Model based software design - Lab 02

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1 Tank level control algorithm description

The main purpose of the laboratory is to achieve control on the fluid level in a tank exploited by a process with a consumption rate between 0.5 and 1 cm^3/s.
The control system should guarantee a level in the range of 175-180 cm activating the two available pumps with the following logic:

- If the fluid level in the tank is increasing, activate High Flow Pump (set HFP_DO to 1 and LFP_DO to 0) when the tank level is below 155 cm, otherwise activate Low Flow Pump (set LFP_DO to 1 and HFP_DO to 0) until the fluid reaches 180 cm, then turn off the pump system (set both HFP_DO, LFP_DO to 0).
- If the fluid level is decreasing, activate High Flow Pump (set HFP_DO to 1 and LFP_DO to 0) when the tank level is below 150 cm, otherwise activate Low Flow Pump (set LFP_DO to 1 and HFP_DO to 0) until the fluid reaches 175 cm. Keep pump system turned off (set both HFP_DO, LFP_DO to 0) until the level in the tank goes below 175 cm.

2 Description of the whole system

2.1 Draw the I/O block diagram of the plant and of the controller, showing how they interact to each other.

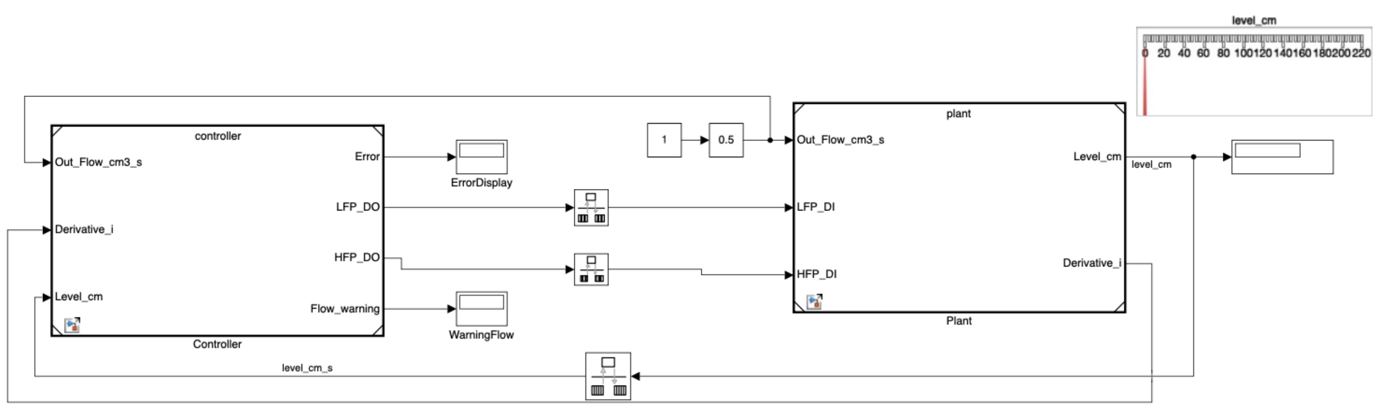

Figure 1: Interaction between controller and plant

2.2 Draw the Finite State Machine (FSM) representing the on/off control logic.

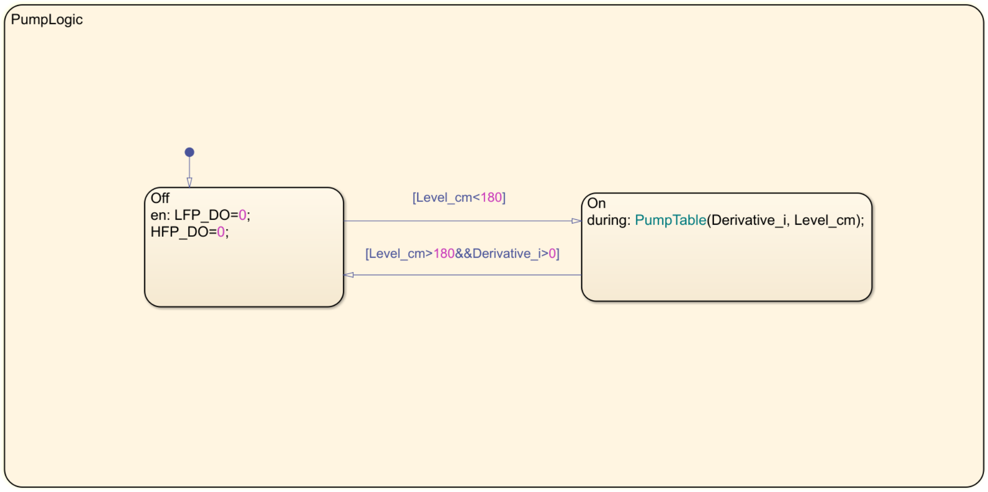

Figure 2: On/Off control Logic

Table 1: On/Off control logic Truth Table

DESCRIPTION	CONDITION	D1	D2	D3	D4	D5
Tank level is decreasing and level_cm is low	i<0 && level<150	T	F	F	F	-
Tank level is decreasing and level_cm is high	i<0 && (level>=150 && level<175)	F	T	F	F	-
Tank level is decreasing and level_cm is high	i>0 && level<155	F	F	T	F	-
Tank level is increasing and level_cm is high	i>0 && level>=155	F	F	F	T	-
	ACTIONS: SPECIFY A ROW FROM THE ACTION TABLE	**A1**	**A2**	**A1**	**A2**	**A3**

