Tutorial 1:
Introduction to Fuzzy Control using MATLAB Fuzzy Toolbox

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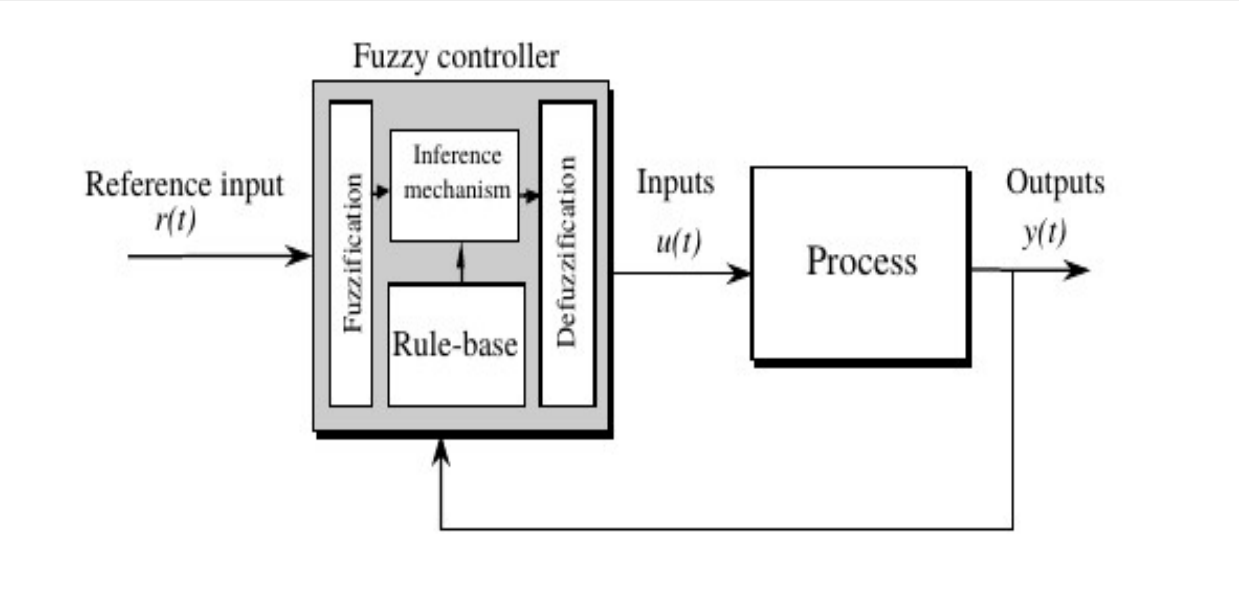
- This tutorial introduces:
  - The MATLAB Fuzzy Logic Toolbox
  - Using Fuzzy Control for a simple feedback control problem
  - Comparison with conventional PID controller
  - Use of the MATLAB Fuzzy Inference System (FIS) editor

