Teaching Control Engineering Courses: Is integrating theory & practice a recipe for success?

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- The story
- EnDiF courses
- Control topics in Engineering programs
- Combining theory concepts with practice
- Engaging students: learning by doing
- Bridging theory & practice: tools & examples
- Is a recipe for success?
- Final remarks

The Engineering Institute

The Engineering Institute

- Our story: from the Institute to Department
- 1990: the Faculty of Engineering
- 2012: the Department of Engineering
- Courses organisation
  - – 1992: academic year of 8 months
  - 1993: 2 semesters
  - 2000 – 2004: from bimester to trimesters
  - 2005 – : 2 periods of 4 months per year

Engineering Dept: EnDiF

Engineering Dept: EnDiF

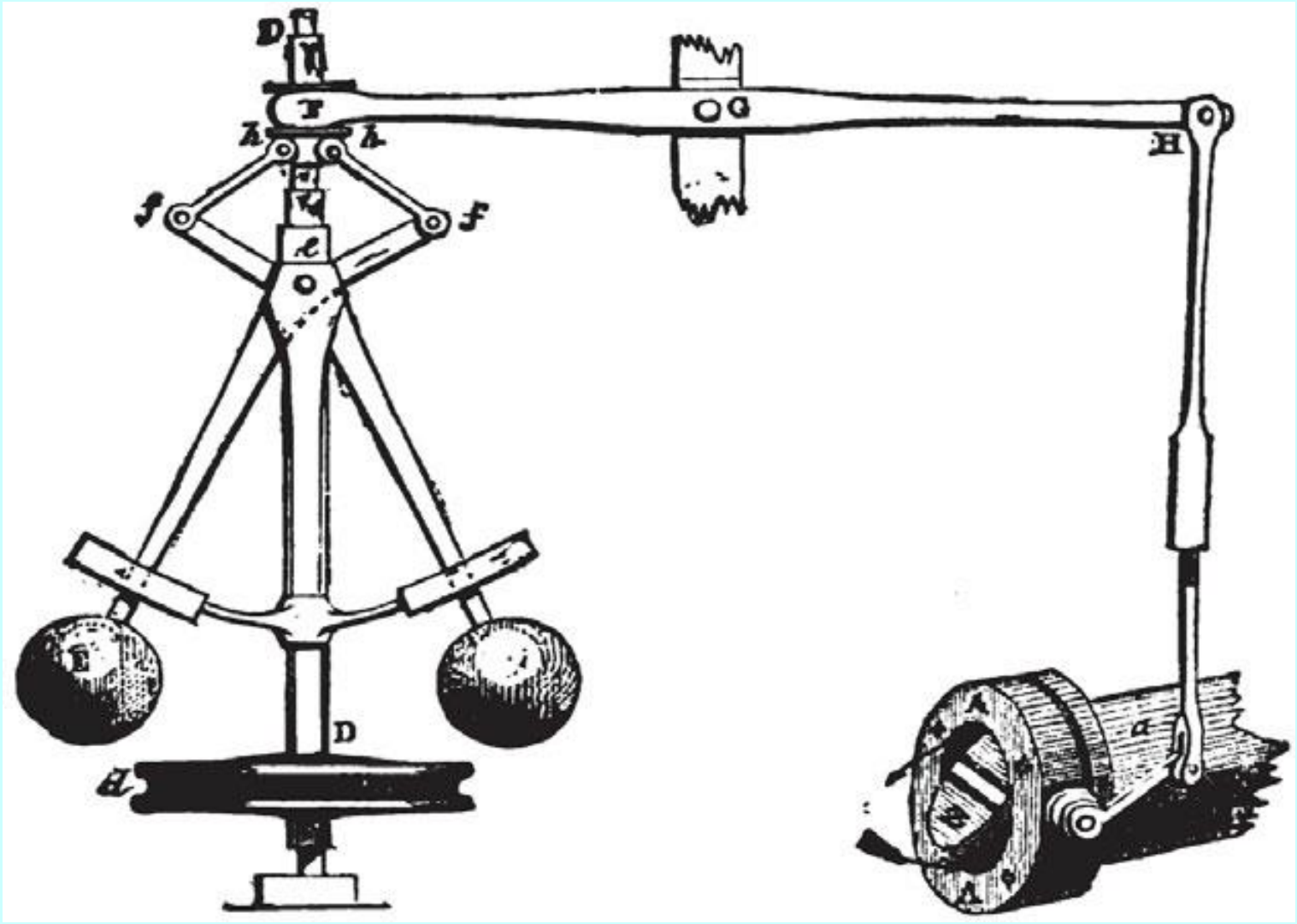
- – 2000: from 5 years degree to 3 + 2
- Bachelor and Master programs: 3 + 2
  - 4 groups: Computer Science, Electronics, Telecommunications and Automatic Control
- 1 common Bachelor degree in Electronics & Computer Science (2012, former ‘Information Science’)
- 2 Master degrees in Automatic Control & Computer Sciences, Electronics & Telecommunications

