Fundamentals

Course Introduction

Riccardo M.G. Ferrari

April 22nd, 2025

TU Delft

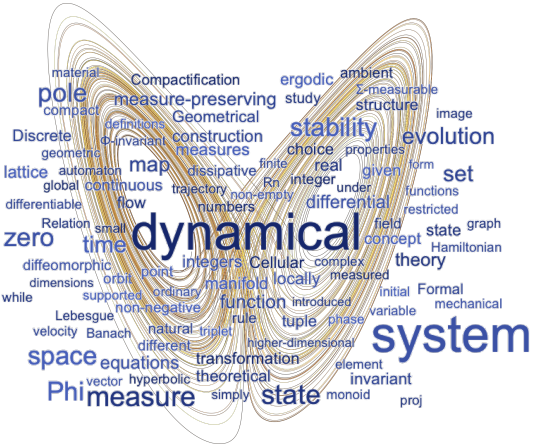
Overview

1. Pre-requisites
2. Course description
3. Resources and tools
4. Conclusion

Pre-requisites

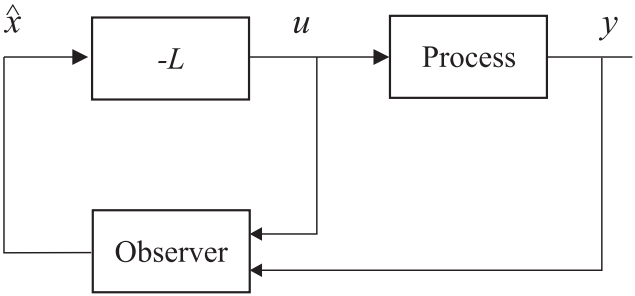
Pre-requisites

Dynamical Systems Theory



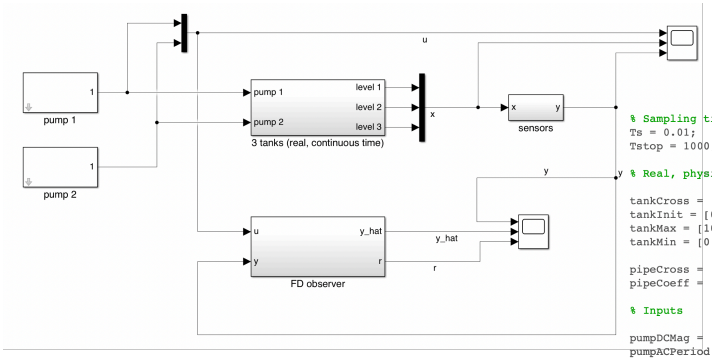
Pre-requisites

Observers and Control Systems Design



Pre-requisites

Matlab+Simulink or Python coding and simulation of dynamical systems




```
% Sampling time, stop time
Ts = 0.01;
Tstop = 1000;

% Real, physical parameters

tankCross = [0.156 0.156 0.156];
tankInit = [0 4.5 5];
tankMax = [10 10 10];
tankMin = [0 0 0];

pipeCross = [5 5 5]*1e-4;
pipeCoeff = [1 1 1];

% Inputs

pumpDCMag = [1.5 1.5]*1e-3;
pumpACPeriod = [10 50];
pumpACMagRelative = [0.1 0.25];

%Faults

faultTime = [1e6 400 1e6];
faultMag = [0 0.01 0];
```

Pre-requisites

Useful resources to integrate/build up knowledge

- **Books**
  - Stephen Lynch. *Dynamical Systems with Applications using MATLAB*. Springer, 2014, Ch. 1 to 3
  - Karl Johan Åström and Richard M Murray. *Feedback systems: an introduction for scientists and engineers*. Princeton university press, 2021
  - Dingyü Xue and Yang Chen. *System simulation techniques with MATLAB and Simulink*. John Wiley & Sons, 2013, Ch. 1 to 6
- **Courses**
  - Control Theory (SC42015)
  - Modeling of Dynamical Systems (SC42155)
  - Integration Project Systems and Control (SC42035)

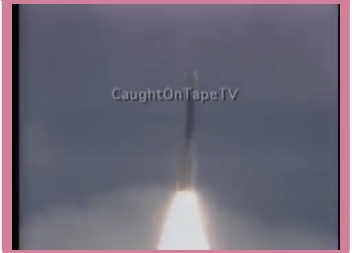
Course description

Course description

Motivation

- Making control systems and plants **fault tolerant**
- Examples of **lack of fault tolerance** (check videos here)

