and the expected operation values, which could be used to improve the operation performance of batch processes by developing the optimization analysis. For quality prediction, the quality criteria are generally different for various processes. Additionally, since some of industrial batch processes are of multi-phase and multi-grade characteristics, it is planned to develop comprehensive performance assessment and quality prediction methods with multiple criteria, based on phase partition and classification of different production grades.