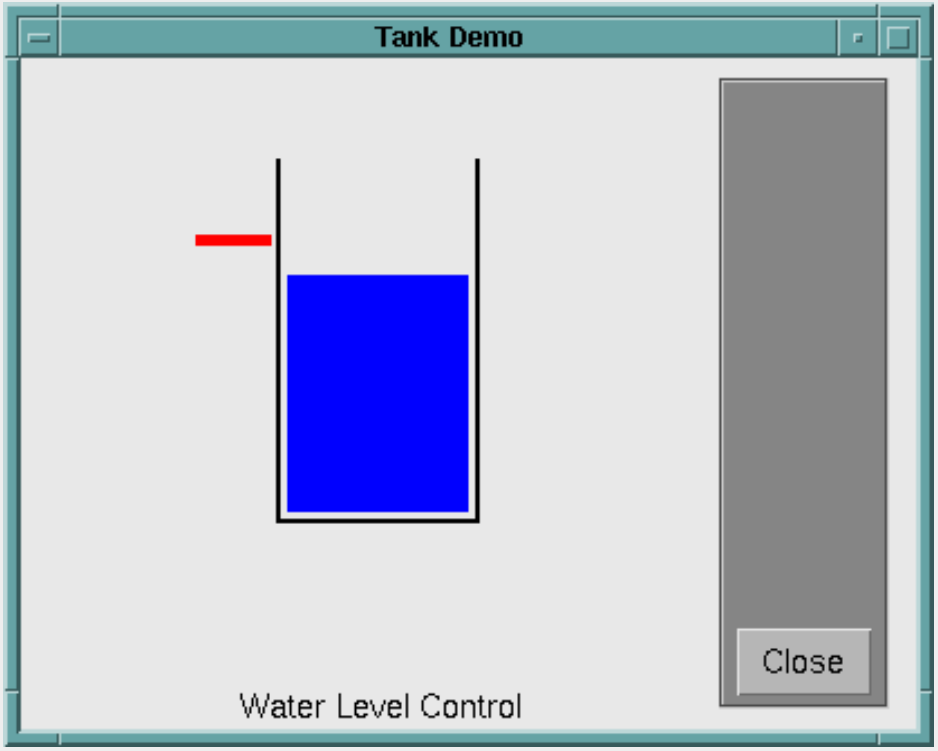
Fuzzy Control System



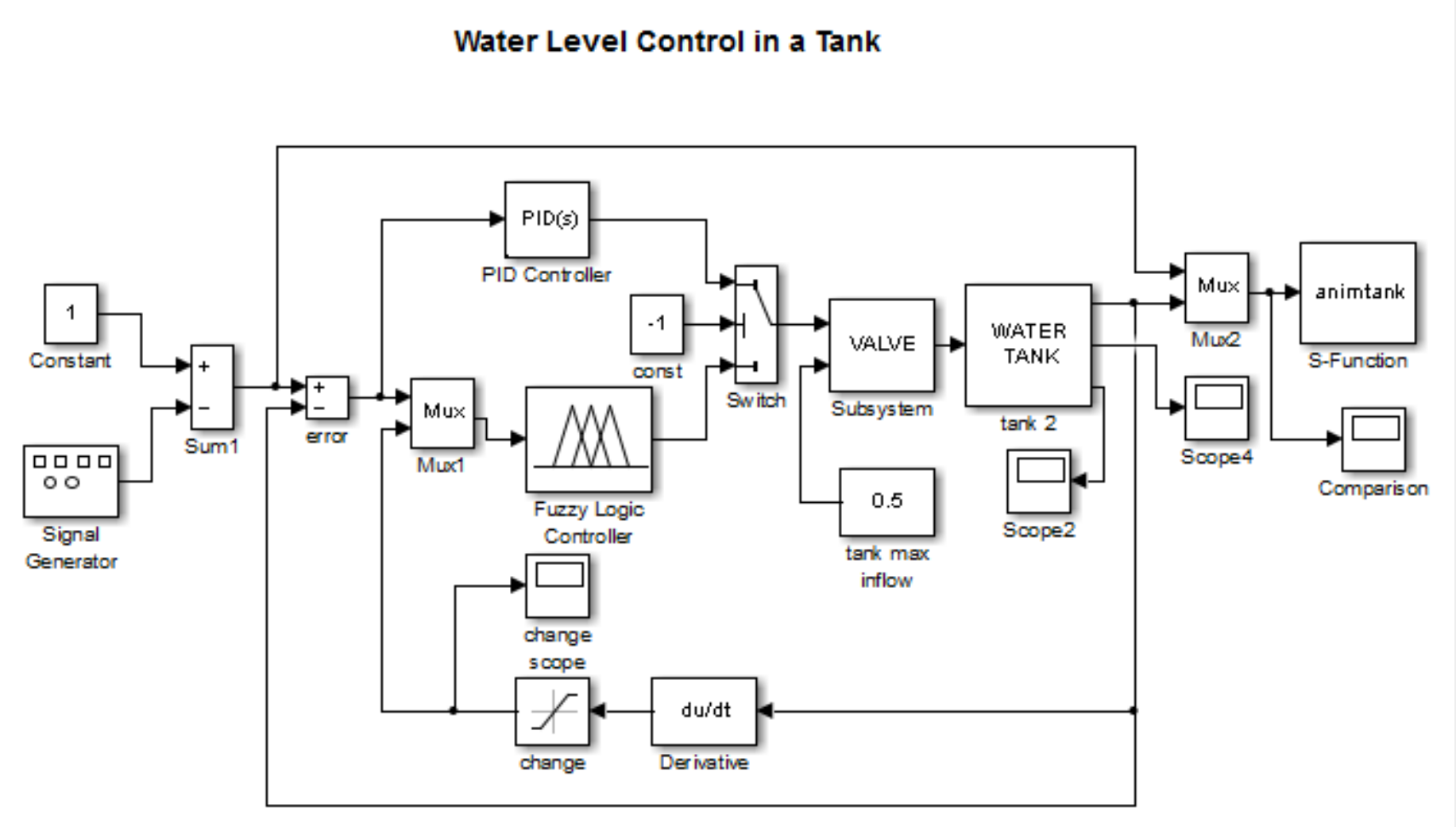
- We are going to see a demo of this using MATLAB and Simulink

