Integrated Classroom Teaching of Control using SIMULINK and MATLAB

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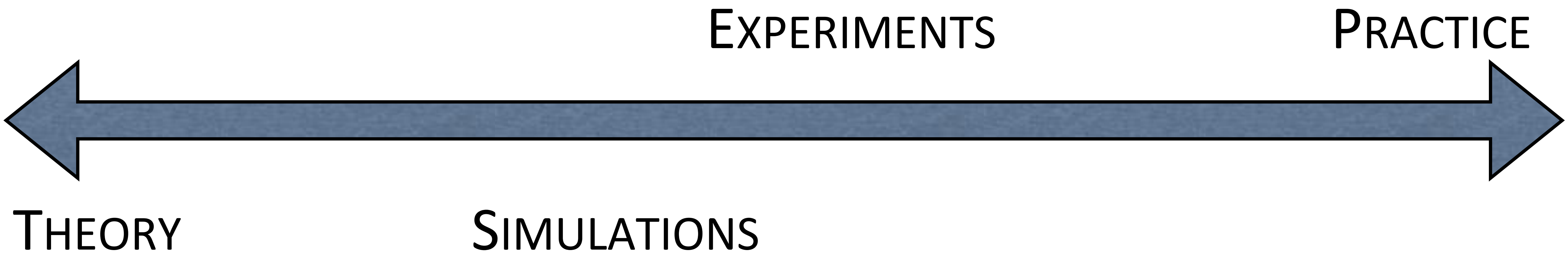
"Soft" Teaching / Learning

Preliminary and conceptual presentation of the problem and its solution with the aid of computational / simulation tools

- Introduce / motivate the problem and the concepts underlying the solution in a "soft" form with minimal or no mathematical abstraction
- Essentially take the students to a virtual lab and conduct "experiments" to demonstrate the core issue and concepts
- Highly useful for math-, stats- and science-intense subjects.

Role of Simulations



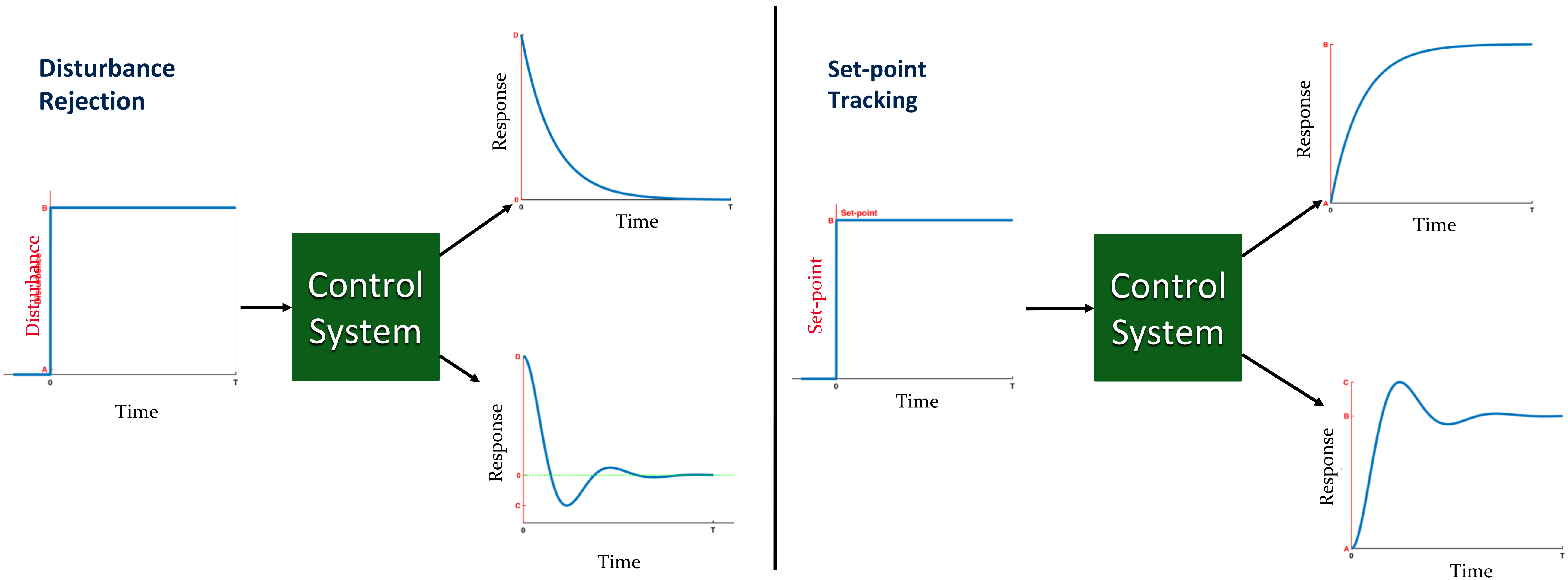
What can simulations offer?

