Modelling and control summaries

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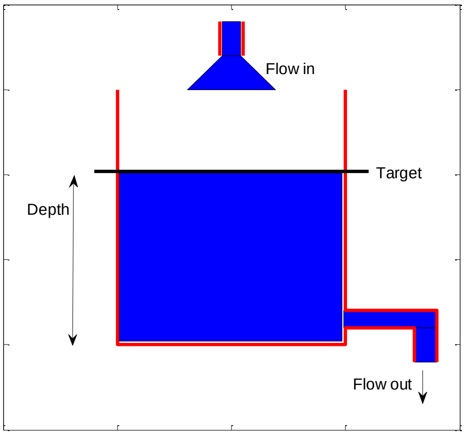
MATLAB GUIs – need for feedback: tank level

ASSUMPTION: Students should understand the dynamics of a tank system with a simple input and outflow proportional to depth.

AIM: The purpose of this GUI is to explore the impact of uncertainty on our ability to control the depth in the tank.

MODEL: For h the depth, A the cross-sectional area, R a constant linked to the outflow pipe and f_{in} = flow in, then a simplified linear model is:

$$\boxed{A\frac{dh}{dt}+Rh=f_{in}}$$



ADD UNCERTAINTY

1. The flow in varies from the measured/planned flow by an unknown, but small amount f_{dist}.
2. The resistance *R* of the outflow pipe is different to the expected value, and thus the outflow f_{out} *and* system parameter R are different from that expected.

$$\boxed{A\frac{dh}{dt}+Rh+\underbrace{R_u}_{\text{unknown}}h=f_{in}+\underbrace{f_{dist}}_{\text{unknown}}}$$

CONTROL of level: Four alternatives are possible which the user selects with a drop down menu.

1. Manual control (estimate f_{in} required) and enter desired flow through a slider.
2. User designed Proportional control.
3. User designed PI control.
4. Auto-tuned PI (based on A and R and tuned to give a time constant equivalent to open-loop dynamics).

Control law structure

$$\boxed{f_{in}=(K_p+\frac{K_i}{s})(r-h)}$$

System parameters: Users are also able to change the default A, R parameters to investigate tanks with different time constants and gains.

STUDENT ACTIVITIES. The MATLAB files runs much faster than real time and is on a continuous loops once started. FILENAMES are **tanklevelwithdisturbance.p, tanklevelwithdisturbance.fig**

The default running mode is with disturbances on so students will notice that:

1. The in flow keeps changing (this is set to fixed values that change randomly very 300 seconds so students can see the impact of uncertainty in the in flow).
2. The time constant and gain change as the R value changes . The true R (that is $R+R_u$) is unknown because, due to stiction and other uncertainty, the outlet value aperture is never known precisely.

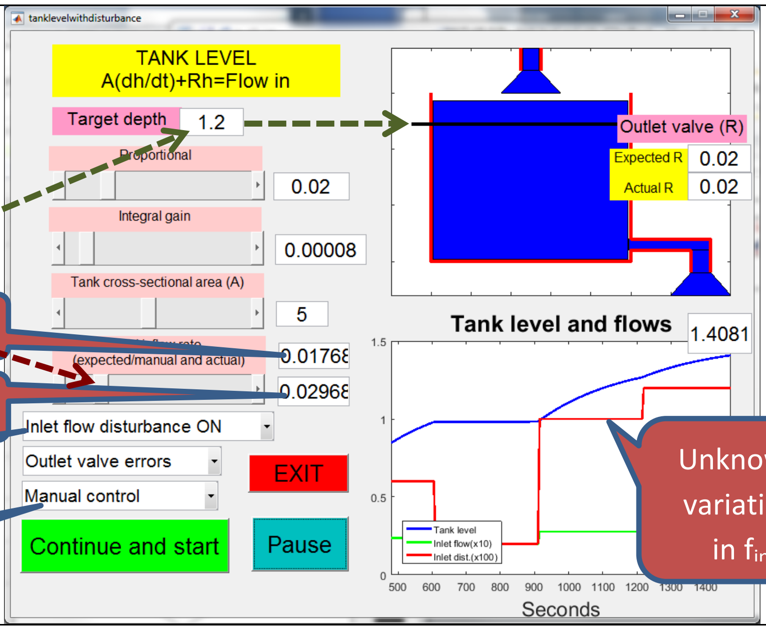
Each disturbance can be switched off individually to observe each effect separately.