SItank (Simulink Tank)

- Picture a tank with a pipe flowing in and a pipe flowing out
- You can change the valve controlling the water that flows in, but the outflow rate depends on the diameter of the outflow pipe (which is constant) and the pressure in the tank (which varies with the water level)
- The system has some very nonlinear characteristics
- To run this demo in MATLAB type **sltank** in the command window.



Simulink Tank Model



Fuzzy Controller

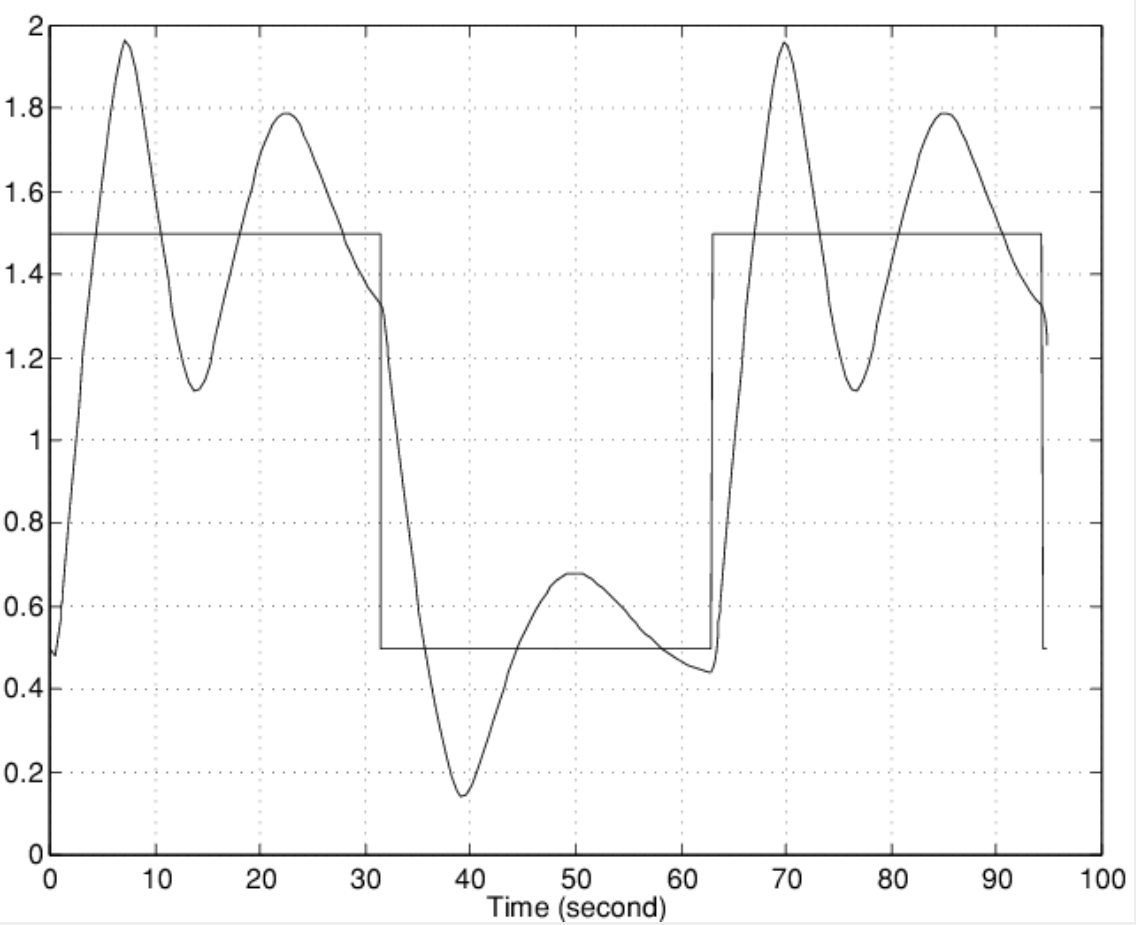
- A controller for the water level in the tank needs to know the current water level and it needs to be able to set the valve.

