Model Reference Adaptive Control Simulation & Implementation to Quadrotor UAV

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Flight Control Systems

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Outlines

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- Modeling the Quad-Rotor UAV
- Model Reference Adaptive Control (MRAC)
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  - LQR
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Introduction

- The advantages of the quad-rotor UAV:
  - VTOL
  - Omni-directional flying
  - Does not require mechanical linkages to vary rotor angle of attack.
  - Can be protected by enclosing within a frame (Qball)

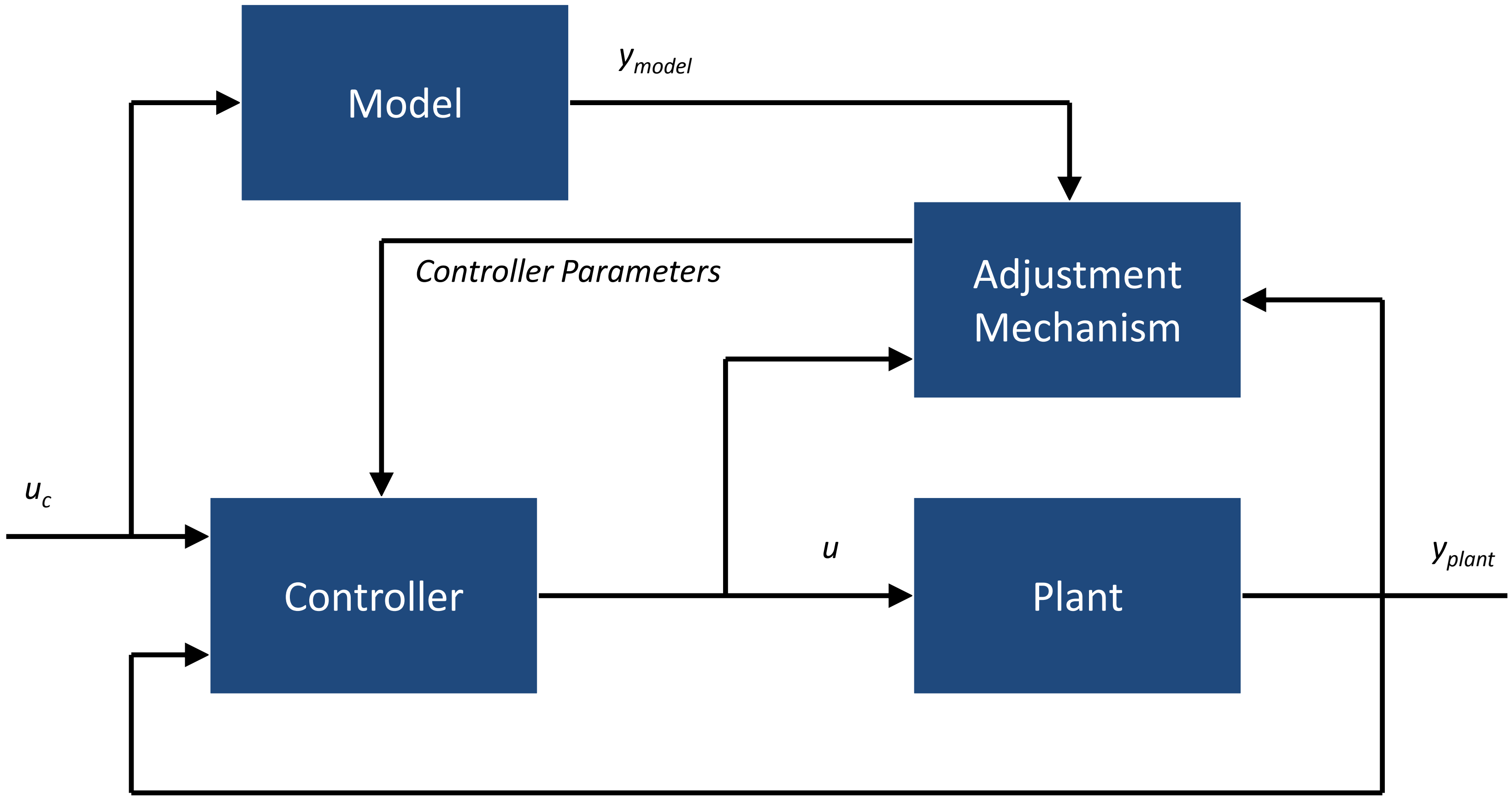
- MRAC controller advantages
  - Robustness: Insensitive to changes to plant parameters and disturbance
  - Variety of applications: Aerospace, Chemical, Petrochemical, etc…
  - The MRAC or MRAS is an important adaptive control methodology