Current Organisation

Engineering Curriculum

- Bachelor program:
  - 1st year: Mathematics, Physics & Computer Science basic courses
  - 2nd year: Mathematics, Physics & Computer Science basic courses + curricula courses
  - 3rd year: curricula courses (Elect. or Comp. Sc.)
- Master program:
  - 1st year: basic + elective courses
  - 2nd year: elective courses

Control Topics in BSc & MSc



Control Topics in BSc & MSc

- ✓ Bachelor program:
  - 2nd year: Automatic Control (II semester)
  - 3rd year: Digital Control Systems + System Identification (II semester)
- ✓ Master program:
  - 1st or 2nd year: Advanced Control Techniques + Fault Diagnosis (I semester)
- ➢ 2002 – : reduction in teachers' hours
- ➢ Laboratory facilities & tools
- ➢ Courses' organisation & BSc/MSc structure
- ❖ Teaching strategy 'optimisation'

Theory & Practice Integration

Theory & Practice Integration

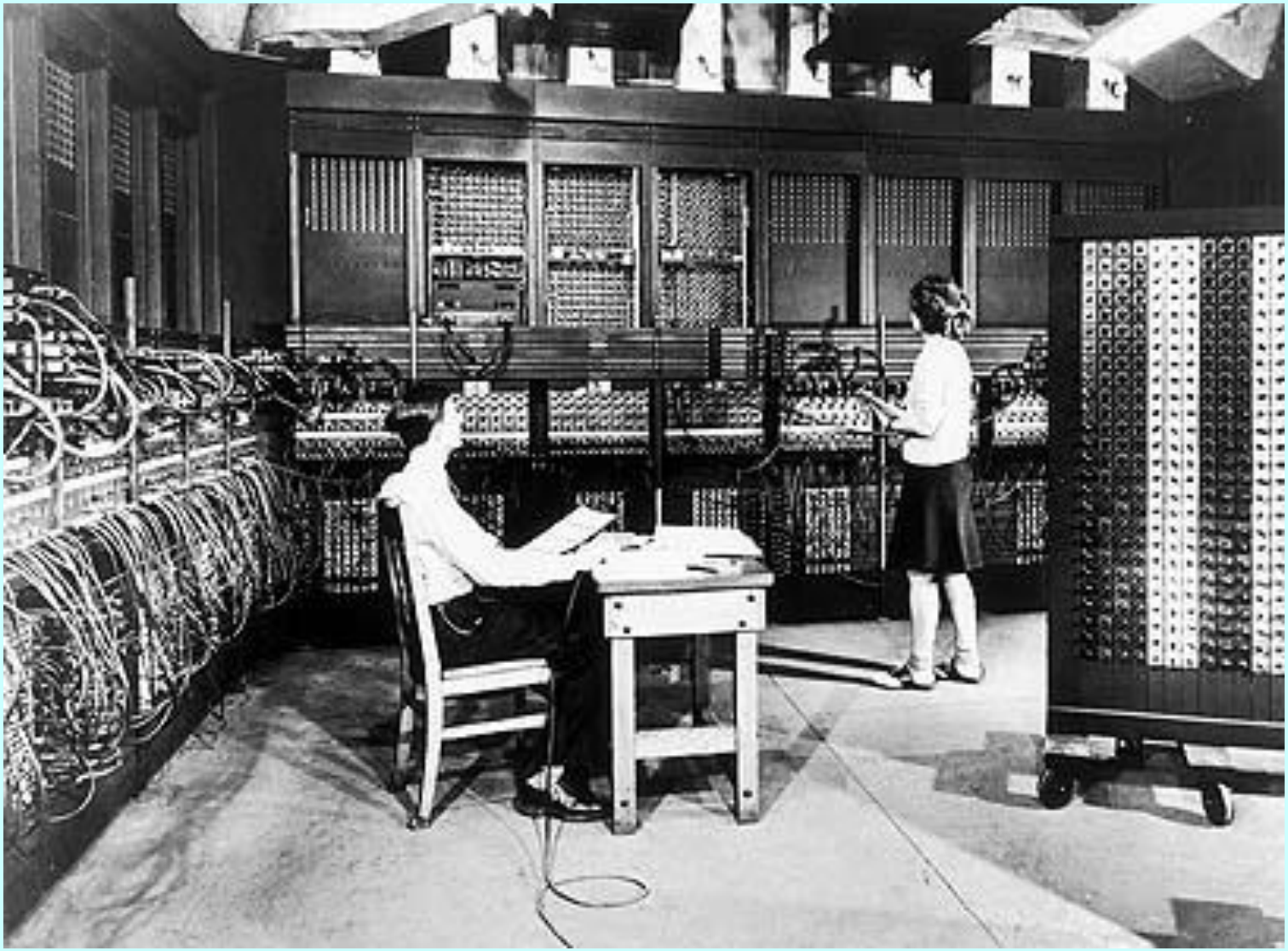
- ✓ Difficult task:
  - ‘Substrate’ quality
  - Previous basic course levels (instructor skills)
  - Lecture distribution: lecture rooms & labs facilities
  - Variable course topic development
- ✓ ‘Adaptive’ system
- ✓ Standard tools? Apps, GUI, …
- ❖ Teaching methodology ‘optimisation’
- ➢ Matlab & Simulink

