Dynamics and Control

A 10-minute introduction

SPECIALIZATION MEETING FOR THE **SYSTEMS AND CONTROL MSC PROGRAM** (SEPTEMBER 13, 2022)

Alessandro Saccon, Assistant Professor

Department of Mechanical Engineering, **Dynamics & Control section**

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Mission of the Dynamics and Control Section

- Our mission is to deliver **Top-Level Education and Research** on **Dynamical Systems and Control**

- We also focus on

  (1) **Bridging the gap between System Theory and Engineering Practice**

  (2) **Fostering Collaborations with National and International Companies and Research Centers** to speed up Knowledge Transfer and Valorization

Topics within the Dynamics and Control Section

DYNAMICS

- Structural Dynamics
- Vibro-Acoustics
- Modeling and Analysis of Mechanical Systems
- Cyber-physical and Complex Systems

&

- Mechatronic Systems Dynamics and Control
- Vehicle Dynamics and Control
- Robot Control, Perception, and Learning
- Hybrid and Networked dynamics and control

CONTROL

- Control of (friction, nonsmooth effects)
- Geometric and Nonlinear Control
- Extremum Seeking Control

Dynamics & Control

Dynamics and Control of Complex Systems


Nathan van de Wouw


Sasha Pogromsky


Hans Zwart

Structural Dynamics
Model Reduction
Multiphysics Simulation


Idoia Cortes Garcia


Rob Fey

Robotics and autonomous systems

Soft-robotics Haptics/ pHRI


Irene Kuling


Alessandro Saccon


Ömür Arslan


Astrid Kappers


Bas Overvelde

Mechatronics


Marceel Heertjes


Hamed Sadeghian

Cyber-Physical and Networked Systems


Carlos Murguia


Erik Steur


Arturo Tejada Ruiz


Erjen Lefeber


Jeroen Ploeg


Mohsen Alirezaei


Tom van der Sande


Igo Besselink

Vehicle Dynamics and Control

Full professor Emeritus


Henk Nijmeijer

Vibrations & Acoustics


Ines Lopez


Geertje Janssen-Dols

Secretary


Erwin Meinders


Ruud van den Bogaert


Peter Teurlings


Harrie van de Loo

Koen de Koning

Technical staff (DSD)

plus

~80 MSc students (you!)
~30 PhD students
~5 PostDocs

Dynamics & Control

Complex and Autonomous Systems

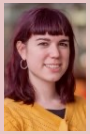
Dynamics and Control of Complex Systems


Nathan van de Wouw


Sasha Pogromsky


Hans Zwart

Structural Dynamics
Model Reduction
Multiphysics Simulation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Offered D&C courses in the MSc Program

4DM30 **Nonlinear control** (5 ECTS)
4SC050 **Performance of Nonlinear Control Systems** (5 ECTS)
4DM10 **Multibody and Nonlinear Dynamics** (5 ECTS)
4AT050 **Vehicle Control** (2.5 ECTS)
4AT000 **Vehicle Dynamics** (5 ECTS)
4DM40 **Modeling and control of Manufacturing Networks** (5 ECTS)
4DM00 **Structural Dynamics and Vibro-Acoustics** (5 ECTS)
4DM60 **Control of Distributed Parameter Systems** (2.5 ECTS)
4DM50 **Dynamics and control of cooperation** (2.5 ECTS)
4AI000 **Machine Learning for Multi-Physics Modelling and Design** (5 ETCS)
…

Research Topics (relevant for MSc assigments)

