Introduction to mechatronics

KON-C2004 Mechatronics Basics

Assistant Professor Raine Viitala
22.10.2024

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Aalto-universitetet
Aalto University

A third of jobs could become redundant as a result of digitisation

Around 12 million jobs could significantly change or become redundant by 2024 as a result of the adoption of digital technologies

TIME

BUSINESS • COVID-19

Millions of Americans Have Lost Jobs in the Pandemic—And Robots and AI Are Replacing Them Faster Than Ever

Postin yt-neuvottelut päättyivät: vähentää 94 työntekijää

5.6.2019 12:42 | päivitetty 5.6.2019 12:42 YT-NEUVOTTELUT TYÖELÄMÄ

Neuvottelujen taustalla on postimäärän raju vähentyminen.

Olet lukenut 1/5 uutisista.

Uusimmat

1 22:00 PUHE
Samsungi

Wärtsilä aloittaa yt-neuvottelut maailmanlaajuisesti – Suomessa vähennetään jopa 200 työpaikkaa

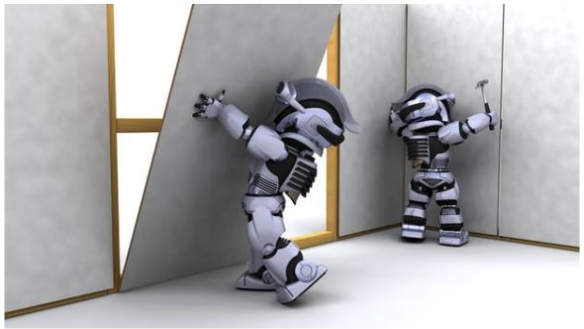
Maailmanlaajuisesti yhtiö suunnittelee 350 työpaikan vähentämistä.

Wärtsilä 25.9.2019 klo 09.42 | päivitetty 25.9.2019 klo 12.35

Kuva: Markku Ojala / AOP

UN report says robots threaten two thirds of jobs in developing countries

Michael Irving | November 10th, 2016



7-Eleven deploys donut delivery drone

Nick Lavars | July 25th, 2016

A chicken sandwich, donuts, hot coffee, Slurpees and candy were packed into a purpose-built container and carried autonomously by a Flirtey drone

DHL's mail-carrying robot delivers the goods in Germany

Nick Lavars | October 19th, 2016

DHL's PostBOT pilot project will run for six weeks

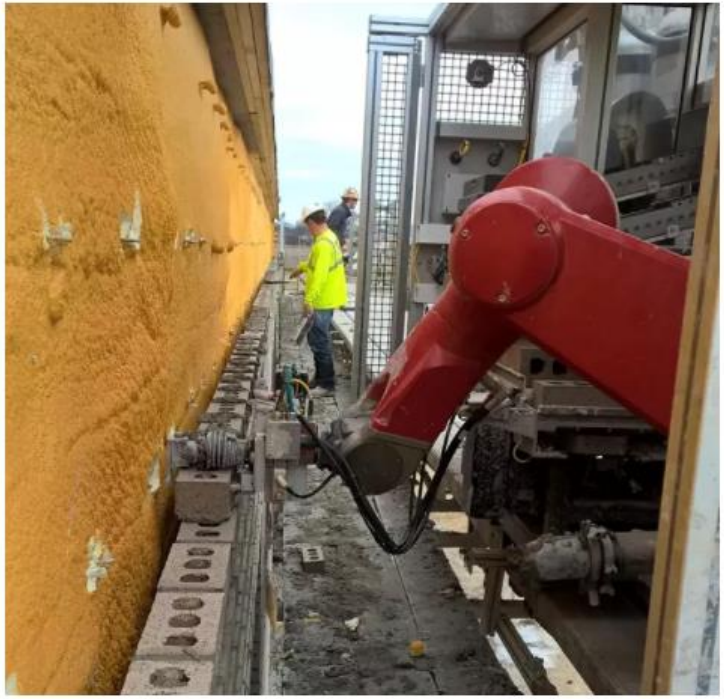
Robotics + Add to myFT

Robots replace humans as labour shortages bite

Automation gathers pace as logistics groups struggle to find workers to deal with surge in next-day deliveries

Newyorkilainen Sam muuraa 3 000 tiiltä päivässä eikä väsy koskaan – robotit tulevat rakennusalalle, jonka tuottavuus on polkenut paikallaan

Robotit tekevät entistä useammin perinteisiä rakennustöitä, kuten muurausta.



Sam tarvitsee rinnalleen avustavia ihmismuurareita, jotka avustavat robottia. (KUVA:

27.10.2017
https://www.hs.fi/talous/art-2000005426573.html?share=001c172a255660e5c028f5a30ec8bc61

Ford's robotic butt simulates a decade of sitting in a Fiesta

Nick Lavars | a day ago

Pleased with the success of its testing in the Fiesta, Ford says the Robutt is now being put to work in all Ford vehicles across Europe

30.10.2017
https://newatlas.com/robotic-butt-ford/51966/

OP-ryhmästä häviää tuhansia työtehtäviä jo lähivuosina, varoittaa eläkkeelle jäävä pääjohtaja Reijo Karhinen HS:n haastattelussa

Reijo Karhisen kaudella OP-ryhmä jyräsi itsensä markkinajohtajaksi asuntolainoissa ja vakuutuksissa. Karhisen seuraajalla on edessä rankka saneeraus, kun uusien tietojärjestelmien mahdollistama automatisaatio hävittää työpaikkoja.