Engaging Students

Engaging Students

- ❖ Learning by doing
- ❖ Bridging theory & practice
- ➢ Tools: Matlab & Simulink basics
  - 2nd & 3rd years of BSc
- ✓ Automatic Control & Digital Control Systems
- ✓ 2016: Basic issues of Estimation Theory
- ❖ 'Adaptive' teaching strategy required
- ➢ Matlab & Simulink @ EnDiF

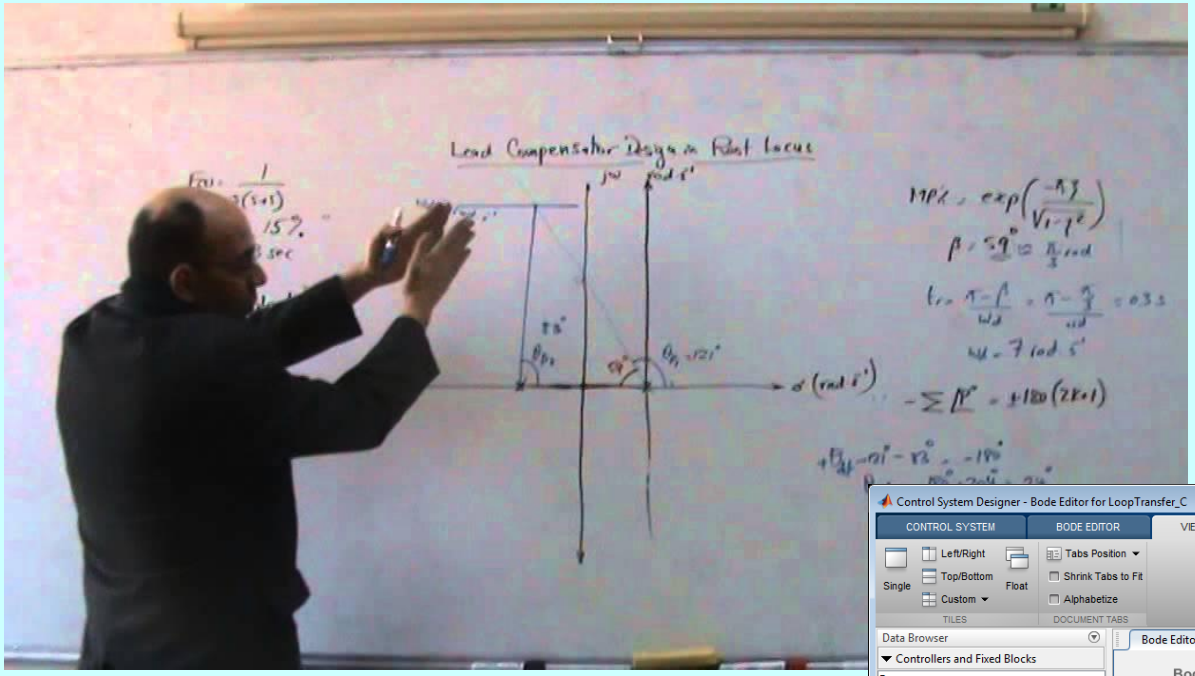
Numerical Tools

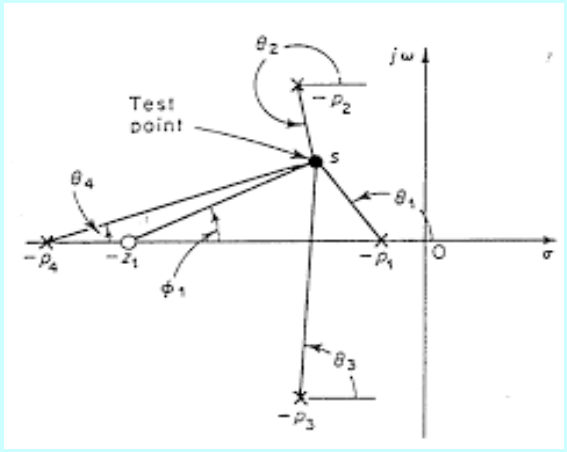