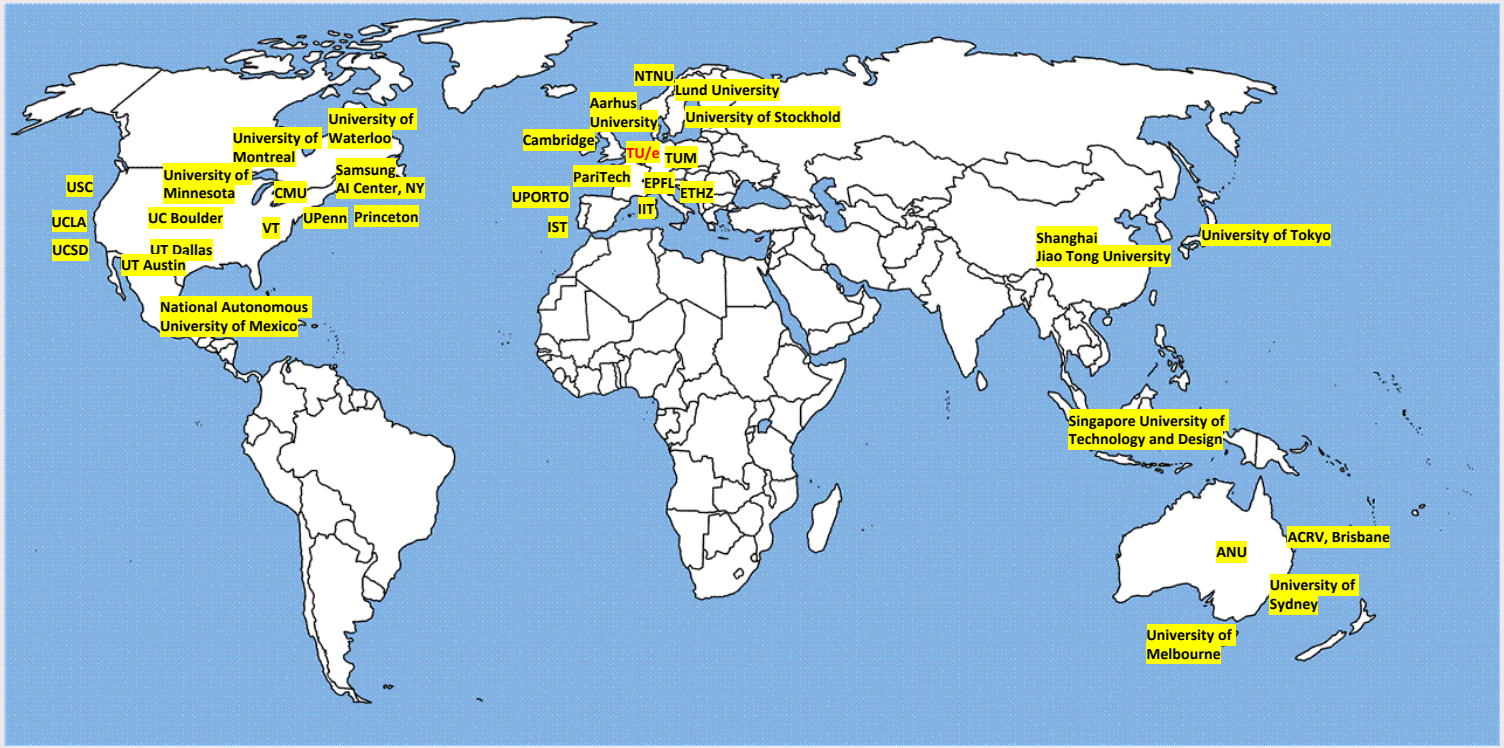
CONTROL and SYSTEMS THEORY

- **Nonlinear** control (including **nonsmooth** control and **geometric** control)
- Networked and distributed control systems / **multi-agent systems** / **cooperative control** / sensor fusion
- **Robot control for physical interaction / Robot learning** / computer vision perception for robotics
- Numerical **optimal control and optimization** / **extremum seeking** control
- Model predictive control / **motion planning**
- Output feedback tracking / **path-following** / maneuver regulation
- Model reduction
- Control of **underactuated** and **nonholonomic** systems
- **Synchronization** / Poincaré method / Bifurcation analysis
- Dynamics and control of **dynamical systems with time and spatial-delays** [… and more]

