Adaptive Control

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About me

Qualification:

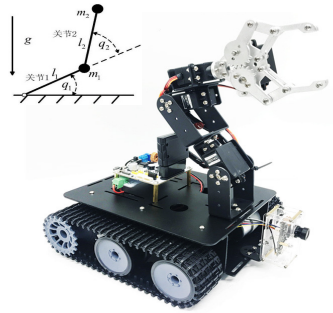
2013 Bachelor degree in Tongji University, Automation

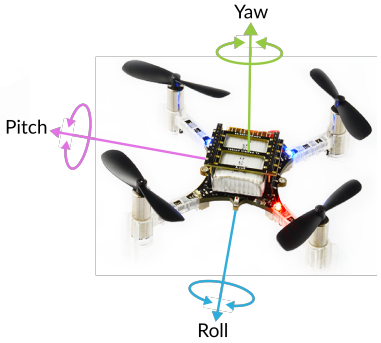
2014 Master degree in ICL, Control Systems

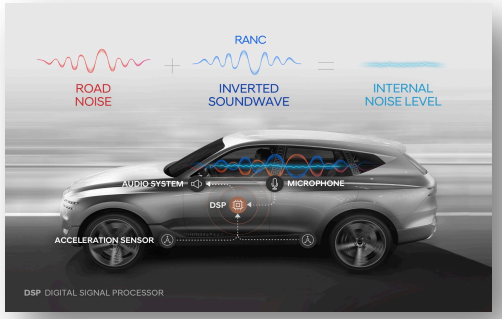
2019 Doctor degree in ICL, Control Theorem

Research Interests:

Nonlinear systems, Adaptive control, Parameter estimation, Multi-agent system control, Active disturbance rejection, etc.







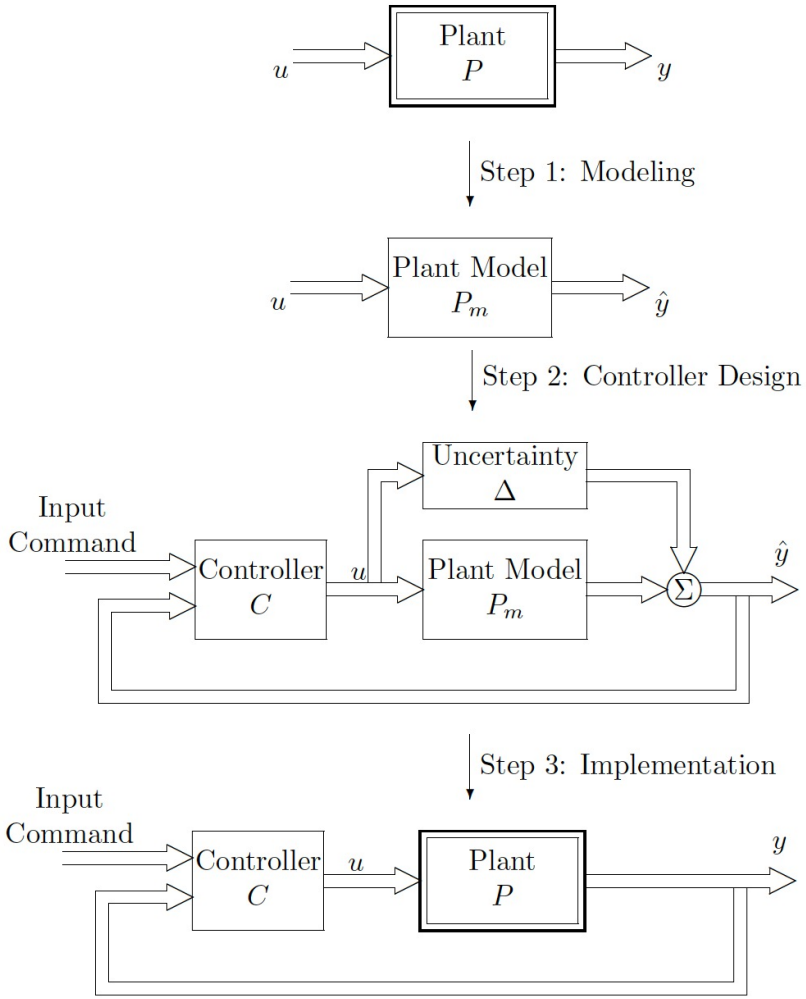
How much do you know about control?

