Everything underControl?

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Prof. Paul M.J. Van den Hof

ASML lithography machine



ASML lithography machine









Tip position



time



4

force





time







Through feedback control, systems can be given a performance, beyond the accuracy specs of their physical components^[1]

and become robust against disturbances

And this applies to systems in any domain of science and engineering:









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Models



Models

How does the system respond to inputs?

Model



Models

How does the system respond to inputs?

Model





Pieter Eykhoff

1974

SYSTEM

Parameter and State Estimatio Pieter Eykhoff



Lennart Ljung

1987

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A selection of research programs



Orthogonal basis functions

Finding an attractive model structure, to represent systems with only a small number of unknowns (parameters)







Orthogonal basis functions

Finding an attractive model structure, to represent systems with only a small number of unknowns (parameters)











Identification for control (1990 - ...)



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• Question:

How to identify models that are best suited for modelbased control ?

• Prime result:



Under closed-loop control of the to-be-designed controller



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Solution through iterative procedure

Modelling for control is learning

Modern version of adaptive control









EU FP7 STREP 2010-2013

Challenge:

Bring industrial process controllers to a higher level of autonomy, through effective use of online data and model / controller updating





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Sasol site Secunda, South Africa









No continuation after 2014



Reservoir Engineering (2002-2018)

Joint effort:

- TUD Systems & Control
- TUD Applied Earth Sciences
- Shell



THE VALUE OF SMARTNESS



Oil Production

- Porous rock with oil in pores
- 1 10 km underground











Oil Production

- Waterflooding (WF) popular secondary recovery process
- Smart wells have sensors and control valves
- Life time of reservoir in the order of decades
- Lack of smart operational strategy



Reservoir characteristics

- heterogenity of reservoir
- flow dynamics determined by geological structure (permeability)



(Gijs van Essen et al., CAA 2006)







• Decision making under geological and economic uncertainty









Decentralized process control



Complex machines



- (Large-scale) interconnected dynamic systems
- Data is "everywhere", Al/machine learning tools

 Learning models from data







- Introducing structure/topology
- Developing the fundamental theory



SYSTE

ORKS

ENTIFICATI

ON IN DYNA

(2014)

C NFTW

ARNE DANKERS



Many open problems





European Research Council











Diagnostics in lithography systems



- Many interconnected subsystems
- Need for very fast recovery from faults
- Tools for automated diagnostics



SYSDYNET MATLAB App and Toolbox







Researcher, supervisor, teacher and

manager





A fantastic job in an international setting



International setting





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It's all about people





The PhD students

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Building a team



Research domains – Control Systems Group





Research domains – Control Systems Group







National setting

disc dutch institute of systems and control

National setting

disc dutch institute of systems and control IFAC 2029 amsterdam

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Education

Highly rewarding

Education

2019

Why the cyber world is so much more attractive than the physical world...

Education – Challenge-based learning

• How to develop analytical skills?

• Which skills are required for engineers in the next decades?

• Delft Center for Systems and Control (2003)

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- MSc Systems and Control (2004-) National recognitions, 2010, 2019

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- MSc Systems and Control (2004-) National recognitions, 2010, 2019
- TU/e High-Tech Systems Center (2013)

Prospects of the field

- In Eindhoven: > 100 PhD students in control
- Smart production systems, energy transition, robotics, mobility

Prospects of the field

- In Eindhoven: > 100 PhD students in control
- Smart production systems, energy transition, robotics, mobility
- Model-based or data-driven ?
- Complex dynamics and large-scale interconnections

Everything under control Al

Final words and thanks

Okko Bosgra

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Jan Willems

Thank you

Ik heb gezegd

Prof. Paul M.J. Van den Hof