- controller's input is the water level ***error***
  - (desired water level minus actual water level),
  - and its output is the rate at which the valve is opening or closing

- A first pass at writing a fuzzy controller for this system might be the following:
  1. If (level is okay) then (valve is no_change)
  2. If (level is low) then (valve is open_fast)
  3. If (level is high) then (valve is close_fast)

- Note that the “level” used here is actually the error wrt the desired level which is changing during the simulation (the signal generator is producing a square wave for the desired level)

Response Plot

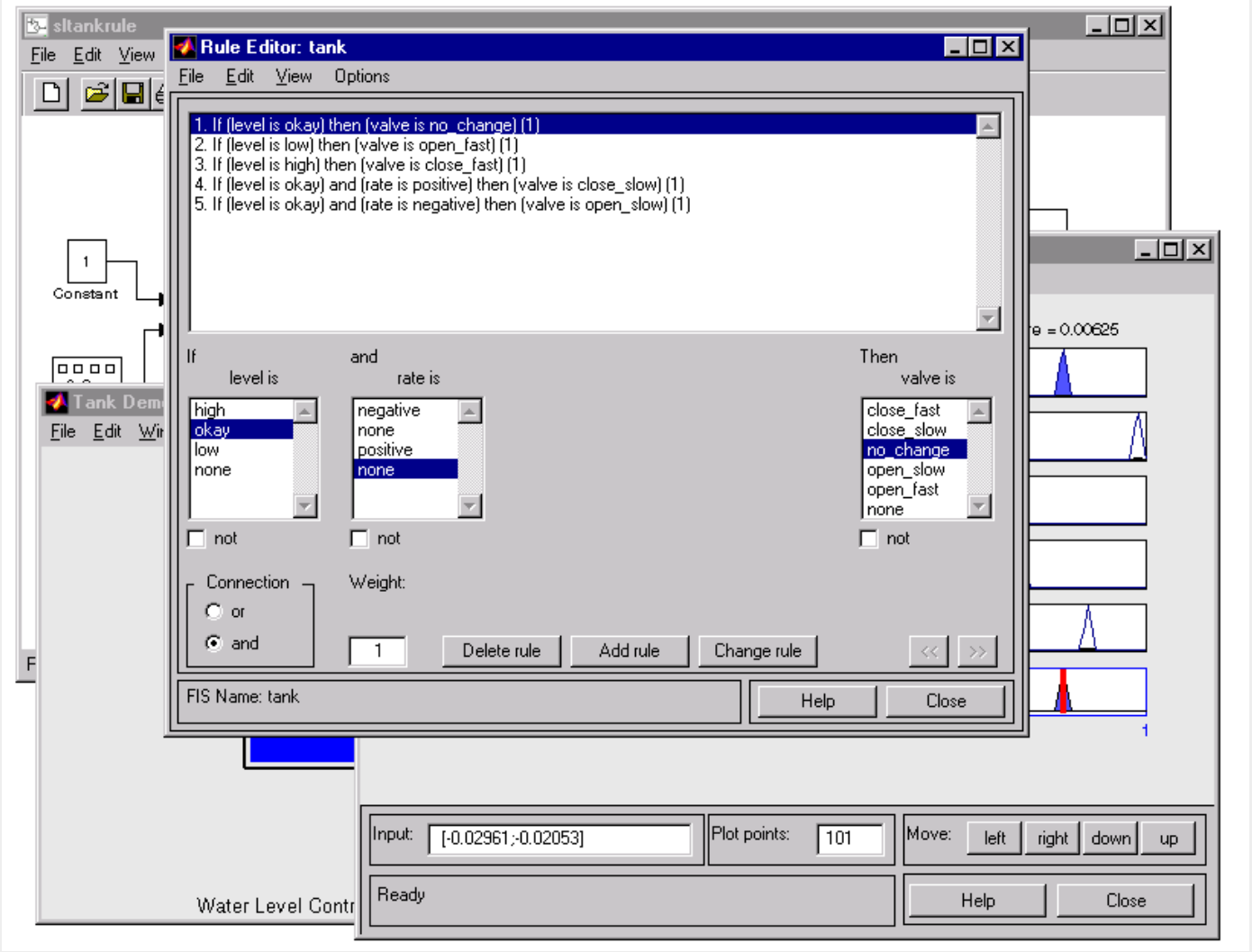


Adding some more rules

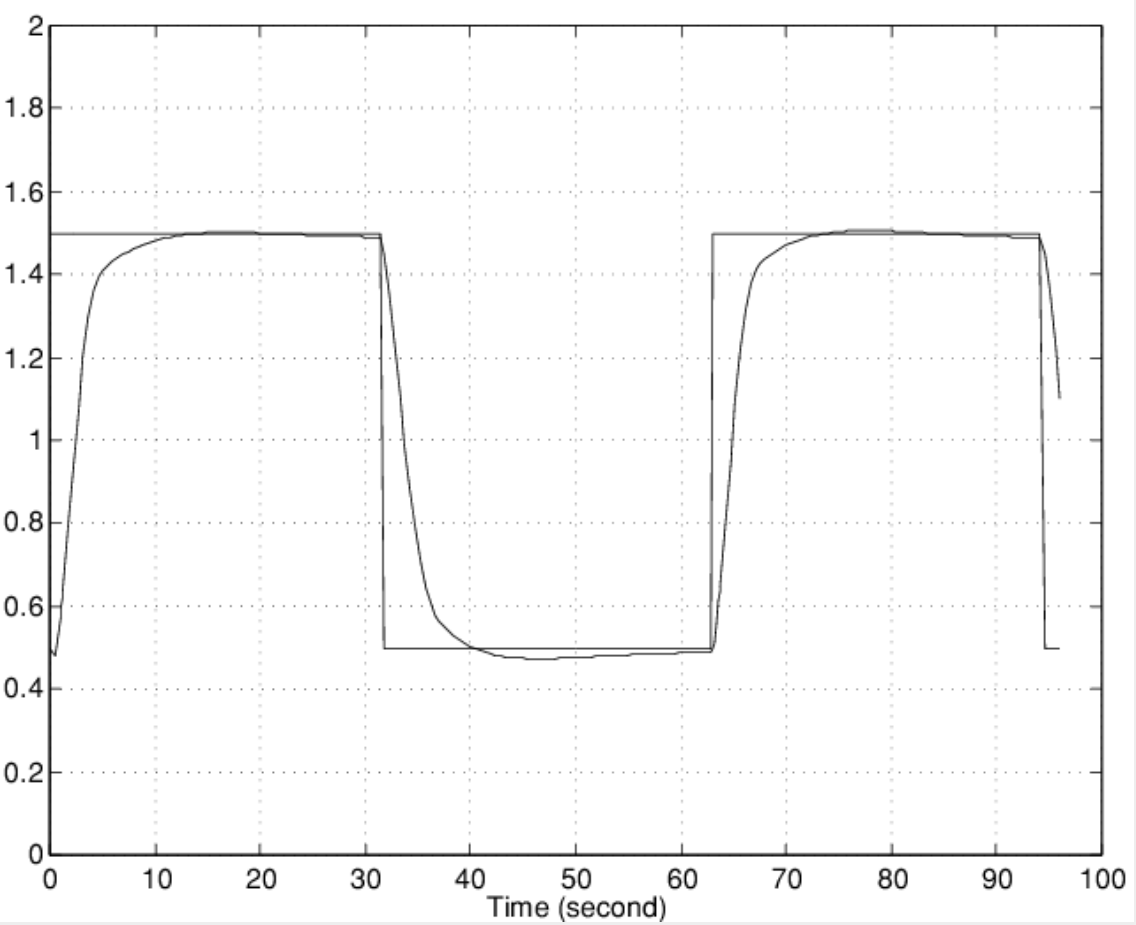
- To improve the control you could add another input: the water level's rate of change
  - slow down the valve movement when it gets close to the right level
- This would require 2 more rules:

4. If (level is okay) and (rate is negative), then (valve is close_slow)
5. If (level is okay) and (rate is positive), then (valve is open_slow)