Delta II rocket

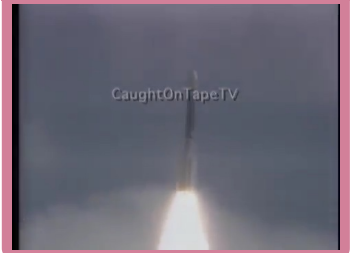


Course description

Motivation

- Making control systems and plants **fault tolerant**
- Examples of **lack of fault tolerance** (check videos here)

Delta II rocket



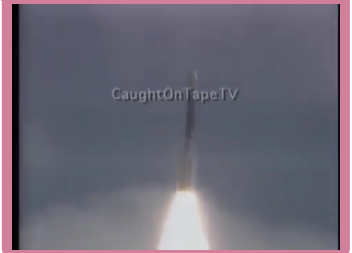
Mississippi bridge

Course description

Motivation

- Making control systems and plants **fault tolerant**
- Examples of **lack of fault tolerance** (check videos here)

Delta II rocket



Mississippi bridge

Helicopter hydraulics

Course description

Learning goals

Goal	Description	Bloom's level
G1	analyse the structure of a system, carry out a Fault Tree and a Fault Modes and Effects Analysis	analyze (4)
G2	analyse and model anomalies that can occur in a given dynamical system	analyze (4)
G3	design an algorithm for detecting, isolate and identify them	create (6)
G4	design a policy for reconfiguring the control system in order to accommodate them	create (6)

Course description

Organization

- 8 weeks of lectures, **in person**
- Theory plus in-class active learning
- **Group assignment** every Thu, deadline on Tue

Day	Mon	Tue	Wed	Thu	Fri
Classes		L1		L2	
Assignment		$\rightarrow\!\vert$		$\vert\!\rightarrow$	

$\Rightarrow$ **enroll on Brightspace!**

Course description

Topics

Week	Date	Module	Description	Lecture number	Instructor	Duration [h:mm]
17 (4.2)		***M1***	***Fundamentals***			**03:00**
	apr 22		Course Introduction	L1.1a	Rick	00:15
			Faults and failures in dynamical systems	L1.1b	Rick	00:45
			Fault diagnosis and fault tolerance	L1.2	Rick	00:30
self-study ONLINE	~~apr 24~~		Graphs and finite state machines	L2.1a	Rick	00:20
			Components and Services Model	L2.1b	Rick	00:40
			IN CLASS	C2.1	Rick	00:30
	apr 24		Homework	A1		
18 (4.3)		***M2***	***Structural Analysis***			**01:30**
	apr 29		FTA and FMEA	L2.2	Bart+Ivo	00:20
						00:40
			IN CLASS	C2.2	Bart+Ivo	00:30
		M3	***Change detection algorithms***			**03:00**
	mag 01		Fundamentals	L3.1a	Rick	00:15
			Basic Probabilistic tests	L3.1b	Rick	00:45
			IN CLASS	C3.1	Rick	00:30
	mag 01		Homework	A2		
19 (4.4)						
	mag 06		Advanced probabilistic tests	L3.2	Rick	01:00
			IN CLASS	C3.2	Rick	00:30
		M4	***Signal-based fault diagnosis***			**03:00**
	mag 08		Time and Frequency analysis	L4.1a	Rick	00:20
			PCA	L4.1b		00:30
			Matrix Profile	L4.1c	Rick	00:20
			IN CLASS	C4.1	Rick	00:20
	mag 08		Homework	A3		

Course description

Topics

20 (4.5)						
	mag 13		AI & ML for signal-based detection	L4.2	Bart+Ivo	01:00
			IN CLASS (bring your laptop)	C4.2	Bart+Ivo	00:30
		M5	***Model-based fault diagnosis***			**03:00**
	mag 15		Filtering approaches	L5.1	Rick	00:30
			Observer-based detection	L5.2	Rick	00:30
			IN CLASS	C5.1	Rick	00:30
	mag 15		Homework	A4		
21 (4.6)						
	mag 20		Robust thresholds	L5.2	Rick	00:30
			Fault isolation and learning	L5.3	Rick	00:30
			IN CLASS	C5.2	Rick	00:30
		M6	***Fault tolerant control***			**06:00**
	mag 22		Introduction to Fault Tolerand Control	L6.1	Rick	00:30
			Model matching		Rick	00:30
			IN CLASS	C6.1	Rick	00:30
	mag 22		Homework	A5		
22 (4.7)						
	mag 27		Virtual sensors	L6.2	Bart	00:20
			Virtual actuators		Bart	00:40
			IN CLASS	C6.2	Bart	00:30
	~~mag 29~~					
	~~mag 29~~		Homework	A6.1		