- Powerful reinforcements and supplements for theory
- Building highly effective motivational and practical case studies
- Excellent tools for zones where theory fears to tread
- Safe and effective substitute for experiments
- Opportunities for innovation and testing

TEACHING CONTROL CONCEPTS USING SIMULINK & MATLAB

What is control?

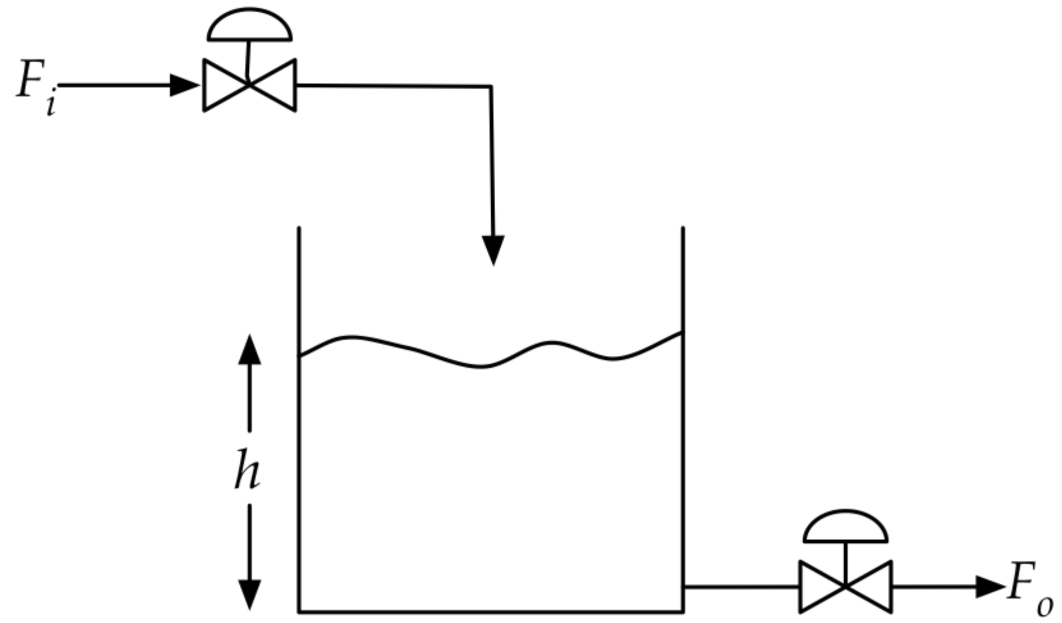
Control is the act of **maintaining** a process variable at a ***desired value*** whenever it deviates (**regulation)** from it or the act of driving a process variable along a specified trajectory (**tracking**).