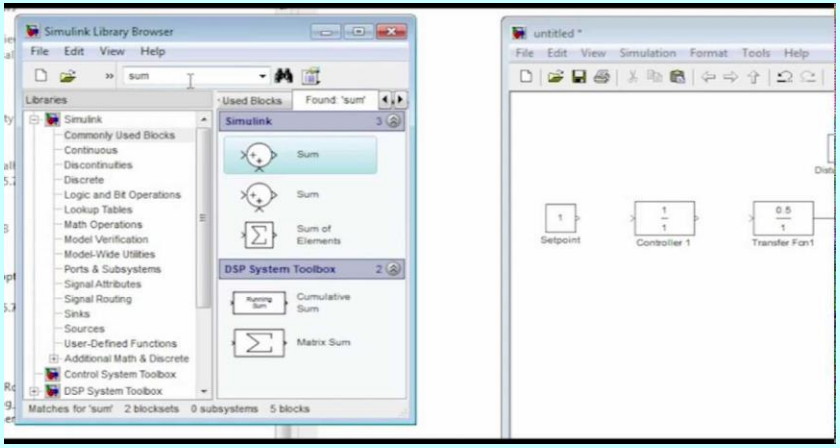
Numerical Tools

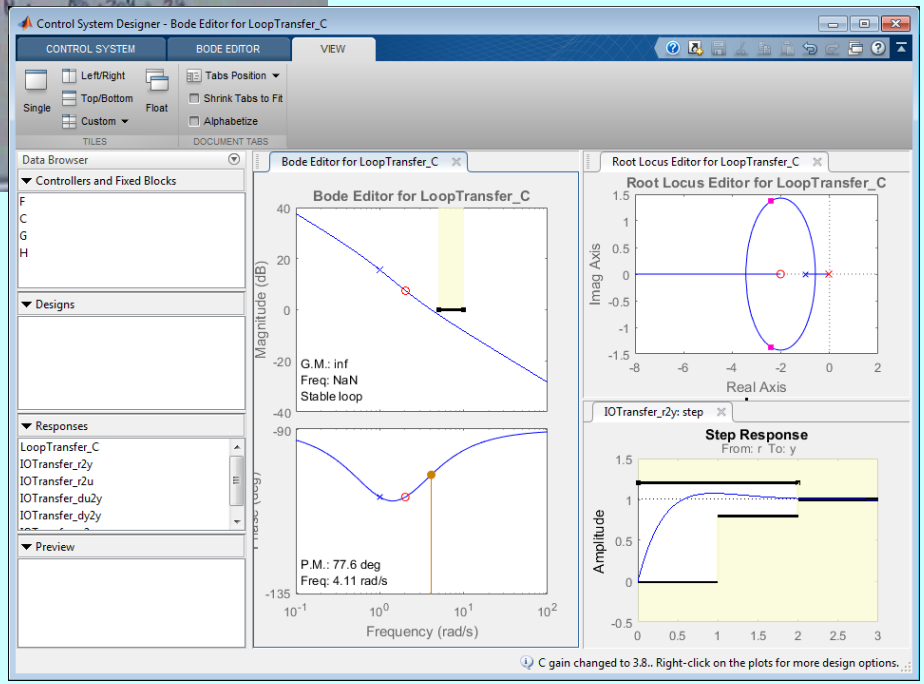
- ❖ 1993: Matlab @ Ferrara University
- ❖ 1999: Simulink
- ➢ Other numerical & programming codes
  - ➢ Pascal, Fortran, C…
- ✓ 2000: Matlab & Simulink used in Automatic Control courses & lecture notes
- ✓ – 2003: practice disconnected from theory
- ❖ 'Adaptive' teaching methodology development
- ➢ Examples with Matlab & Simulink

