TOPIC: ADAPTIVE REINFORCEMENT LEARNING OF NONLINEAR SYSTEMS WITH DISTURBANCES BASED ON TIME-VARYING RISE METHOD

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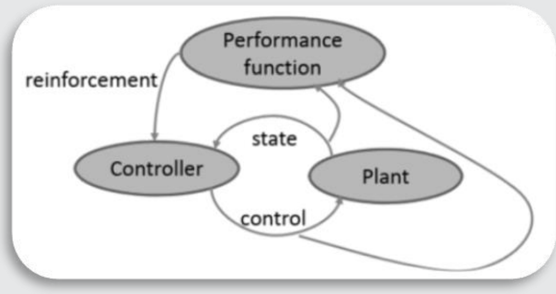
INTRODUCTION

In control theorem and control engineering, optimal control is a significant research area. It solves the problem determining a control strategy that optimally steers the dynamics system to equilibrium in terms of minimizing a performance index function.



Besides, nonlinear dynamical systems of uncertainties and parameters variation have been studied extensively in the literature. Those systems have been always considered as a challenge possessing special care from scientific people.

OBJECT & RESEARCH PURPOSE

In this research, a new class of RISE-based control combines with Actor-Critic Neural Networks has been proposed for uncertain/disturbed nonlinear mechanical systems.

The research purpose is finding an optimal control that minimizes the cost function and guarantees the robustness stability under disturbances and model uncertainties.

To verify the effectiveness of the proposed tracking control algorithm, a simulation is carried out by a 2-DOF planar robot manipulator system.

DYNAMIC MODEL

Consider the planar robot manipulator systems:

$$M(\eta)\ddot{\eta}+C(\eta,\dot{\eta})\dot{\eta}+G(\eta)+F(\dot{\eta})+d(t)=\tau(t)$$

Using the sliding variable:

$$s(t)=\dot{e}_1+\alpha_1 e_1 \ (\alpha_1\in\mathbb{R}^{n\times n}>0,\ e_1(t)=\eta_{ref}-\eta)$$

The control input can be designed as:

$$\tau=f+d-u$$

where:

$$f=M(\ddot{\eta}_{ref}+\alpha_1\dot{e}_1)+C(\dot{\eta}_{ref}+\alpha_1 e_1)+G+F$$

After adding some additional states, finally we can obtain the affine system:

$$\dot{X}=A(X)+B(X)u$$

CONTROL DESIGN

The optimal cost function and the optimal controller are approximated as:

$$\hat{V}(X)=\hat{W}_c^T\psi(X);\ \hat{u}(X)=-\frac{1}{2}R^{-1}B^T(X)\left(\frac{\partial\psi}{\partial X}\right)^T\hat{W}_a$$

The proposed time-varying RISE structure is presented as:

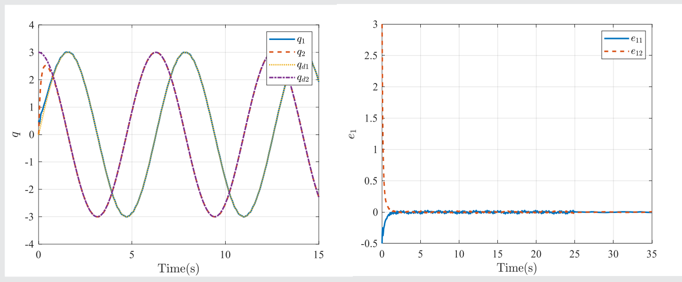
$$\varepsilon(t)=f+d=\left(K_s(.)+1\right)e(t)-\left(K_s(t_0)+1\right)e(t_0)+\int_{t_0}^{t}\left[\left(k_{s0}+1\right)\alpha(.)e(\tau)+\beta\,\mathrm{sgn}(e(\tau))\right]d\tau$$

To ensure PE qualitatively, an exploratory signal $n(t)$ is added to the control, therefore:

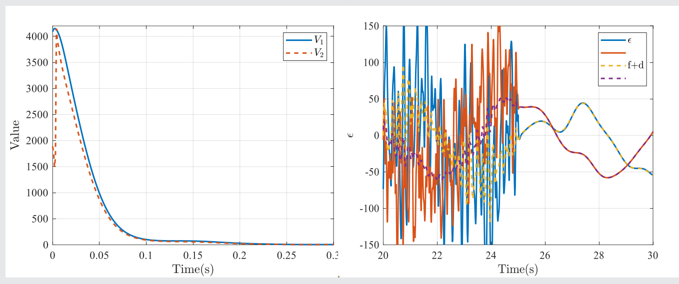
$$\tau=\varepsilon-u+n$$

SIMULATION RESULTS

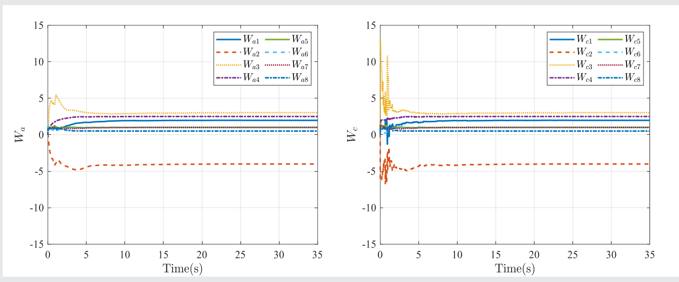
A simulation is carried out in a 2-DOF planar robot manipulator system:



Tracking trajectory and tracking error



Cost function value and estimation of RISE



Actor and Critic weights' convergences

CONCLUSION

This work proposed a new time-varying RISE combined with ARL controller for dynamical systems of uncertainties and parameters variation. Simulation results on 2-DOF robot manipulator confirmed the performance of the proposed scheme, which help bring in faster and smoother convergences, compared to the standard RISE method.

Future works

1. Considering the completely unknown dynamics of the system in off-policy integral reinforcement learning with the proposed time-varying feedback RISE controller.

2. Co-operative control of multiple robot manipulators is also an interesting topic can be futher implemented.

References

1. Dupree, Keith and Patre, Parag M and Wilcox, Zachary D and Dixon, Warren E. (2011). Asymptotic optimal control of uncertain nonlinear Euler-Lagrange systems. Automatica,1, 99-107.

2. Xian, B., Dawson, D. M., Queiroz, M. S., & Chen, J. (2004, July). A Continuous Asymptotic Tracking Control Strategy for Uncertain Nonlinear Systems. IEEE Transactions on Automatic control, 49(7), 1206-1211