GUI INTERFACE

Activity 1: Try and meet the target depth by controlling the flow through the 4th slider with disturbances active. Students will notice that even though the uncertainty only changes every 300 seconds (faster in GUI time), it is not possible to achieve effective control by manual selection of the flow.

Switch on the inlet flow disturbance which means that the actual flow (green) will differ from the expected flow. The red line shows a scaled version of the disturbance flow only.

Manually set the expected flow and try to meet the target depth.



Set expected flow

Actual flow differs

Set disturbance flow on

Set flow control to manual

Unknown variation in f_{in}

Activity 2: Try the auto-tuned PI control (4th option in the bottom pull down menu)
Students should notice how the compensator (after transients as there is no bumpless transfer), will effectively reject any variations in both the flow in and the out flow resistance R.

Activity 3: Try manually tuned PI control (2nd and 3rd options in the bottom pull down menu)
Students should use some modelling and offline design to select their PI parameters. You can get step responses by switching off the disturbances and manually changing the in flow rate.

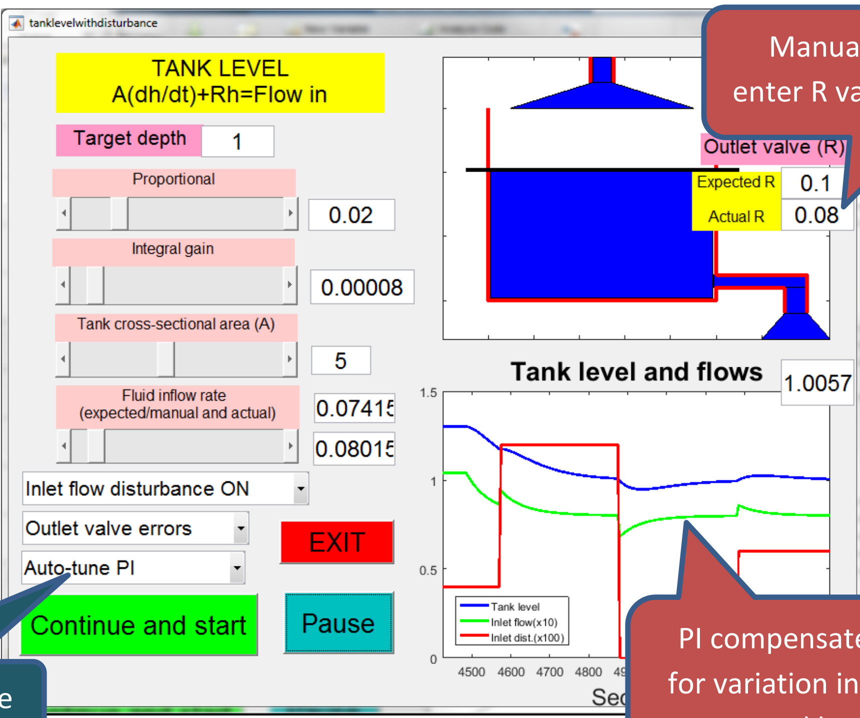
WARNINGS:

The GUI is slow to detect changes in the target depth and some other parameters. Wait a few cycles (say 600 sec) to be sure the effect is in place.

The uncertain value of R must be entered manually (within limits of $0.01<R<0.1$, $0.008<R+R_u<0.12$). This allows the user to investigate more precisely the impact of such changes.

With small R, the system time constant may be larger than 500 and level control will become difficult.

With large R, you may need to exceed flow limits of 0.1 and thus not obtain target.



Manually enter R values.

Set flow control to auto-tune

PI compensates for variation in f_{in} to control level