- Goal is not to merely drive the variable to its final value but also to shape its trajectory
- Control is achieved by adjusting / manipulating a causal variable (known as input)

QUICK INSIGHTS THROUGH VIRTUAL EXPERIMENTS

Process in focus: Liquid level system



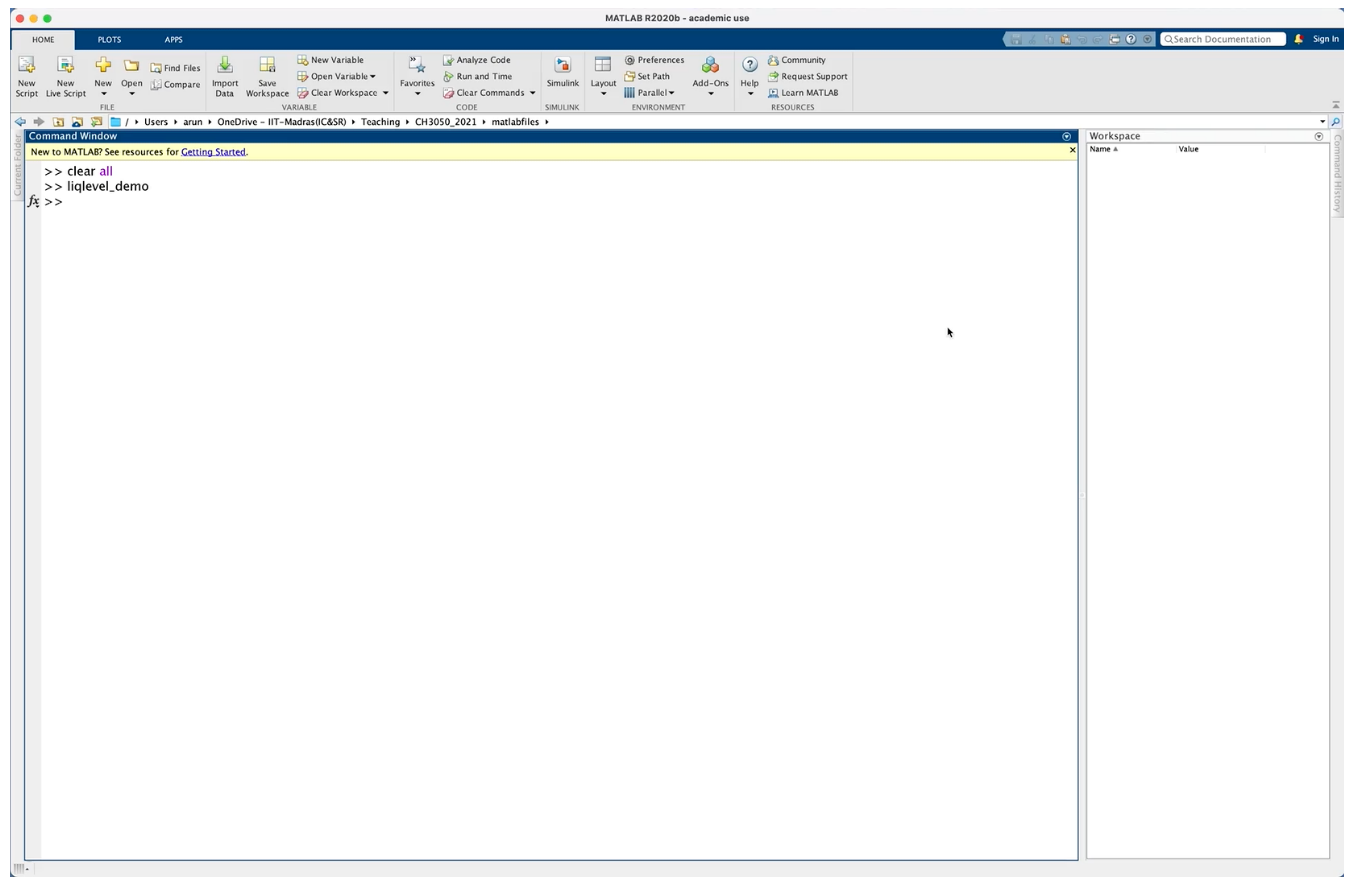
Goal: Control liquid level $h(t)$ (CV) by adjusting inlet flow $F_i(t)$ (MV)

- Why are we interested in control of level?
- In principle, we have two choices for MV. Why do we choose $F_i(t)$?
- Strictly speaking, we manipulate the valve position and not the flow rate
- What is the first step towards control?