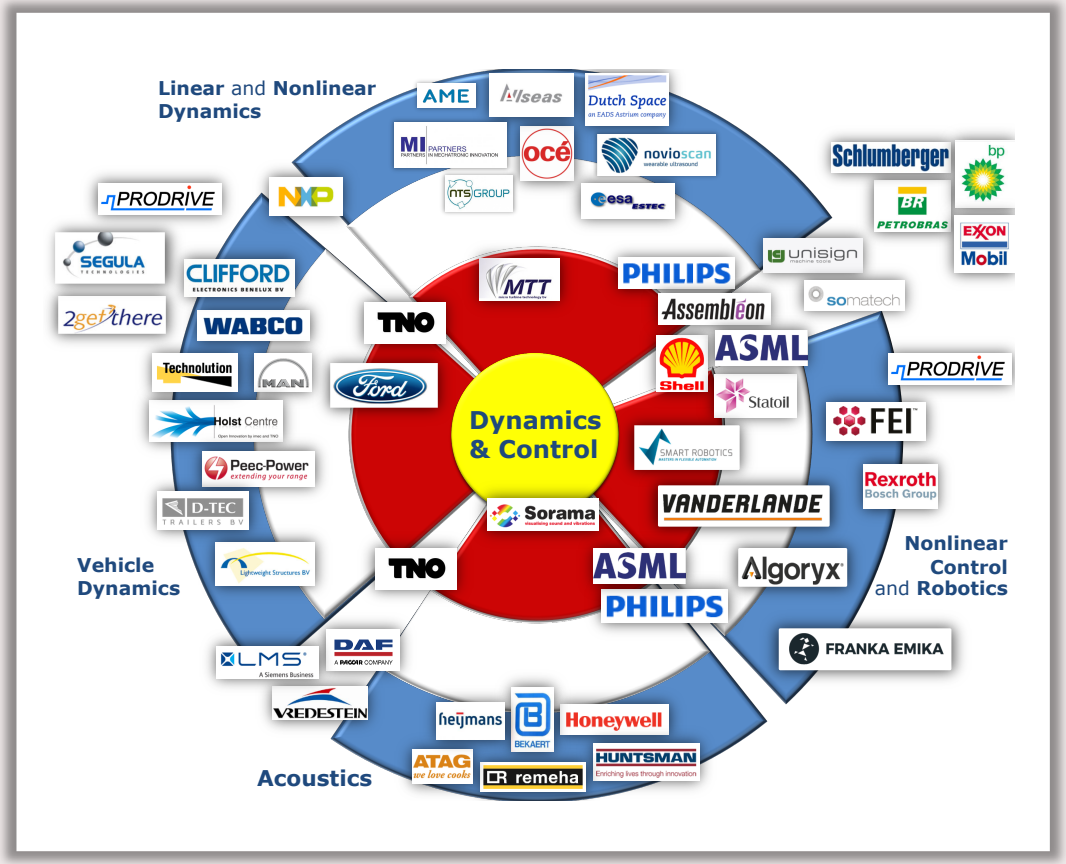
DYNAMICS

- Nonlinear and Nonsmooth Mechanics (systems with dry friction, stick/slip, contact mechanics/robotics, …)
- Multi-body dynamics
- Structural dynamics [… and more]

Main International network (for internships abroad)



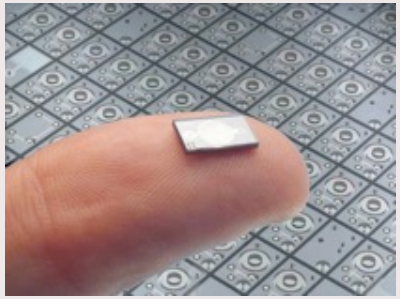
A visual impression of our industrial collaborations (relevant for national internships and MSc assigments)



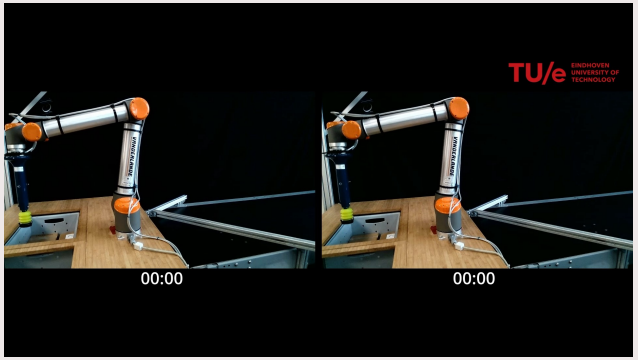
Application domains

Mechatronics

Automotive



MEMs



Robotics

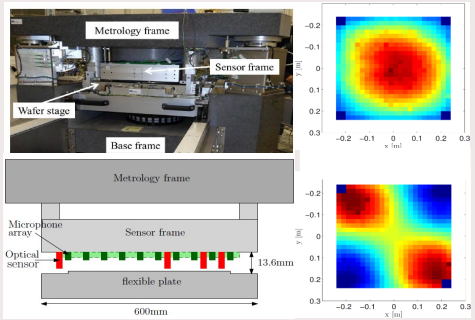
Resource exploration

Manufacturing

Sample of Dynamics & Control MSc projects

Cooperative Autonomous Cruise Control

Advanced Robotic Manipulation for Logistic Applications



Thermal Modeling for Motion/Temperature Control

Mechanical Ventilation/ Healthcare Devices

Way too many projects to try to list them! The best is for you to **take a look at the following shared folder**:

https://surfdrive.surf.nl/files/index.php/s/B62wn1vBeOADrun

Lab Tour

As opportunity to **further interact with you** and see some of our facilities for research, on **Monday September 26** (**10:45-1:00pm)**, we will organize a lab tour