- Transfer function
- State-space
- Open-loop
- Feedback
- PID control

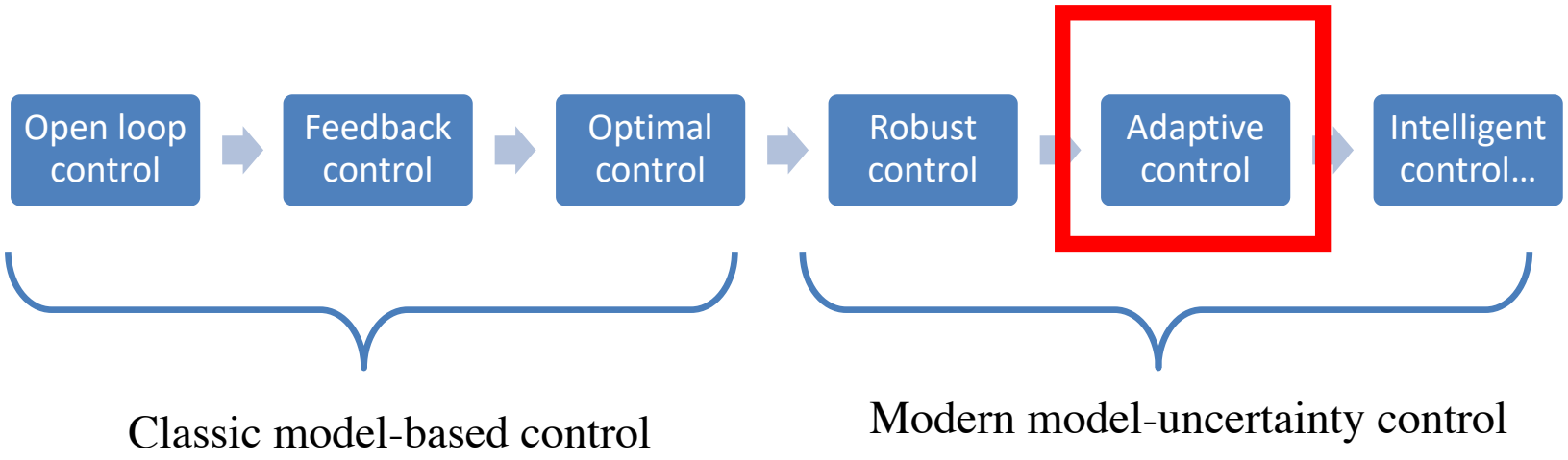
- Controllable &Observable
- Poles and zeros
- Hurwitz
- Bode Diagram

- Asymptotically Stable
- Minimum phase
- Relative Degree
- Persistent Excitation
- Input-to-state stable
- Least-square
- Model Reference Control

A general control design steps



About Adaptive Control



Adaptation:
change oneself so that its behaviour will conform to new, unknown or changed circumstances.

About Adaptive Control

Motivating Example:

$$\dot{x} = ax + u$$

Feedback control law:

$$u = -k\,x$$

with $k > |a|$.

What if the value of a is unknown?

Robust control law:

$$k > \max|a|$$

Adaptive control law:

$$\dot{k} = x^2$$

About Adaptive Control

Definitions

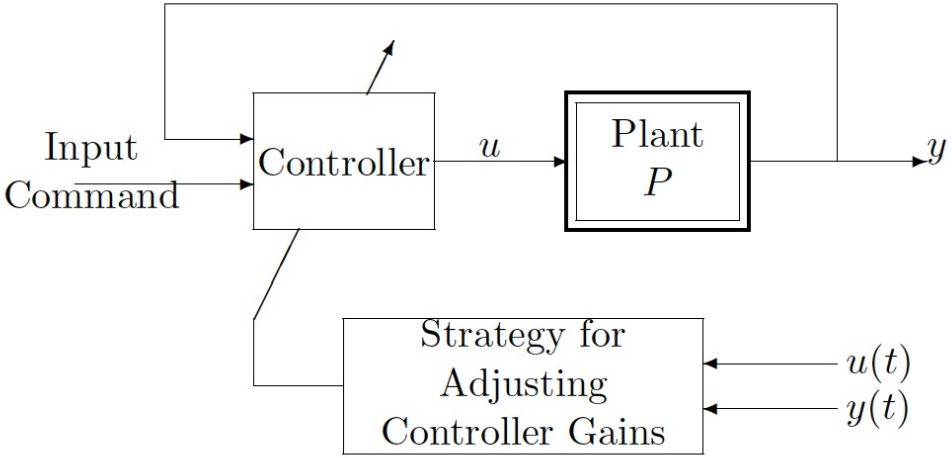
- A combination of parameter estimation which generates parameter estimates online, with a control law in order to control the **plants with some parameters are completely unknown or change with time in an unpredictable way**.
- A technique of applying some system identification technique to obtain a model of the process and using this model to design a controller. The parameter of controller are adjusted **during the operation of the plant** as the amount of data available for plant identification increases.
- 在控制系统的过程中，系统本身不断地测量被控对象的状态，性能或参数，从而‘认识’或‘掌握’被控对象，然后根据掌握的被控对象信息，与期望的性能相比较，进而做出决策来改变控制器的结构和参数，或者根据自适应规律来改变控制作用。

Key factors:

- Uncertain system : unknown or slowly time-varying
- Online estimation/identification: Learning
- Automatic adjustment of controller

About Adaptive Control

A general structure



The controller structure consists of a feedback loop and a controller with adjustable gains. The way of changing the controller gains in response to changes in the plant and disturbance dynamics distinguishes one scheme from another.

About Adaptive Control

Classification
- Direct Adaptive control
- Indirect Adaptive control

Classic methods
- Gain scheduling
- Self-tuning regulators
- **Model reference adaptive control**
- **Adaptive pole placement control**

Advanced methods
- Robust adaptive control
- Switching adaptive control
- Self-organization adaptive control
- Adaptive optimal control
- Adaptive sliding-mode control
- Adaptive fuzzy control
- NN-based adaptive control

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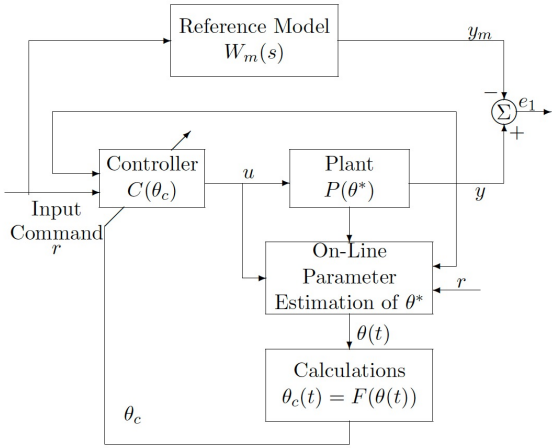

Figure 1.9 Indirect MRAC.

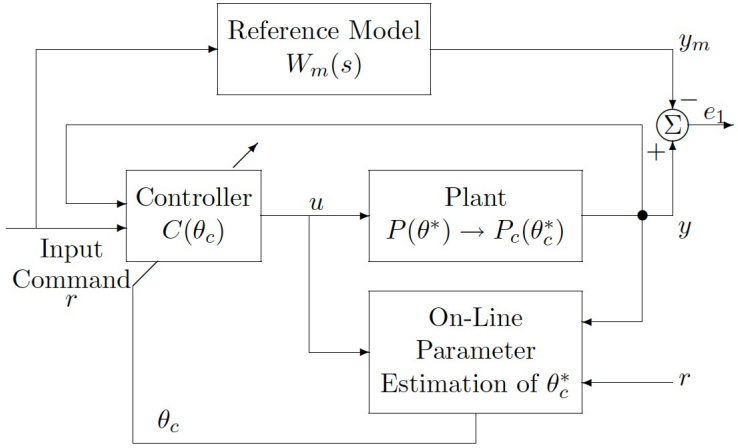

Figure 1.10 Direct MRAC.