Bridging Theory & Practice







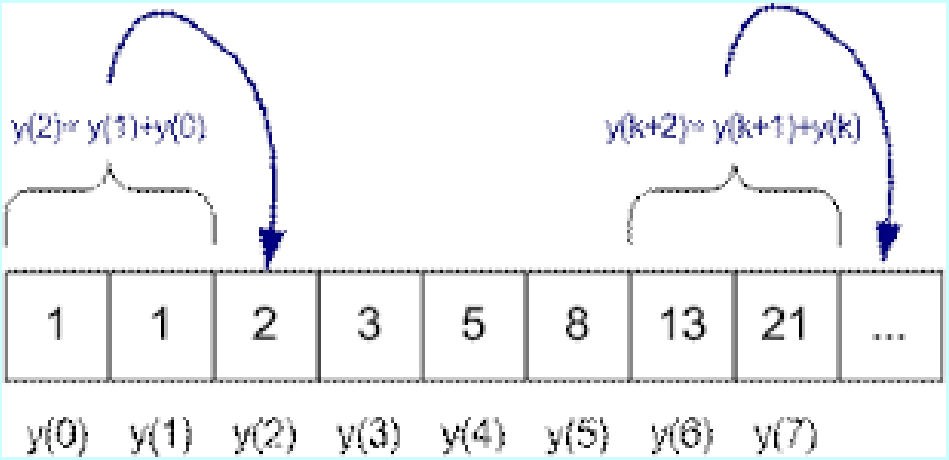


Bridging Theory & Practice (1)

- Example: difference equations (Digital Control)
- ✓ Fibonacci equation
  - From theory

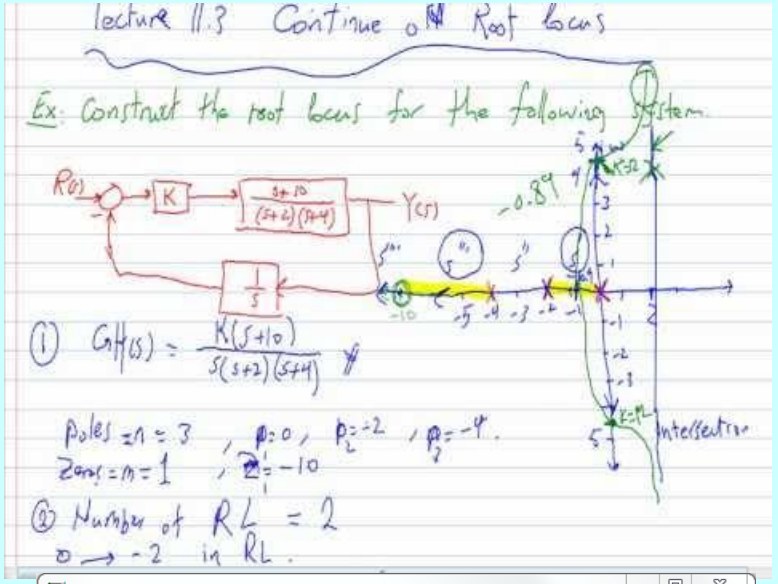
$$F_n = \frac{\left(1 + \sqrt{5}\right)^n - \left(1 - \sqrt{5}\right)^n}{2^n\left(\sqrt{5}\right)}$$