- Robotics Lab
- Automotive Lab
- Vanderlande's Innovation Lab @ TU/e campus
- Motion Lab

Open **just by subscription** by sending an email to me (a.saccon@tue.nl) with subject **[D&C lab tour]**

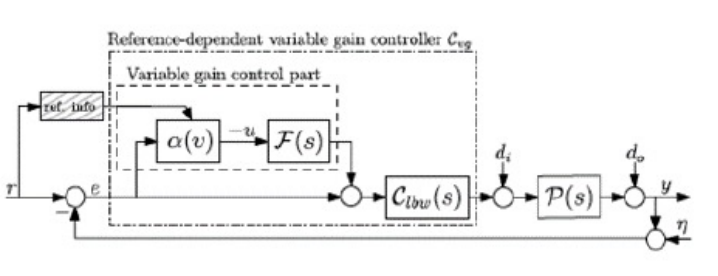
Useful links with extra information

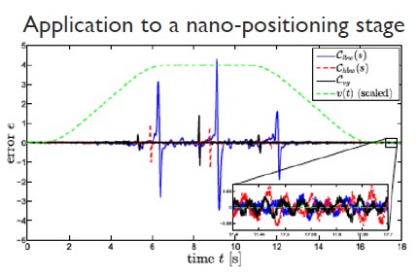
- **Dynamics and Control** offered courses https://www.tue.nl/en/research/research-groups/dynamics-and-control/education/master/
- **LinkedIn page** (follow us for news!) https://www.linkedin.com/company/eindhoven-university-of-technology-dynamics-and-control
- **Dynamics and Control** TU/e official website https://www.tue.nl/en/research/research-groups/dynamics-and-control/

The following slides, **not shown** during the oral presentation, should give you further insights about the research activities and possible MSc project assigments within the **Dynamics and Control Section** in the field of Systems and Control

Hybrid and Nonlinear Control of Motion Systems

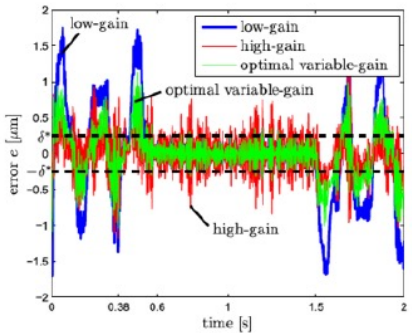
Bandwidth-on-demand control





Control of motion systems with friction
Dry friction (nonsmooth effect!)
limits performance of classical PID control

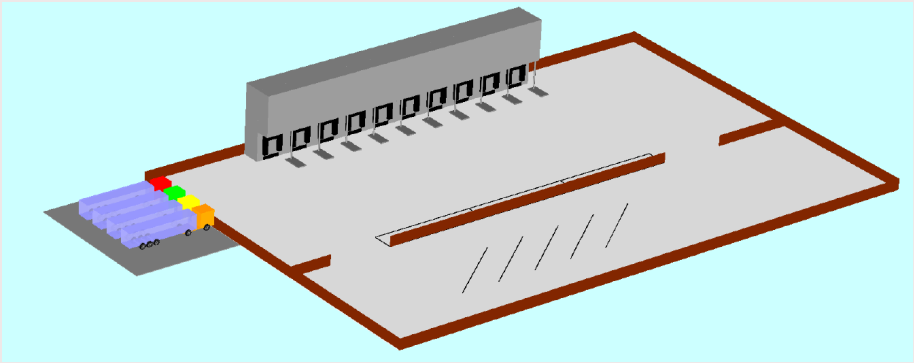
Adaptive data-based control:
Application to controller tuning
for an inverted planar motor