About Adaptive Control

Applications：

Flight control(1950s MIT)

Autonomous driving

Electrical system, power flow control

Process control

Mechanical system, robotic manipulator

Economic system

Biological system

…

About the Course

This course gives an introduction to methods for adaptation and learning in control of dynamic system with uncertain parameters, including:

- Basic stability theory
- On-line parameter Learning
- Direct and indirect adaptive control algorithms
- Other advanced topics

Who will benefit?

a)Students simply interested in algorithms without fully understanding the analytic and technical proofs.(30%)

b)Students also want to understand the analytic schemes for more complex texture.(40%)

c)Students who want to study and understand the detail of the long and technical proofs as training for pursuing research in adaptive control and related topics.(30%)

About the Course

- Learning Outcomes

a) Apply on-line parameter estimation algorithm.

b) Develop an adaptive and learning control system.

c) Detailed knowledge of methods and tools of stability analysis of nonlinear system

d) Be able to communicate with control experts

e) GET 4 credit hour

About the Course

How to achieve our goals：

Lecture time： every Wednesday and Friday morning 10:15-11:55am.

Lecture style： slides + English whiteboarding writing + Chinese explanation

Office Hour: every Wednesday afternoon 1:30-2:30 pm, 1D201E

All information about the lecture slides, news, homework, references, project requirements etc. will be on BlackBoard！

About the Course

Week 1 Parametric Models	Week 2 Stability Theory	Week 3 Stability Theory	Week 4 Parameter Estimation
Week 5 Parameter Estimation	Week 6 MRAC	Week 7 MRAC	Week 8 MRAC
Week 9 APPC	Week 10 APPC	Week 11 Robust Adaptive Control	Week 12 Robust Adaptive Control
Week 13 Aerospace Applications	Week 14 Other Advanced Topic(exam irrelevant)	Week 15 Other Advanced Topic(exam irrelevant)	Week 16 Project Presentation

About the Course

Grading:

Homework(20%)+Project(30%)+Final Exam(40%)+Attendance(10~15%)

Homework:

- Biweekly, around 5-6 times
- Submit the e-version on BB
- **1~1.5 week** time to finish, ASK early if you are absolutely no idea
- TA will grade the homework, complain within **one week** after you get your feedback

Attention:

Do it by yourself!

About the Course

Grading：

Homework (20%)+Project(30%)+Final Exam(40%)+ Attendance(10~15%)

Project in terms of journal paper:

Via the project, you will learn advanced technique in adaptive control and learn some simple stability analysis，learn how to use the simulation to verify your algorithm.

- A 30-mins oral presentation on the 15-16th week（20%）
- A final report(mainly the simulation) due on 18th week(10%)

You can propose your own project, some recommended topic will be given after mid-term.

Attention: Independently!

About the Course

Grading：

Homework (20%)+Project(30%)+Final Exam(40%)+ Attendance(10%~15%)

Final Exam(40%):

Closed-book exam with a A4 cheat sheet

Generally, Friday on the 17th week

I will organize a review lecture before the exam

Attendance(10%-15%):

No more than 3 times absence (10%) or you can propose an oral examination to justify your absence

Impressive behavior including (5%)

Attention:

没有传说中的按比例挂人!

Academic integrity! Cheating is mission impossible.

About the Course

Preparation：

- Pen and paper;
- Brain and a brave heart to embrace math;
- Matlab 2017+;
- Basic knowledge on Linear systems and Linear Algebra : concepts like rank, inverse, state space, eigenvalue.
- Textbooks:

1) P. Ioannou and Baris Fidan, Adaptive control tutorial, SIAM, Philadelphia, PA, 2006

2) P. A. Ioannou, J. Sun, Robust Adaptive Control, Prentice-Hall, 1996, reprinted by Dover in 2012.

3) S. Sastry and M. Bodson. Adaptive Control: Stability, Convergence and Robustness. Prentice Hall, Upper Saddle River, NJ, 1989.

About the Course

- References:

1) Classic control: Bishop，Modern Control Systems，Prentice Hall，2010
2) Nonlinear system: H.K.Khalil, Nonlinear Systems, Prentice-Hall, 2002 (third edition).
3) Chinese version: 陈新海 李言俊 周军，自适应控制及应用，西北工业大学出版社， 1998
4) Available in Library :张卫忠自适应控制理论与应用,北京理工大学出版社有限责任公司 ,2019

Hope we all enjoy the 64 hours we are going to spend together!