VIRTEX 1: KNOW OUR PROCESS

Objective: To understand our process, especially to learn how the process variable (CV or PV) responds to changes in inputs (MV)

- Introduce simple changes in the MV (e.g., a step, sinusoid, pulse)

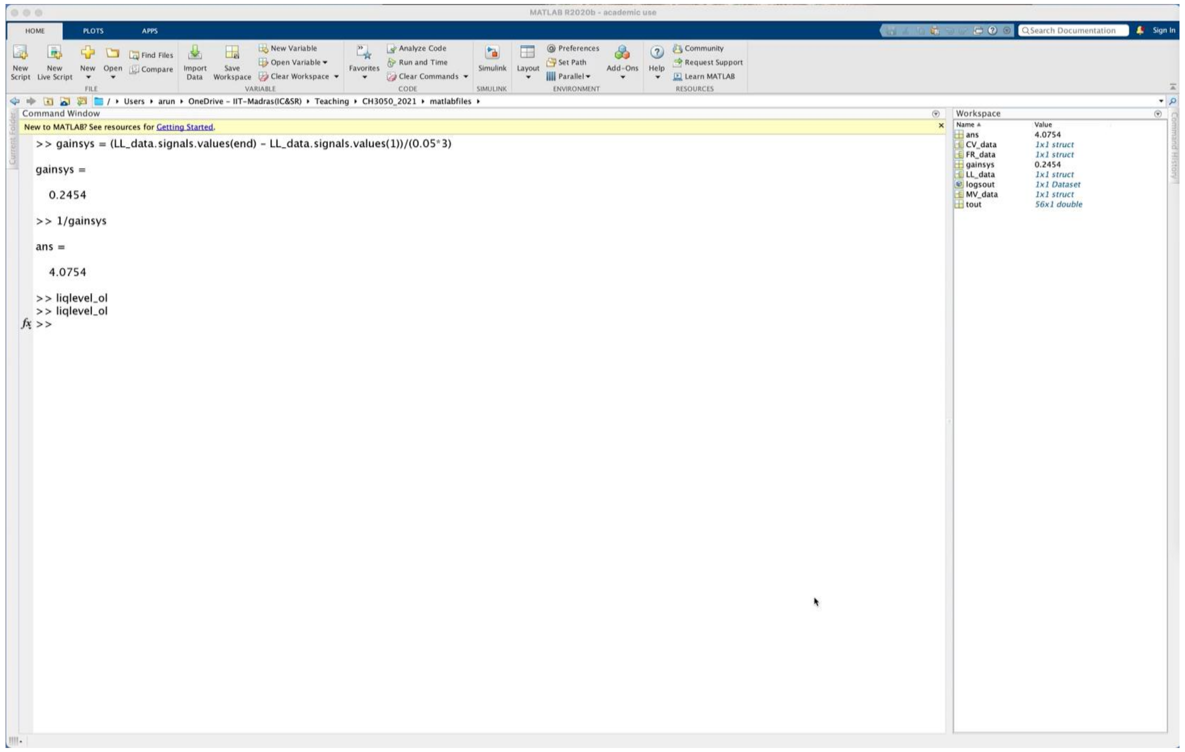


Does the response reach a steady state? How quickly? Is there an overshoot / delay?

VIRTEX2: INTUITIVE CONTROL FOR TRACKING

Objective: Implement an intuitively simple idea to drive the liquid level to a new user-specified steady-state

- **Idea:** Introduce a step change in flow rate to achieve the specified level at steady-state. Calculate the required change based on our experience in VIRTEX 1.