Course description

Topics

23 (4.8)						
	giu 03		Learning-based Methods and Control Allocation for FTC	L6.3	Rick	00:20
			IN CLASS	C6.3	Rick	01:10
	giu 05		Recent advancements on adaptive methods	L6.4	Rick	00:45
			IN CLASS	C6.4		00:45
	giu 05		Homework	A6.2		

24 (4.9)		***M7***	***Extra topics***			**03:00**
	giu 10		ML&AI for FDI and FTC	L6.5a	Rick	00:45
			IN CLASS	C6.4		00:45
	giu 12		Cybersecurity for Industrial Control Systems		all	01:30

Course description

Assessment

Element	Weight
Homework (group assignments)	30%
Final exam (written, individual test)	70%

Resources and tools

Resources and tools

Books

- **Mogens Blanke et al. *Diagnosis and fault-tolerant control*. Vol. 2. Springer, 2006**
- Rolf Isermann. *Fault-diagnosis systems: an introduction from fault detection to fault tolerance*. Springer Science & Business Media, 2006
- Michele Basseville, Igor V Nikiforov, et al. *Detection of abrupt changes: theory and application*. Vol. 104. prentice Hall Englewood Cliffs, 1993
- Jie Chen and Ron J Patton. *Robust model-based fault diagnosis for dynamic systems*. Vol. 3. Springer Science & Business Media, 2012
- Steven X Ding. *Model-based fault diagnosis techniques: design schemes, algorithms, and tools*. Springer Science & Business Media, 2008
- George J Vachtsevanos et al. *Intelligent fault diagnosis and prognosis for engineering systems*. Vol. 456. Wiley Hoboken, 2006

Resources and tools

Software and tools

- **Coding and simulation**
  - Matlab and Simulink
- **Material dissemination, news, assignments**
  - Brightspace
- **Online collaboration**
  - Microsoft Teams

https://teams.microsoft.com/l/team/19%3ANx4HYIHLf05fQcLtQHmQ00PxI80shJJKvs2FTM6o0hg1%40thread.tacv2/conversations?groupId=49107539-c634-4f20-9012-495b83cdc3aa&tenantId=096e524d-6929-4030-8cd3-8ab42de0887b

Resources and tools

Staff

Course Responsible Instructor: Dr. Riccardo Ferrari
Email: r.ferrari@tudelft.nl
Teaching on: Tuesdays + Thursdays (some)

Teaching Assistants: Bart Wolleswinkel, Ivo van Straalen
Email: B.Wolleswinkel@tudelft.nl, i.vanstraalen@tudelft.nl
Teaching on: Thursdays

Conclusion

Conclusion

In this lecture we covered

- **Pre-requisites**
- Course **description**
- **Learning goals**
- **Structure** and **dates**
- **Assessment**
- **Resources** and **tools**
- **Staff** and **support**

Conclusion

Thank you for your attention!

For further information:

Course page on **Brightspace**

or

our **MS Team**

References I

Karl Johan Åström and Richard M Murray. *Feedback systems: an introduction for scientists and engineers*. Princeton university press, 2021.

Mogens Blanke et al. *Diagnosis and fault-tolerant control*. Vol. 2. Springer, 2006.

Michele Basseville, Igor V Nikiforov, et al. *Detection of abrupt changes: theory and application*. Vol. 104. prentice Hall Englewood Cliffs, 1993.

Jie Chen and Ron J Patton. *Robust model-based fault diagnosis for dynamic systems*. Vol. 3. Springer Science & Business Media, 2012.

Steven X Ding. *Model-based fault diagnosis techniques: design schemes, algorithms, and tools*. Springer Science & Business Media, 2008.

References II

Rolf Isermann. *Fault-diagnosis systems: an introduction from fault detection to fault tolerance*. Springer Science & Business Media, 2006.

Stephen Lynch. *Dynamical Systems with Applications using MATLAB*. Springer, 2014.

George J Vachtsevanos et al. *Intelligent fault diagnosis and prognosis for engineering systems*. Vol. 456. Wiley Hoboken, 2006.

Dingyü Xue and Yang Chen. *System simulation techniques with MATLAB and Simulink*. John Wiley & Sons, 2013.