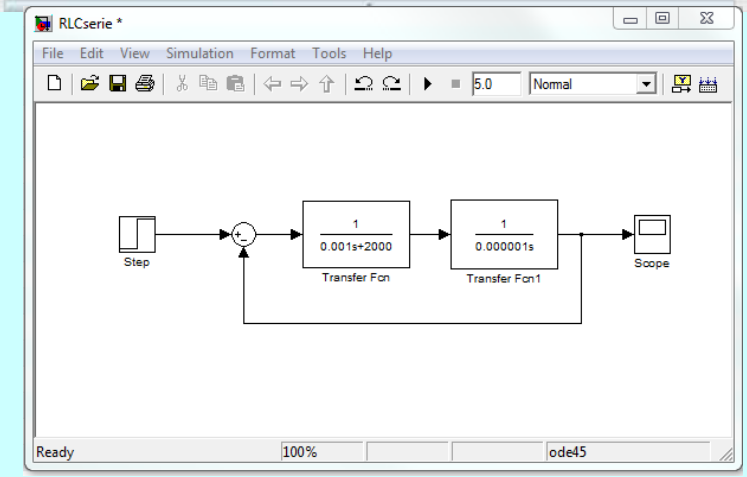
- ✓ To practice
  - Solution
  - Stability concepts
  - Matlab arrays
  - Graphs
  - Simulin blocks



Bridging Theory & Practice (2)

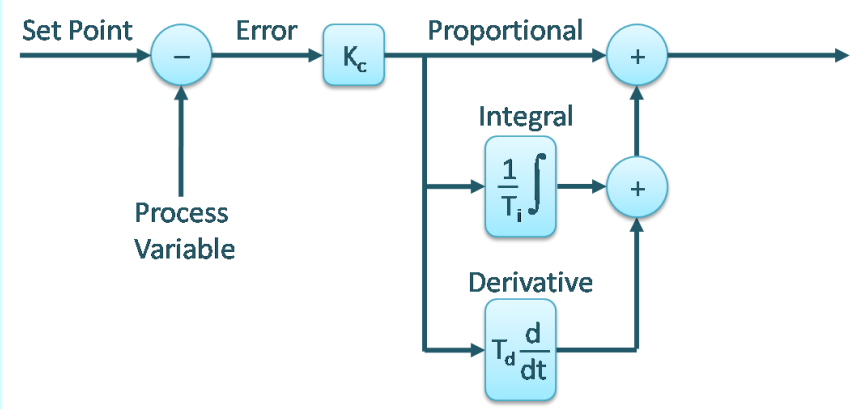
- Example: digital control system design
- ✓ Analytical approach
  - From theory
- ✓ To practice
  - Transfer functions
  - Root locus
  - Lead & lag networks
  - Simulink PID autotuning
  - Advanced control…



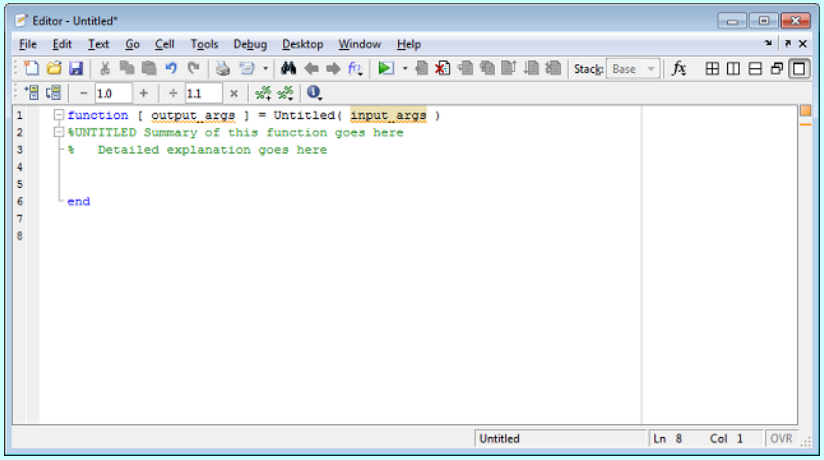


Bridging Theory & Practice (3)

- Example: PID controllers
- ✓ Design approach
  - Z-N + oscillation method
- ✓ To practice
  - Critical gain
  - PID parameters
  - Autotuning with Simulink
  - Matlab code
  - Matlab functions

