Imposing a Weight Norm Constraint for NeuroAdaptive Control

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Outline

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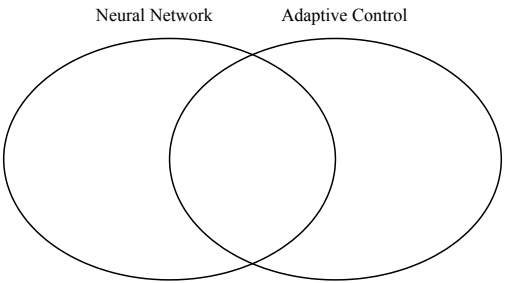
NeuroAdaptive Control

- **Neuroadaptive control** (NAC) is a control strategy that combines **neural networks (NNs)** with **adaptive control techniques** [1].
- It is used to handle **uncertainties** and **nonlinearity** in dynamic systems.



Advantages of Neuro-Adaptive Control

- **Adaptability**: NAC adapts to changing environments and system dynamics.
- **Stability Guarantee**: The closed-loop stability is ensured using **Lyapunov stability theory**.
- **Online Learning Capability**: NAC adapts in **real-time** to new data with stability guarantees.
- **Robustness**: NAC handles **uncertainties and disturbances** effectively with adaptive control techniques.

Challenges

- **Optimality**: In general, the adaptation laws are deriven with respect to the tracking error, which may not guarantee optimal performance.
- **Unpredictable Amplitude of NN Weights**:
  - NN weights may diverge, leading to instability.
  - This can result in unpredictable behavior of the controller.
- **Parameter Dependency**:

In general, the NN outputs are bounded by limiting the maximum amplitude of the NN weights.

1. **Projection Operator**
   - Cats
   - Dogs
   - Birds

2. **ϵ-modification, and σ-modification**
   - Cats
   - Dogs
   - Birds

Research Objectives

Objective 1: Optimality

- Formulate a constrained optimization problem to minimize the tracking error.
- Guarantee the stability of the system and the NN weights.

Objective 2: Stability

- Derive an adaptation law that guarantees the stability of the system.
- Ensure that the NN weights remain bounded during operation.

Objective 3: Boundedness of

- Ensure the controller is robust to uncertainties and disturbances.
- Validate the proposed method through numerical simulations.

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Objectives:

- Minimize the tracking error by adapting the NN weights $\widehat{\boldsymbol{\theta}}$.
- Guarantee the stability of the system and the NN weights $\widehat{\boldsymbol{\theta}}$.

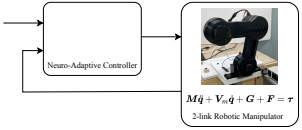

Figure: Architecture of the constrained optimization-based neuro-adaptive controller (CONAC).

Notations: $\boldsymbol{M}$: Inertia matrix, $\boldsymbol{C}$: Coriolis matrix, $\boldsymbol{G}$: Gravity vector, $\boldsymbol{\tau}$: Control input, $\boldsymbol{q}$: Joint position, $\widehat{\boldsymbol{\theta}}$: Estimated NN weights.

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Representative Simulation Results

Box-and-Whisker Plots

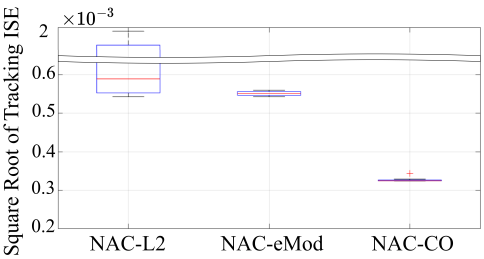

Figure: Parameter dependencies of the proposed method.

Table: Largest cities in the world (source: Wikipedia)

City	Population
Mexico City	20,116,842
Shanghai	19,210,000
Peking	15,796,450
Istanbul	14,160,467

Parameter Dependencies

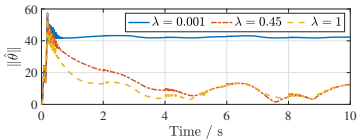

Figure: Weight norms of NAC-L2

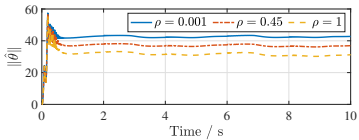

Figure: Weight norms of NAC-eMod

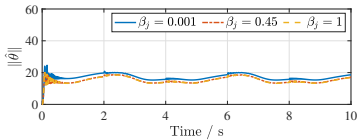

Figure: Weight norms of NAC-CO

The weight norms of the proposed method (NAC-CO) are bounded, while ...

Parameter Dependencies

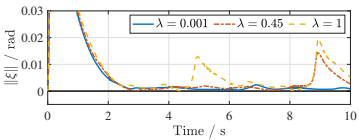

Figure: Tracking error of NAC-L2

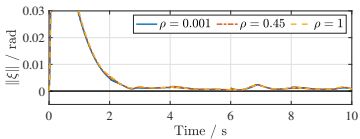

Figure: Tracking error of NAC-eMod

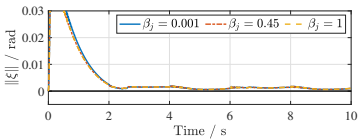

Figure: Tracking error of NAC-CO

The Tracking error ...

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Conclusion

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Alert

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Example

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Thank you for your attention!

References I

[1] J. A. Farrell and M. M. Polycarpou, *Adaptive Approximation Based Control: Unifying Neural, Fuzzy and Traditional Adaptive Approximation Approaches (Adaptive and Learning Systems for Signal Processing, Communications and Control Series)*.
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