01_Process of Controller Design and Synthesis

1. Obtain Process Model

Linear Controller + Nonlinear Process

Hammerstein-Wiener Models

$$\begin{cases} \dot{x} = A(\theta)x + B(\theta)f(u,\theta) & \text{(actuator nonlinearity)} \\ y = h(x,\theta) & \text{(sensor nonlinearity)} \end{cases}$$

Linear Controller Design for Hammerstein-Wiener Models

- Design a linear controller for the linear part
- apply h^{-1} to y and f^{-1} to u to compensate nonlinearities

Linear Controller Design for General Nonlinear Process

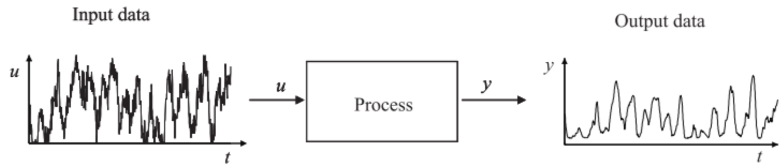
- linearize around suitable (equilibrium) points
- design a linear controller for the linearized process

This works only near the linearization point

From Physically via First-Principles Modeling

Just from the first-principles modelling

From Data via System Identification



Data $u(1), u(2), \ldots, u(N) \qquad y(1), y(2), \ldots, y(N)$

Model $y_\theta(k) = -\sum_{i=1}^{n} a_i y(k-i) + \sum_{i=0}^{m} b_i u(k-i)$

Parameter $\theta(k) \triangleq [a_1\ a_2\ \ldots\ a_n\ b_0\ b_1\ \ldots\ b_m]^\top$

Identification $\min_\theta \sum_{k=2}^{N} \|y_\theta(k) - y(k)\|^2$

2. Controller Design

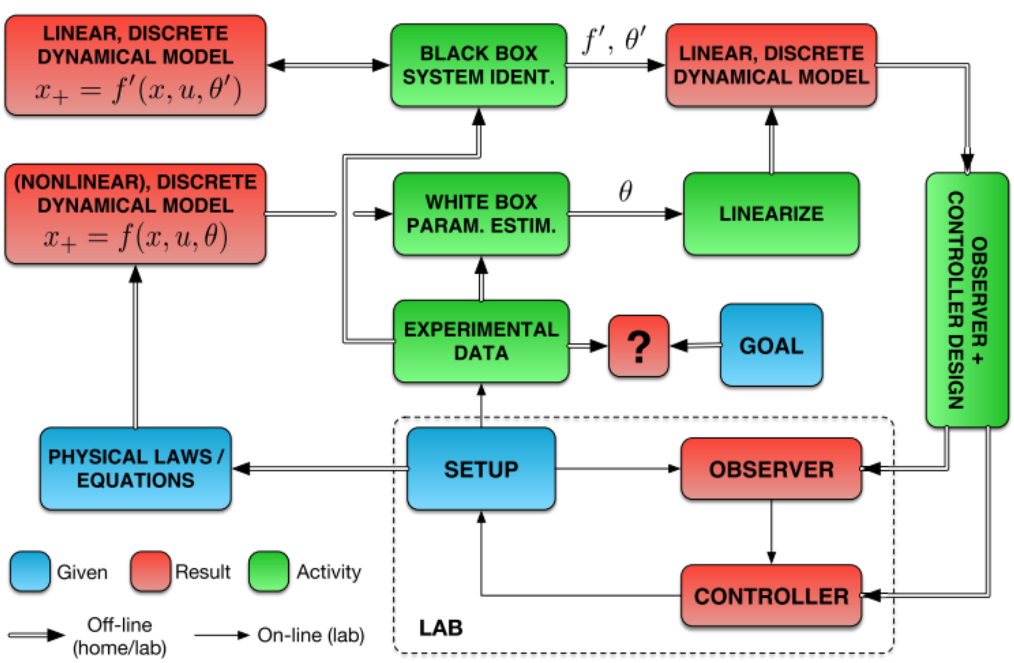
Ideal Procedure

1. Develop a **mathematical model** of the process.
2. **Implement the model** for simulation purposes, **estimate parameters**.
3. **Analyze dynamic properties** of the system.
4. Determine the **specifications (objective)** for the controller.
5. **Design a controller** to comply with specs.
6. **Test** controller in **simulations**, **redesign** (if necessary).
7. Implement on the process, test, evaluate.

Industrial Process

1. You are given a system description and a control specification
   - This usually includes a *Motors and Sensors List*
2. Design offline a controller as in-class (items 1-3 and 5-6).
3. Go to the plant
   - Check for differences between the *as built* system and the description you received
   - Do a *preflight test* of all the sensors and actuators (in this order) you plan to use
   - If differences in system, sensors or actuators are too big (outside robustness guarantee of controller), re-iterate on controller design
4. Deploy your controller in *bypassing* mode
   - This means your controller runs in parallel with a proven controller, and synced to it
   - Plant outputs are fed to both, but the new controller output is fed only partially, or not at all, to the plant
   - Redesign controller if needed
5. Deploy your controller in *production* mode

Laboratory Workflow



Summary

- Linear Controller + Nonlinear Process
- Obtain Process Model
  - From Physically
  - From Data
- Controller Design Process
  - Ideal Process
  - Industrial Process