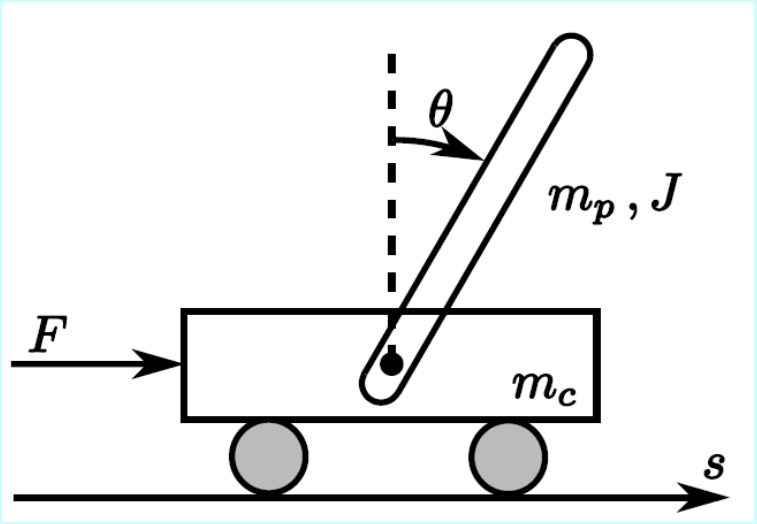


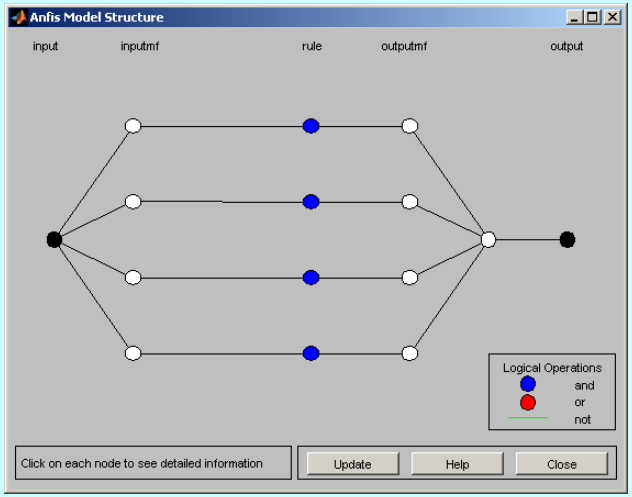
Controller	K_p	T_i	T_d
P	$0.5\,K_{cr}$	Infinity	0
PI	$0.45\,K_{cr}$	$P_{cr}/1.2$	0
PID	$0.6\,K_{cr}$	$P_{cr}/2$	$0.125\,P_{cr}$

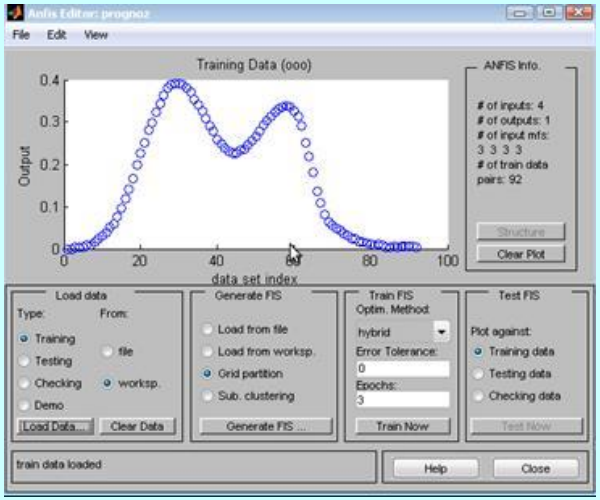


Bridging Theory & Practice (4)