Different Adaptive Systems

Model-Reference Adaptive Systems

- The MIT rule
- Lyapunov stability theory
- Design of MRAS based on Lyapunov stability theory
- Hyperstability and passivity theory
- The error model
- Augmented error
- A model-following MRAS

MRAC Structure



Design controller to drive plant response to mimic ideal response (error = y_{plant}- y_{model} => 0)
Designer chooses: reference model, controller structure, and tuning gains for adjustment mechanism

The MIT rule

- Original approach to MRAC developed around 1960 at MIT for aerospace applications
- With $e = y - y_m$, adjust the parameters θ to minimize

$$J(\theta) = \frac{1}{2}e^2$$

- It is reasonable to adjust the parameters in the direction of the negative gradient of J:

$$\frac{d\theta}{dt} = -\gamma\frac{\partial J}{\partial \theta} = -\gamma e \frac{\partial e}{\partial \theta}$$

- $\partial e/\partial \theta$ is called the sensitivity derivative of the system and is evaluated under the assumption that θ varies slowly

The MIT rule

- The derivative of J is then described by

$$\frac{dJ}{dt} = e\frac{\partial e}{\partial t} = -\gamma e^2 \left(\frac{\partial e}{\partial \theta}\right)^2$$

- Alternatively, one may consider $J(e) = |e|$ in which case

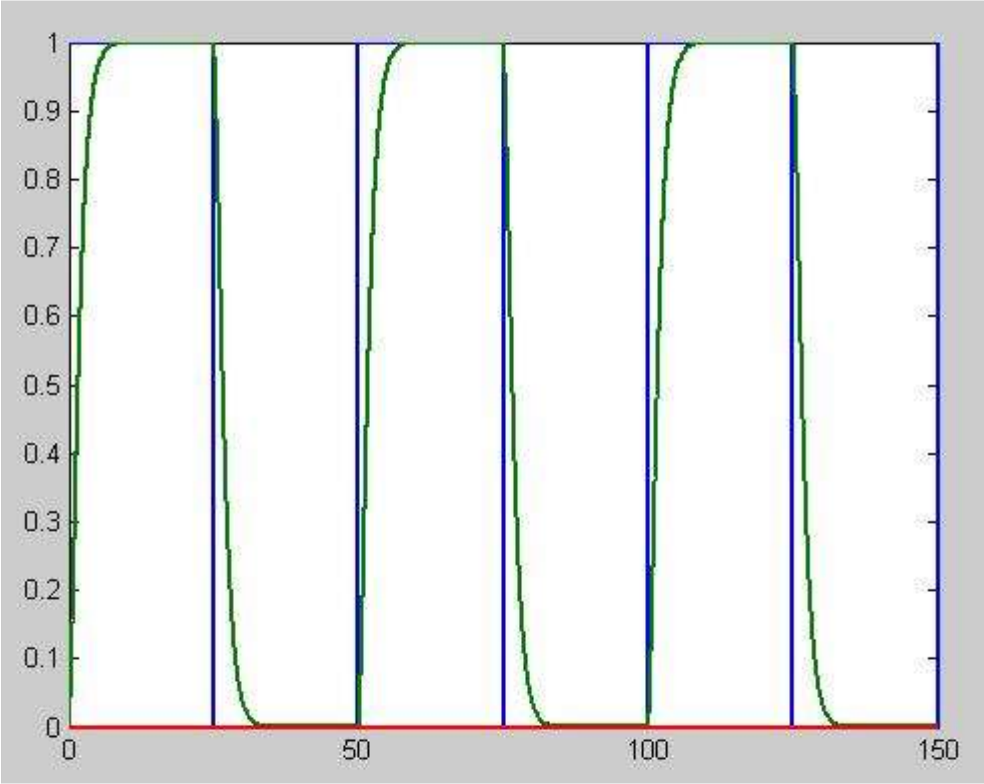
$$\frac{d\theta}{dt} = -\gamma\frac{\partial J}{\partial \theta} = -\gamma\frac{\partial e}{\partial \theta}\mathrm{sign(e)}$$

