Laboratory 1 - Control of the water level in a tank

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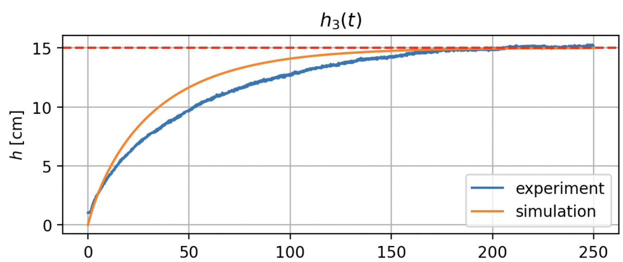
I. Open-loop control

<u>Relation between q_p and h_3 :</u> We can derive a relation between q_p and h_3 by seeking an equilibrium point that will allow us to linearize the system afterwards. The relation is the following : $h_3 = \frac{1}{2g}\left(q_p/S_{S30}\right)^2$.

<u>Data vs Theoretical evolution :</u>



The differences between the simulation and the reality could be explained by the fact that the model doesn't represent the reality in a perfect manner, and by some measure errors.

II. Closed-loop control

<u>Difference between open- and closed-loop :</u>

- $r(t)$: input of closed-loop system, i.e. the reference function, the height we would like to have [cm].
- $e(t) = r(t) - h_3(t)$: error function between the target and the real value [cm] and the input of the controller.
- $u(t) = K_p \cdot e(t)$: product of the gain K_p and the error $\left[\frac{mL}{s}\right]$. This function is the output of the controller.
- $K_p = C(s)$: transfer function of our controller $\left[\frac{cm^2}{s}\right]$.
- $y(t) = h_3(t)$: output of our closed system, i.e. the height of the water.

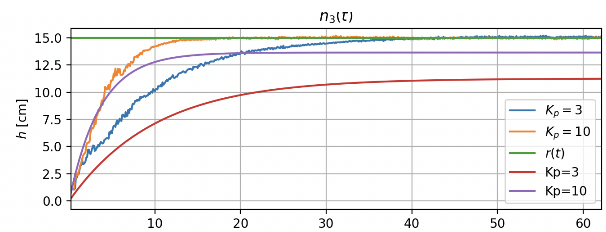
The most important difference between the open loop system and the closed loop is the nature of the input. For the open loop the input is only the flow rate q_p. However, for the closed-loop system, the input is the height reference (noted as $r(t)$). In a close-loop system, we will be able to damp disturbances.

Furthermore, in the open-loop system, we determine a fixed input q_p by trials and errors to get the output we desire; while in the closed-loop system, we only entered a value of gain and the correct input value was determined exclusively by the system.

<u>P controller without a disturbance, static error :</u>
We can observe that as K_p increases, the system is more reactive.

Theoretically, we should observe a static error that decreases as K_p increases. This is explained by the fact that the gain of the closed-loop system is different from 1. So if we want to minimize our static error, we will have to push K_p towards its maximum value (which is limited by physical constraints like voltage, current,...).

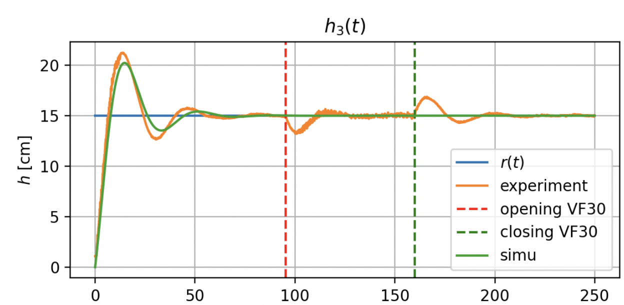
<u>Data vs Theoretical evolution :</u>



We do not observe a static error in the reality. We can also observe that the simulation gives the right gain ($3/4$ for $K_p = 3$ and $10/11$ for $K_p = 10$). Note : the simulations are in red and purple on the graph.

<u>P controller with a disturbance, static error :</u> In presence of a disturbance, the output changes suddenly, and we can observe a static error. Depending on the value of K_p, we observe a different static error : for a high K_p, we have a small static error and for a small one, we have a large static error. We can explain this by the non zero value of the gain of the transfer function between the disturbance and the output.

<u>Ziegler-Nichols and its parameters :</u> Using the first Ziegler-Nichols method in a graphical way, we find values for the parameters $K_p = 4.5$ and $K_i = 1.35$. Compared with the P controller, we now observe an overshoot.



We observe that the presence of an I controller will, over time, totally erase the error created by the disturbance. It comes form the fact that the gain of the transfer function between the output and the disturbance is now zero.