Autonomous vehicles

TU/e TruckLab

Warehouse simulation environment
Autonomous maneuvering for docking

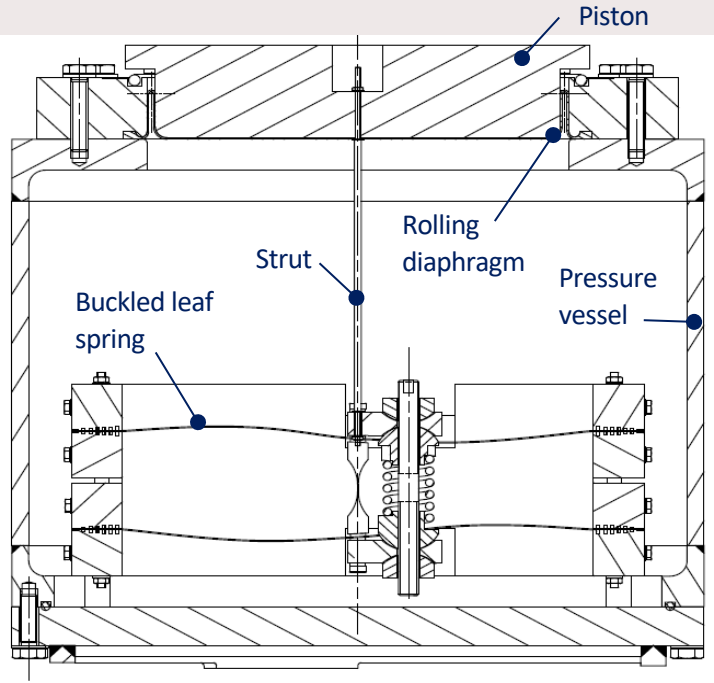


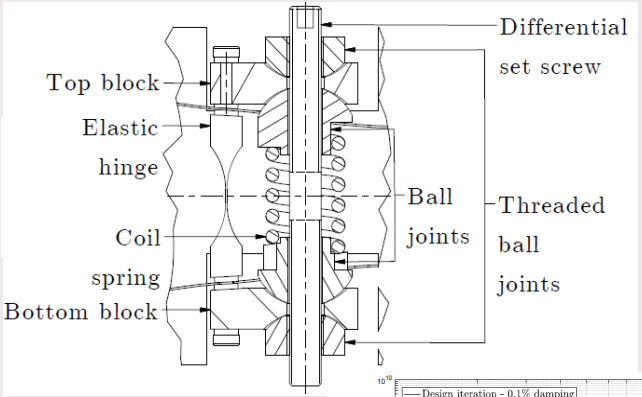
JUMBO

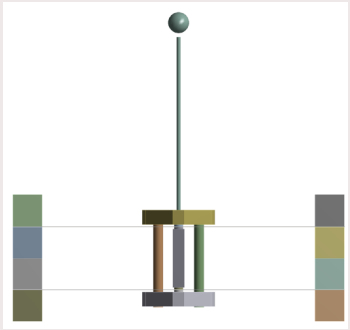
Autonomous Truck System

Passive vibration isolation with negative stiffness

Independent optimization of isolation frequency (~0.3 Hz) and load capacity (3500 kg) – MSc Roy Jacobs (2018)

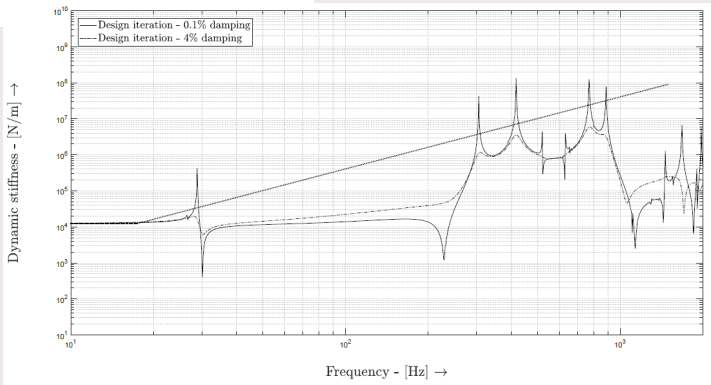






Passive vibration isolation system with adjustable negative stiffness

Dynamic stiffness from base frame displacement to POB force w/ and w/o damping vs. specification (+2 slope)



Ref: Jacobs, R.H.E.M., Design and analysis of a passive vibration isolation system using negative stiffness, MSc report, Eindhoven University of Technology, April 26, 2018 (Patent applied, 2018PF00100)