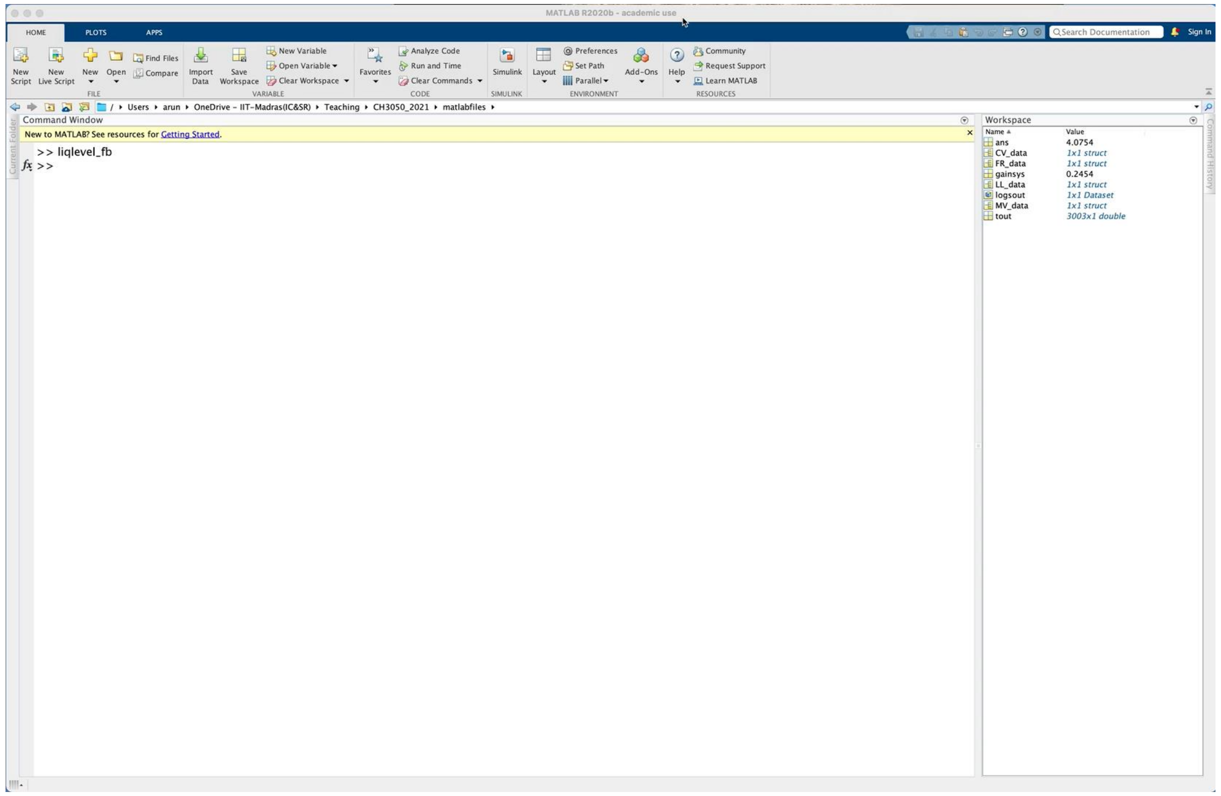


Are you satisfied with the performance? Do you anticipate any issues (e.g., if our process knowledge was inaccurate?)

VirtEx 3: Feedback - the Super Saviour

Objective: To test if feedback aids in handling uncertainties and improving the response speed of the system

- **Idea:** Sense the process variable and pass on the measurement to the controller so as to dynamically change the action. Use a popular controller such as PI.