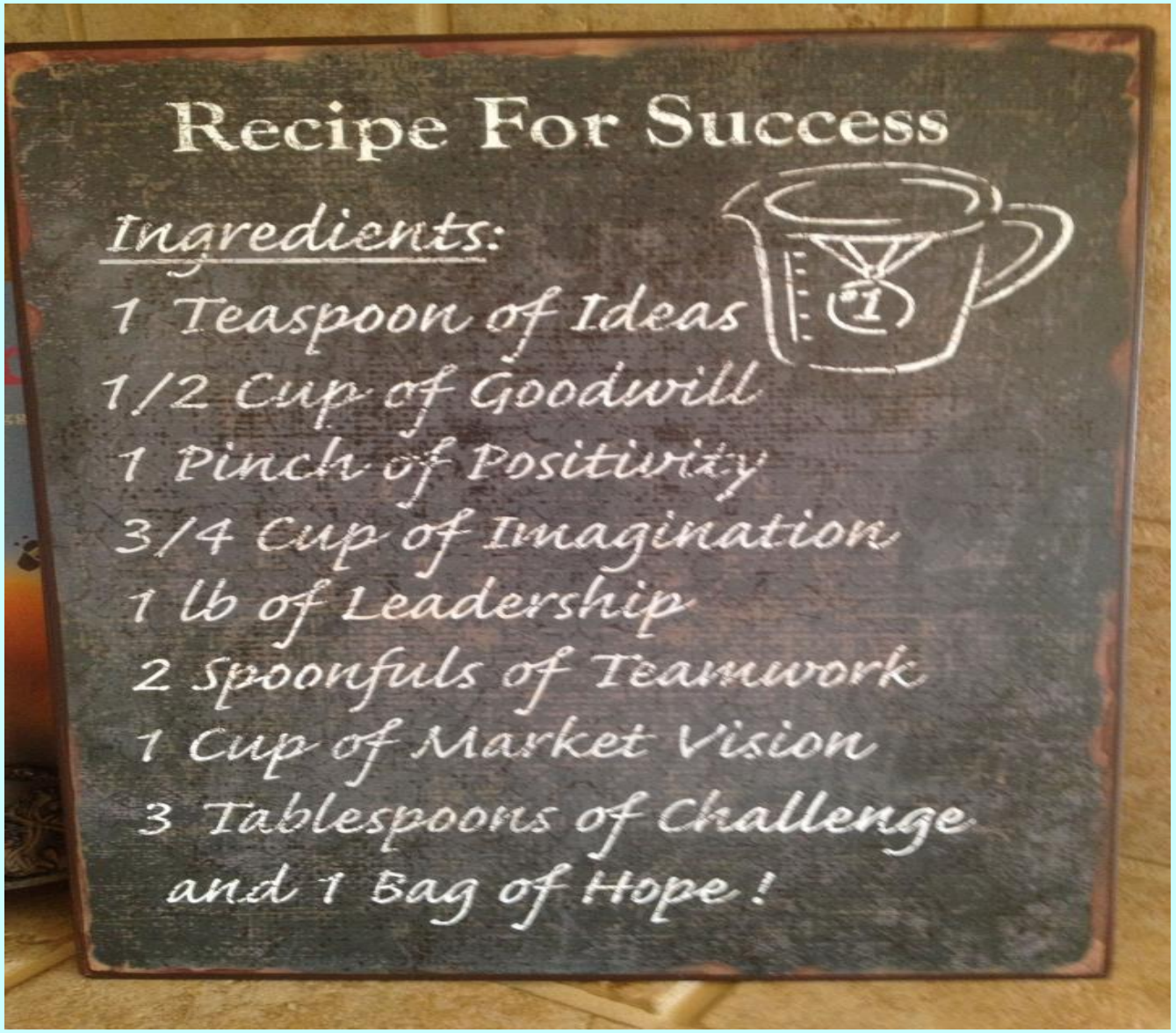
- Example: nonlinear control
- ✓ Analytical approach
  - From theory (FL - SM)
- ✓ To practice
  - Neural networks
  - Fuzzy logic
  - ANFIS
  - nntool
  - LQR/LQG







A Recipe for Success?



Bridging Theory & Practice

- Tough task
- Complex trade-off
  - ‘Substrate’ quality: varies every year
  - Topic development: changing requirements
- Lecture topic synchronisation
- Advanced tool standardisation (e.g. Apps, GUI)
- It can be enhanced using basic tools

… Still working on it!

Concluding Remaks

- ✓ Theory & practice integration
- ✓ Matlab & Simulink tools
- ✓ Integrated in Control Engineering curriculum
- ➢ Interdisciplinary teaching enhanced
- ➢ Courses are connected with a common set of tools
- ❖ University-industry technology transfer
- ❖ Independent study essential for professional engineer

Thanks You for Listening