Hybrid and Nonlinear Control of Motion Systems

Linear motion systems (wafer scanners, pick-and-place machines, electron microscopes) are controlled by linear strategies. **How to achieve improved performance at lower cost using innovative hybrid control strategies?**

Wafer Scanners

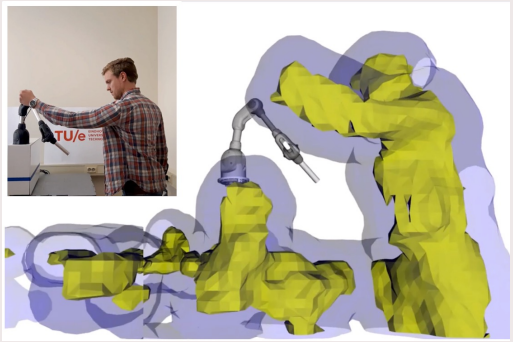
Pick and place machines

Electron microscopes

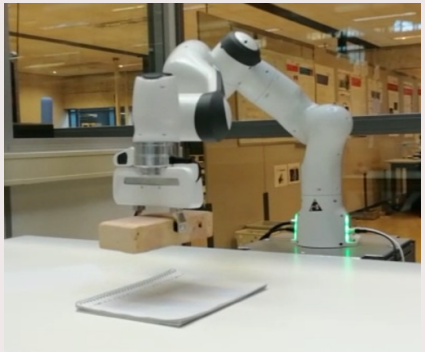
TU/e

Physical Robot-Environment Interaction

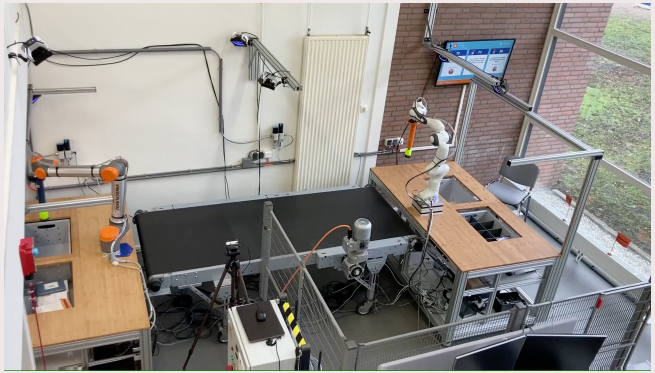
- Advanced modeling and control of robot manipulator in **dynamic contact** situations (including **impacts**), for applications in **logistics** and **construction**.
- **Vision based tracking and collision avoidance**



Vision-Based perception
Collaboration/Collision avoidance



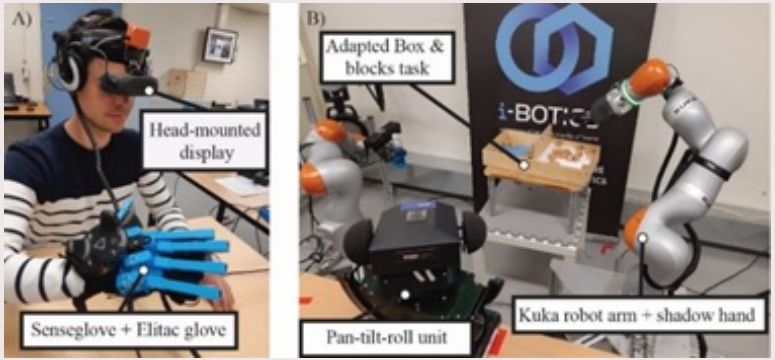
QP robot control /
Robot Torque Control

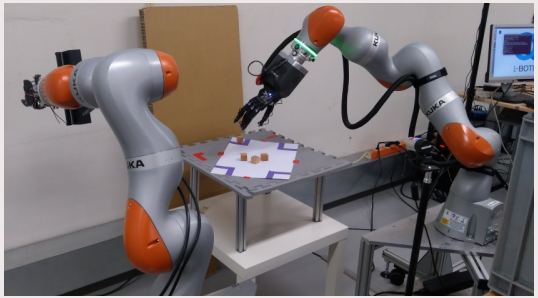


Impact-Aware Manipulation
(www.i-am-project.eu)