- The sign-sign algorithm used in telecommunications where simple implementation and fast computations are required, is

$$\frac{d\theta}{dt} = -\gamma\frac{\partial J}{\partial \theta} = -\gamma\mathrm{sign}\left(\frac{\partial \mathrm{e}}{\partial \theta}\right)\mathrm{sign(e)}$$

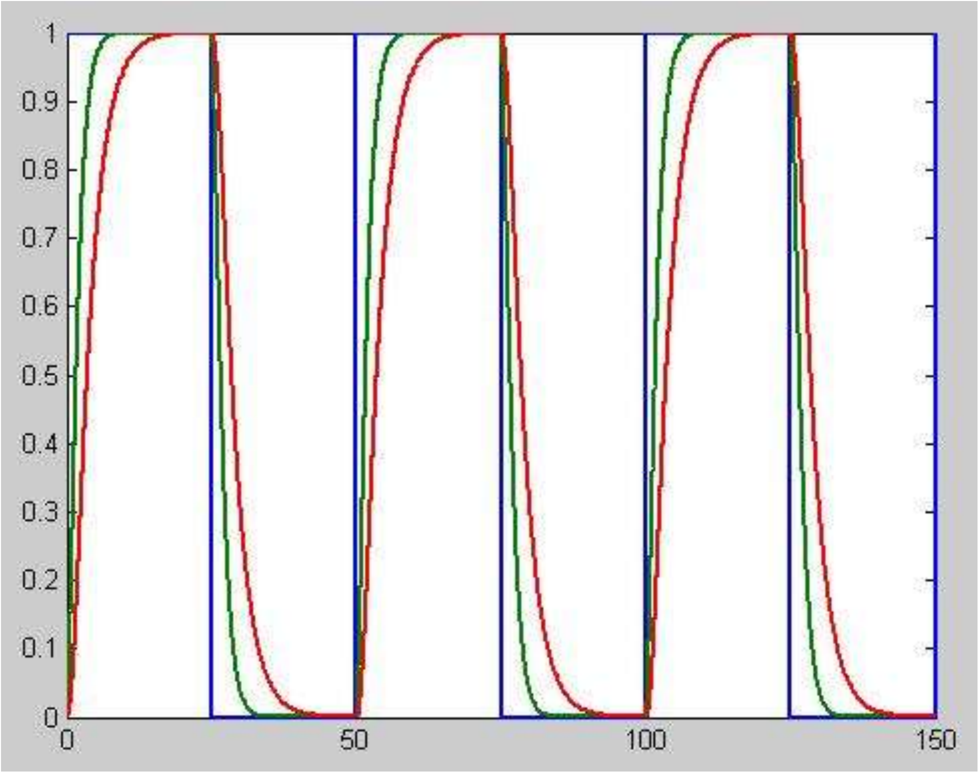
Simulation Results