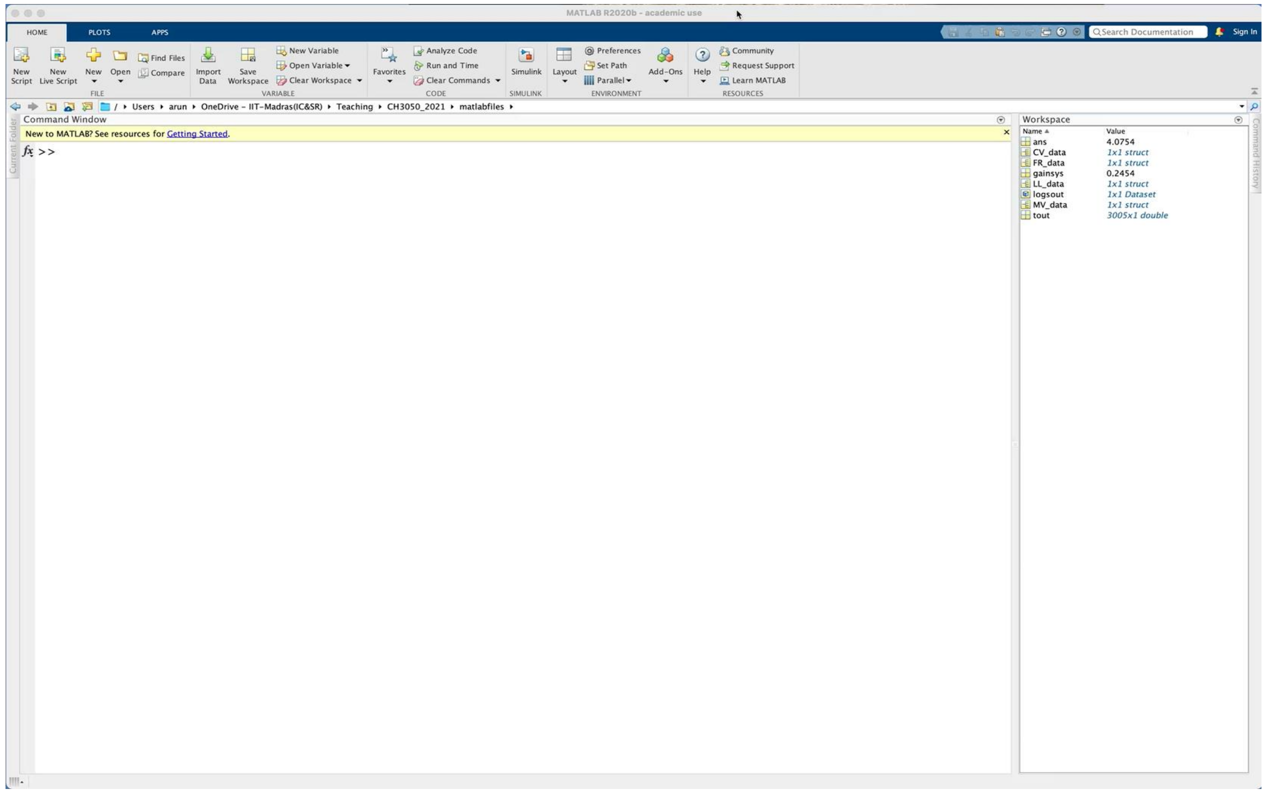


Did feedback help? What difference did we notice when we turned on and off the 'I' part of the controller? Have we struck gold?

VirtEx 4: Uncertainties along the ride

Objective: How well can the controller handle uncertainties in process knowledge and / or sensor?

- Introduce different values of measurement delay and study the response



Was the controller ***robust*** to handle delays of all ranges? Was there a compromise on performance?

QUESTIONS FOR JOURNEY AHEAD

The virtual experiments gave us a preliminary feel of why feedback control is needed and the possible risks

- Questions / points that require detailed study (mathematical + simulations):
  - *Can we determine the stability and speed of response mathematically? (model)*
  - *Is feedback control always preferred to open-loop / feedforward control?*
  - *Given a mathematical description, how do we design & tune a feedback controller?*
  - *What is the PID technology? Why is it used widely? Does it have any limitations?*
  - *Can we synthesise a general controller for a process from its model?*
  - *How does one quantify the "robustness" of a controller?*
  - *Do we have to be concerned with any operating constraints on variables?*
  - *What are the different ways of assessing a control loop performance?*