Dynamics and control of tele-manipulation

- Control and mapping of the fingers (dexterity)
- Mapping of the arm movements
- Delays (and how to deal with them)
- Haptic feedback
- Haptic shared control (with AI)
- Bimanual manipulation without collisions

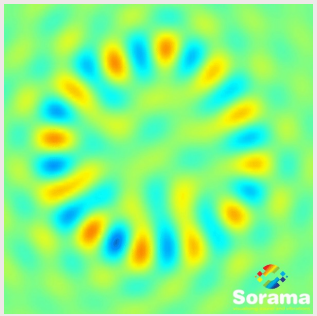


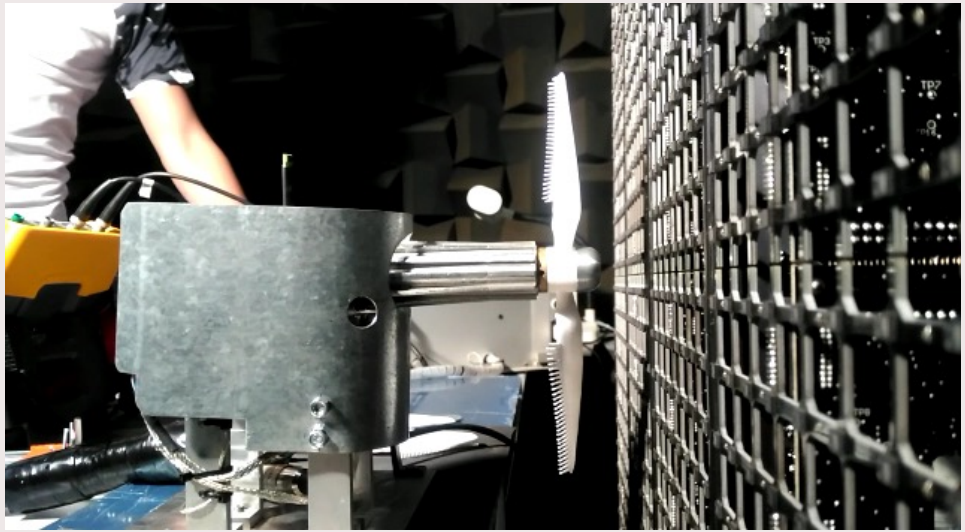


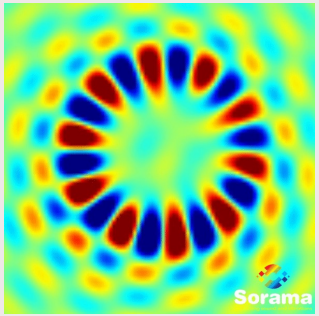
i-botics.com

https://www.youtube.com/watch?v=QwfncoyckcY

AI + sound cameras = Smart Monitoring

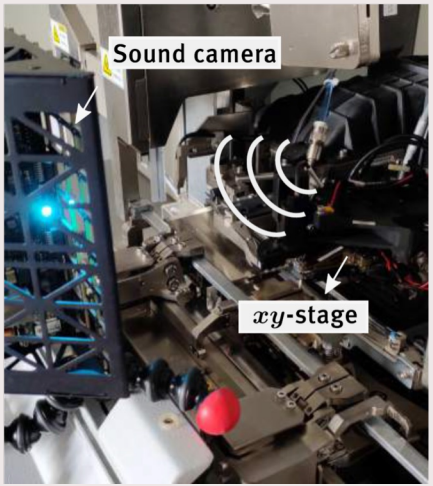


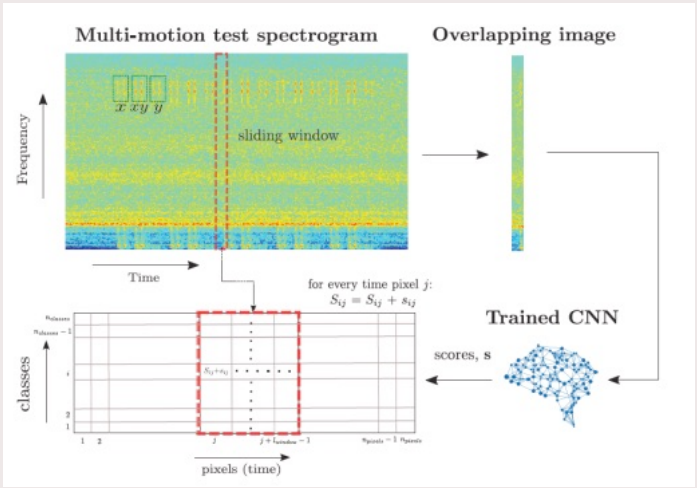


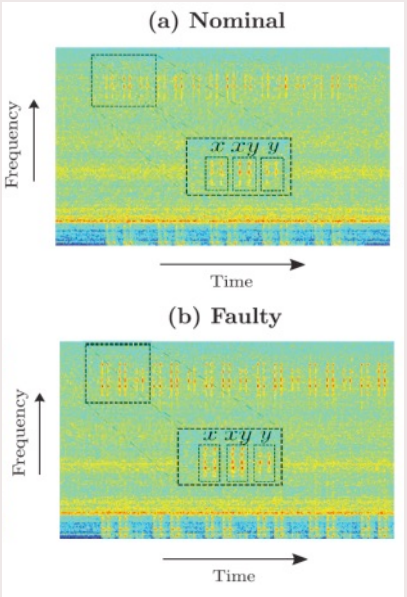


Condition monitoring of wire-bonder

Detect motion along single axes and combined axes in healthy and faulty conditions







Alessia Aulitto e.a., Machine health diagnostics using acoustic imaging and algorithms for machine learning, MEDYNA 2020
Kiran Anginthaya e.a., Machine fault identification using acoustic imaging and deep convolutional neural networks, ISMA 2020

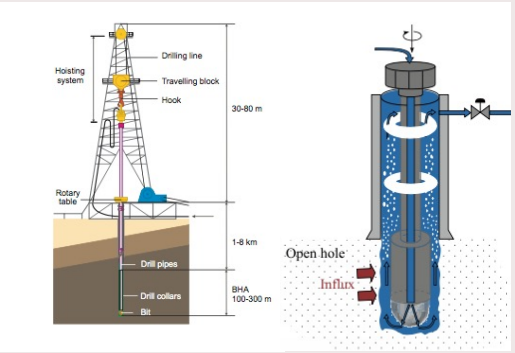
More examples of AI applications