Using the Rule Editor

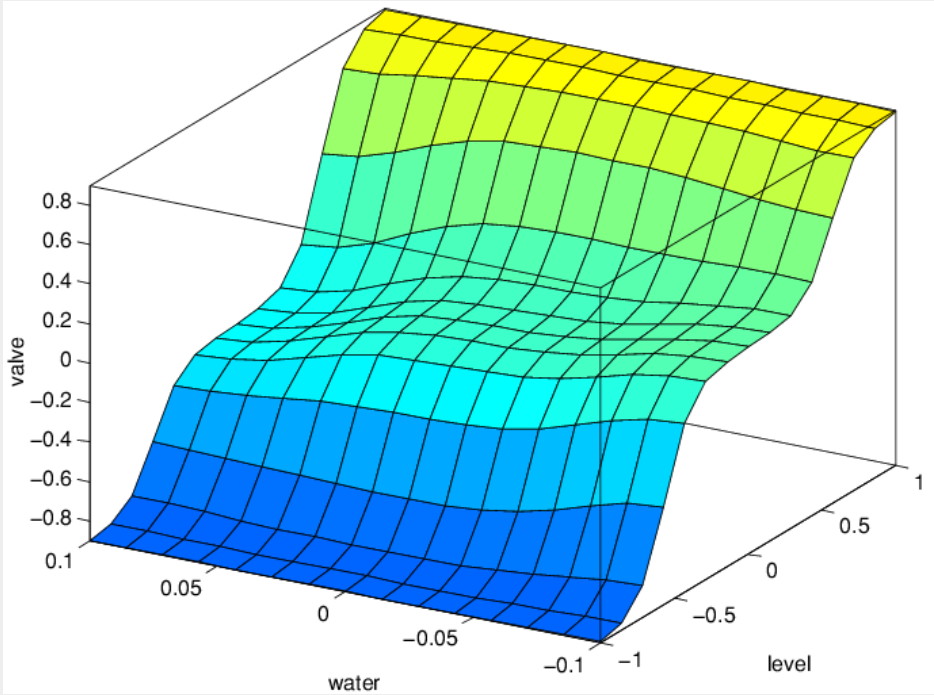


Improved Control using rate (derivative)

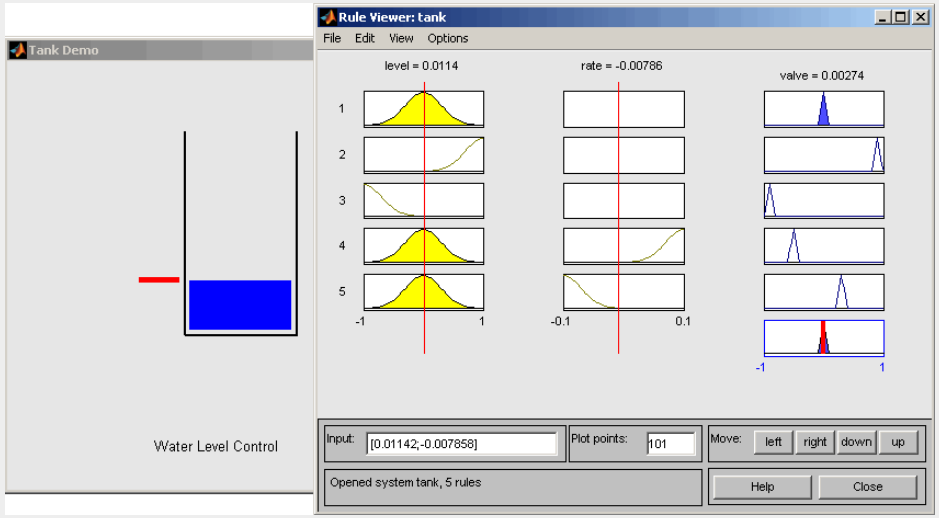


Asymmetric Rate of Change

- One interesting feature is that the tank empties much more slowly than it fills up because of the specific value of the outflow diameter pipe.
- You can deal with this by setting the **close_slow** valve membership function to be slightly different from the **open_slow** setting.
- A PID controller does not have this capability.
- The valve command versus the water level change rate (depicted as water) and the relative water level change (depicted as level) surface looks like this. If you look closely, you can see a slight asymmetry to the plot.



Rule viewer



Type **`sltankrule`** to see the rules operating during simulation

Exercise

- Change the controller to a PID controller
  - Hint: there is a switch in the Simulink model to do this for you
  - Experiment with different values for the P, I and D gains
  - Use the ‘scope to compare the simulated water level with the desired level
- Go back to the Fuzzy Controller
  - Type **`fuzzy tank`** to edit the Fuzzy Inference System
  - Look at the input Membership functions – can you understand them?
  - Experiment with the Membership Functions, rules and operators to see if you can improve on the defaults