MRAC and LQR both are set to zero



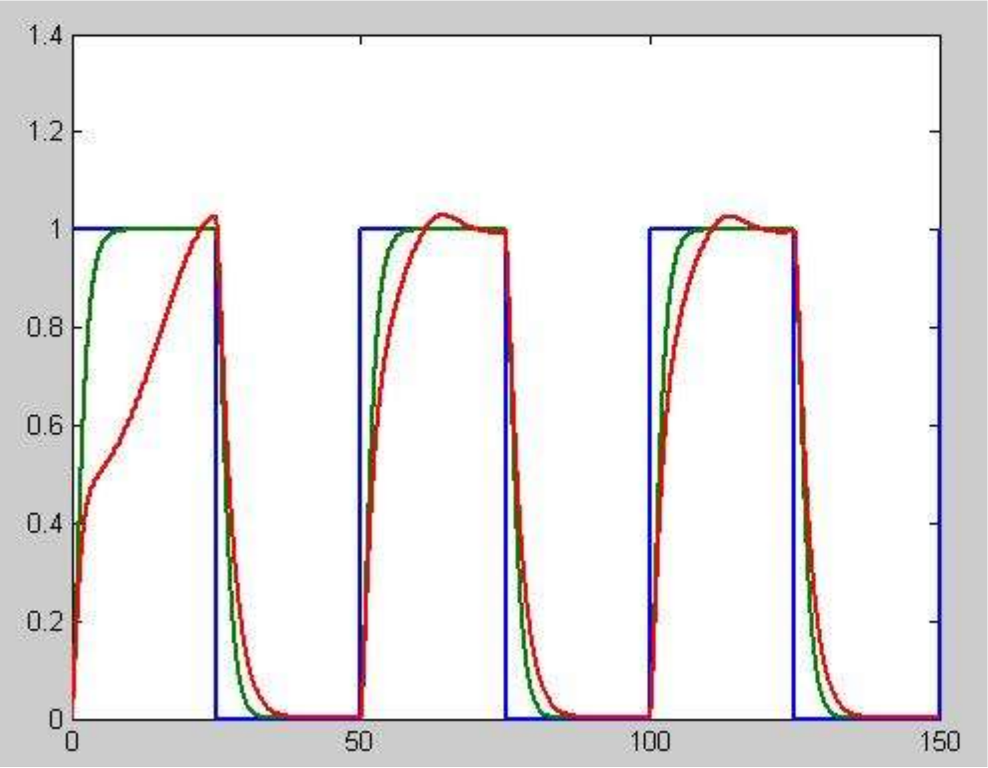
Simulation

MRAC is set to zero



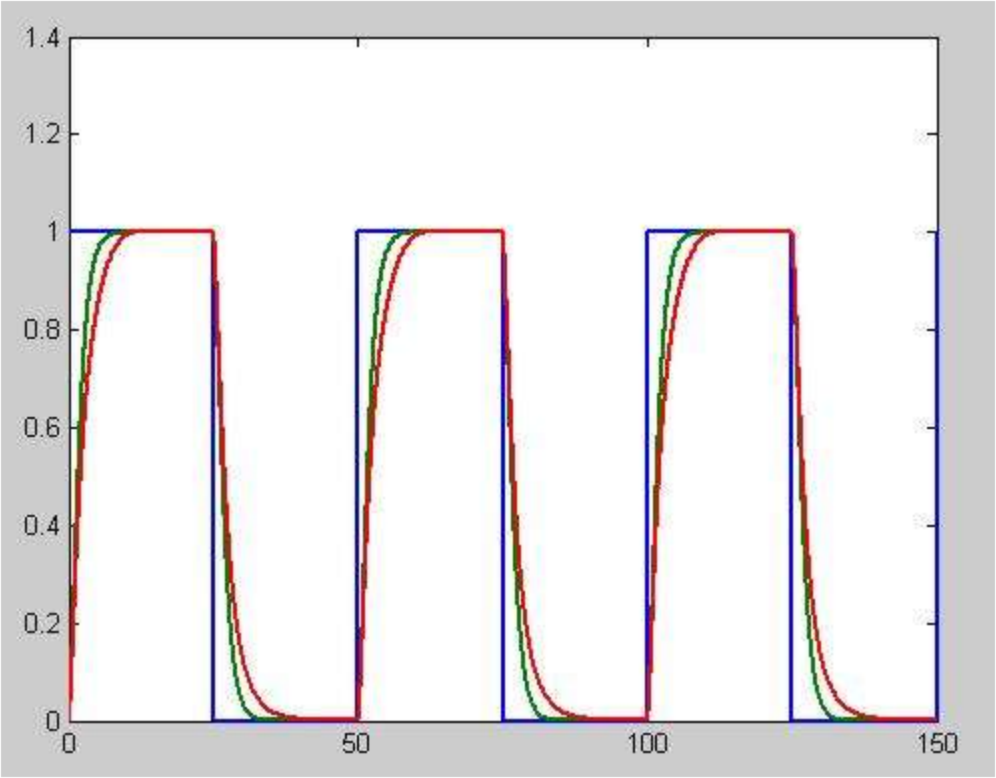
Simulation

LQR is set to zero



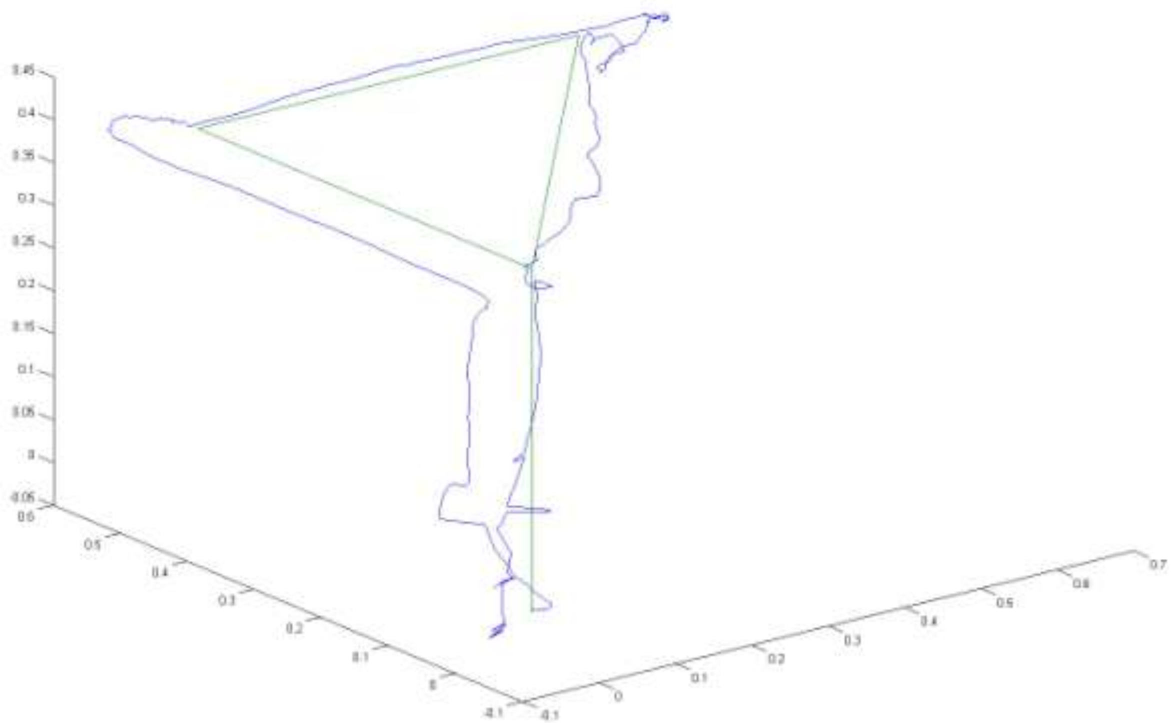
Simulation

MRAC+LQR



Implementation

Triangle trajectory tracking



Conclusions

1. Model Reference Adaptive Control forces the dynamic response of the controlled plant to approach asymptotically to that of reference model
2. MRAC and LQR give the best performance to the system.
3. The MIT rule is the only method applied on Qball for this project and the result is satisfactory.
4. Model Reference Adaptive Control is very robust to disturbance

Thank you

Questions