DESCRIPTION	ACTION
Turn on High Flow Pump	A1: HFP_DO=1; LFP_DO=0;
Turn on Low Flow Pump	A2: HFP_DO=0; LFP_DO=1;
Turn off device	A3: HFP_DO=0; LFP_DO=0;

2.3 Draw the FSM representing the plausibility check on the level behavior.

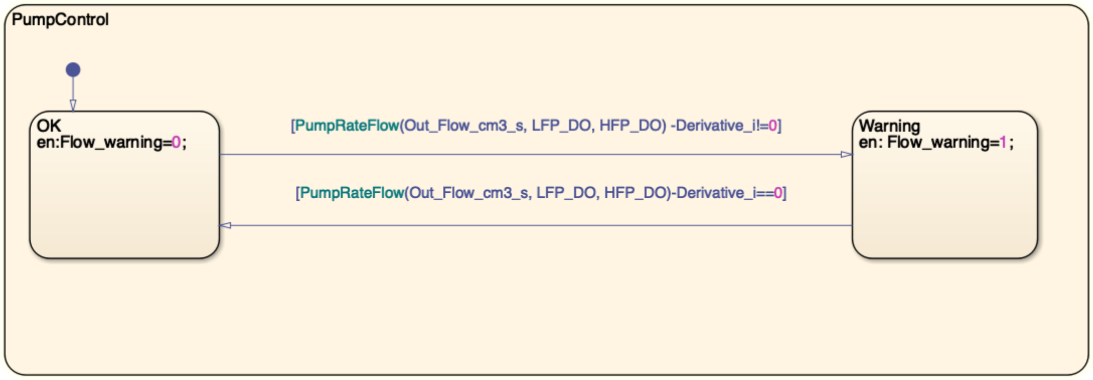

Figure 3: Plausibility check Logic

In which *PumpRateFlow* is the following Matlab function, used to compute the flow rate (Figure 4):

```
function f = PumpRateFlow(out_flow, pump_low, pump_high)

    if (pump_low)
        f=1 - out_flow*0.5;

    elseif(pump_high)
        f=3 - out_flow*0.5;

    else
        f=0 - out_flow*0.5;
    end
end
```

3 Controller SW Unit specifications

The Finite State Machine (FSM) controlling the activation logic of HFP and LFP (Fig.2) was developed through the truth table function in Tab.1.

In addition two other FSMs working in parallel were implemented:

- **ErrorControl**, used to alert the system if the level in the tank surpasses 200 cm (set $Error = 1$).
- **PumpControl**, a plausibility check system that gives a system warning if the theoretical flow rate, f, (computed by subtracting input flow and the output flow, Eq.1) is different from the empirical one (obtained as the derivative of the fluid level in the tank).
  For the aforementioned FSM (Fig.3) an appropriate MATLAB function (Fig.4) computing the theoretical flow rate was exploited. Different computation are executed based on pump flow condition (Eq.2).
  A rapid change in the warning flag (from 0 to 1 and vice versa) was noticed when a sudden change in the rate flow happened, this is probably due to the fact that there is a small delay in the system making the theoretical flow different from the empirical one only for a brief instant (the issue does not appear on the warning display since the difference is perceived exclusively during pump switching).

$$f = \text{input\_flow} - \text{output\_flow} \tag{1}$$

$$f = \begin{cases} 3 - \text{output\_flow} \; * 0.5, & \text{if HFP\_DO} = 1 \\ 1 - \text{output\_flow} \; * 0.5, & \text{if LFP\_DO} = 1 \\ 0 - \text{output\_flow} \; * 0.5, & \text{if HFP\_DO} = 0 \text{ and LFP\_DO} = 0 \end{cases} \quad (2)$$

For what concerns physical interfaces, the controller receives three inputs and returns four outputs to the plant (Tab.2):

- **Inputs**:
  - *Level_cm*, returns the fluid level in the tank.
  - *Out_Flow_cm3_s*, report the fluid consumed by the process from the tank.
  - *Derivative_i*, represents the derivative of *Level_cm*, taken from plant file before performing the integration.
- **Outputs**:
  - *Error*, an error flag activating if *Level_cm* exceed 200 cm.
  - *HFP_DO*, a boolean signal used to activate the high flow pump when needed.
  - *LFP_DO*, a boolean signal used to activate the low flow pump when needed.
  - *Flow_warning*, a warning flag activating if the flow rate measured differs from the theoretical flow that shall be observed.

Table 2: Interfaces table

NAME	UNIT*	TYPE	DATA TYPE	DIMENSION	MIN	MAX
Level_cm	cm	INPUT (analog)	DOUBLE	SCALAR	0.00	200.00
LFP_DO	-	OUTPUT (discrete)	BOOLEAN	SCALAR	-	-
HFP_DO	-	OUTPUT (discrete)	BOOLEAN	SCALAR	-	-
ERROR	-	OUTPUT (discrete)	BOOLEAN	SCALAR	-	-
Derivative_i	cm/s	INPUT (analog)	DOUBLE	SCALAR	-0.5	2.75
Out_flow_cm3_s	cm3/s	INPUT (analog)	DOUBLE	SCALAR	0.50	1.00
Flow_warning	-	OUTPUT (discrete)	BOOLEAN	SCALAR	-	-