Assignment 2
Machine Learning Techniques for Real-time Control

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The mathematical model of a two link revolute joint robot manipulator have the following form.

$$M(q)\ddot{q} + V_m(q,\dot{q})\dot{q} + F_d\dot{q} = \tau$$

The structures of the respective matrices are shown below.

$$M(q) = \begin{bmatrix} p_1 + 2p_3c_2 & p_2 + p_3c_2 \\ p_2 + p_3c_2 & p_2 \end{bmatrix}$$

$$V_m = \begin{bmatrix} -p_3s_2\dot{q}_2 & -p_3s_2(\dot{q}_1 + \dot{q}_2) \\ p_3s_2\dot{q}_1 & 0 \end{bmatrix}$$

$$F_d = \begin{bmatrix} f_{d_1} & 0 \\ 0 & f_{d_2} \end{bmatrix}$$

The parameters of the system are given by $p_1 = 3.473\ kg.m^2$, $p_2 = 0.196\ kg.m^2$, $p_3 = 0.242\ kg.m^2$, and $f_{d_1} = 5.3\ Nm.sec$, $f_{d_2} = 1.1\ Nm.sec$. Further, $c_2 = \cos(q_2)$ and $s_2 = \sin(q_2)$.

(This model is implemented in the shared simulink file.)

Q.1> Design a single-layer Learning-based Neural Network (NN) controller $\tau(t)$ using radial basis function (RBF) networks to track a desired trajectory $q_d(t) = [0.5\sin(t), 2\cos(\frac{t}{4})]^T$.

(This controller is already implemented in the shared simulink file.) Just hit the run button in the task bar, once you open the simulink file (.slx file) in Matlab environment.

The number of Neurons is chosen as $L = 10$. However, the weight update mechanism does not include any robust modification. **Can you observe parameter drift after running the .slx file?**

Modify the learning rule using σ-mod and e-mod and observe the performances. **Is parameter drift obviated? In σ-mod, can you observe learning-unlearning repeatedly? Is that effect reduced in e-mod?**

Further, change $L = 100$ and $L = 500$ (don't forget to change the dimension of the initial conditions $\hat{W}(0)$ in the corresponding integrator block) and

compare the performance with $L = 10$ for both the cases of σ-mod and e-mod (choose the gain of σ-mod and e-mod as $k_\sigma = 5$). **Can you observe any change in tracking performance? If yes, can you justify the reason?**

What you have to submit :

a> For $L = 10$, provide the plots of tracking error $e(t)$, filtered-tracking error $r(t)$, weight estimation $\hat{W}(t)$, control input $\tau(t)$ vs time t for each of the 3 cases (without robust modification, σ-mod, e-mod)

b> Provide the same set of pots for $L = 100$ and $L = 500$ using σ-mod and e-mod. (Specially observe the difference of σ-mod and e-mod in learning performance for $L = 500$.)

c> Comment on the above mentioned (bold-faced) questions.

Q.2> Design a multi-layer Learning-based NN-controller using sigmoid function structures for the same tracking objective given in Q.1.

What you have to submit :

a> Provide the plots of tracking error $e(t)$, filtered-tracking error $r(t)$, parameter estimation error $\tilde{\theta}(t)$, Weight Estimates $\hat{W}(t)$ and $\hat{V}(t)$ control input $\tau(t)$ vs time t using σ-mod.

b> Provide the modified simulink file for the multi-layer Learning-based NN controller design.

Submit two files- 1> a single PDF file incorporating all the answers along with your name, email-id and roll number, 2> the modified simulink file.