- Digital Twinning (collaboration with ASML, VDL ETG, Canon, ASM PT)
  Use of data to:
  1- Improve models of dynamical systems
  2- Improve controllers
  3- Improve fault detection

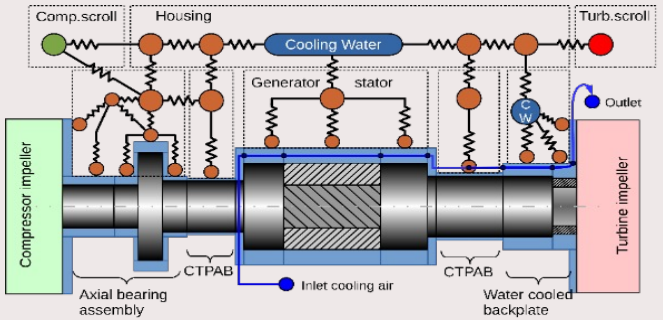
- Mechanical ventilation (collaboration with Demcon, Erasmus MC)
  How can we automatically identify patient properties while supported with artificial respiration and provide doctors with this information.

Reduced order modelling

- Models of engineering systems becomes more and more complex (= multi-physics, large-scale, etc.)
- Complexity makes using models for design, optimization and control challenging
- **How to reduce the complexity (typically number of states/degrees of freedom) and while retaining accuracy?**



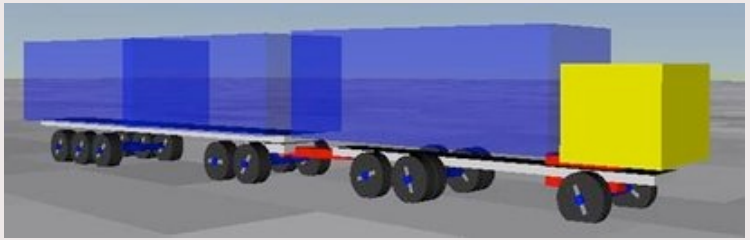
Pressure control in drilling



Thermal modeling for motion/temperature control

Steering systems for future modular road transport

Longer heavier vehicles



Benefits:

- cheaper transport
- traffic reduction
- emission reduction

Challenges:

- speed manoeuvrability and high speed stability
- Active trailer steering control