Nordea aikoo vähentää jopa yli 6 000 työtehtävää, vähennys jakautuu neljälle vuodelle

Jättipankin johtajan karu arvio: Suuri osa työntekijöistä korvataan roboteilla, koska ”he käyttäytyvät jo kuin robotit”

VS.

Human factor

- Our ability to interpret statistics is limited: the human mind tends to trust personal observations over information.
- Probability calculation is unnatural to human mind.
- We are facing a new challenge as **future engineers**: Can I make decisions based on data and recommendations generated by a computer, even when they contradict my own instincts? Am I capable of admitting I'm wrong, even if I don't fully understand how I'm wrong?

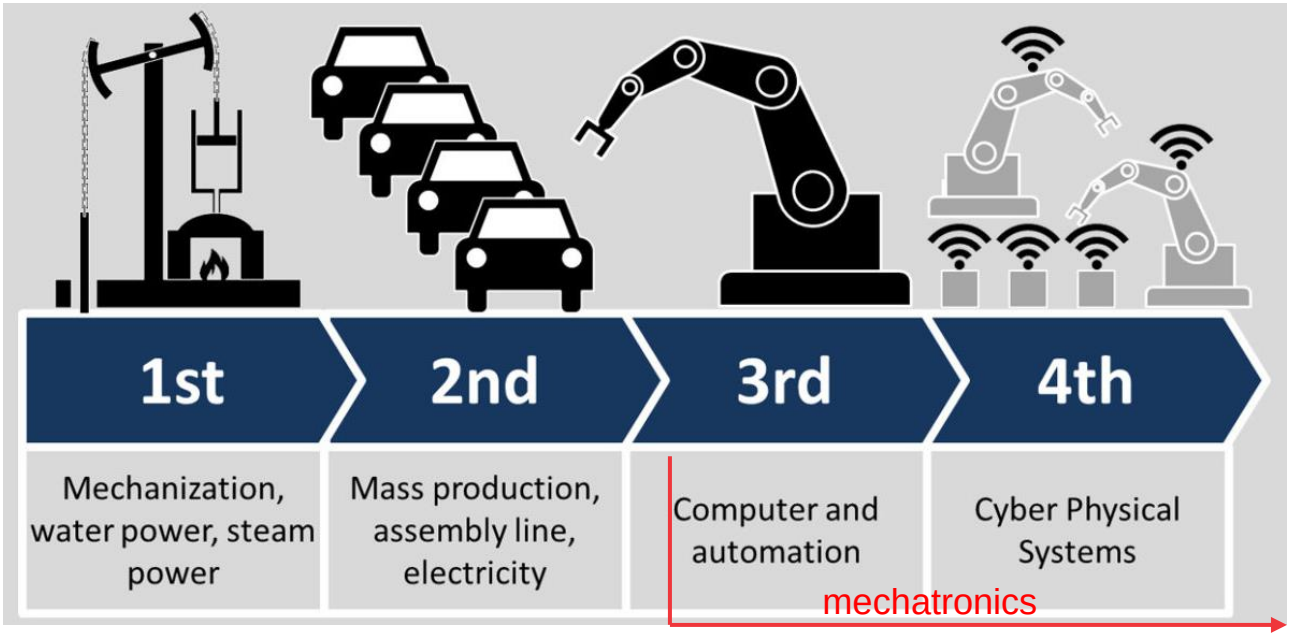
Peter Donnelly: How stats fool juries https://www.youtube.com/watch?v=kLmzxmRcUTo

Alan Smith: Why you should love statistics https://www.youtube.com/watch?v=ogeGJS0GEF4

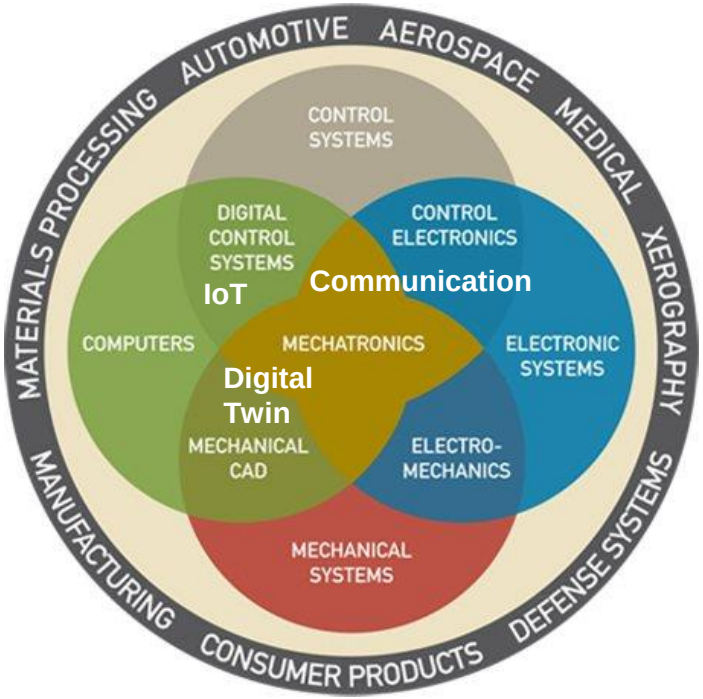
Motivation for removing human factor

- **Target: Getting more for less**
  - Individual: more comfortability for less work and less time investment
  - Industry: more products (profit) for less money invested
  - Societies globally: less energy consumed to get more output
- **Method: Build tools to increase productivity, efficiency and standards of living**
- **Current situation**
  - We have mechanical muscles
    they are great but often expensive
  - We have mechanical eyes
    they are sharp but have limitations, usually expensive
  - We have mechanical minds
    they are fast but stupid (? -> Getting better all the time)

Industrial revolutions



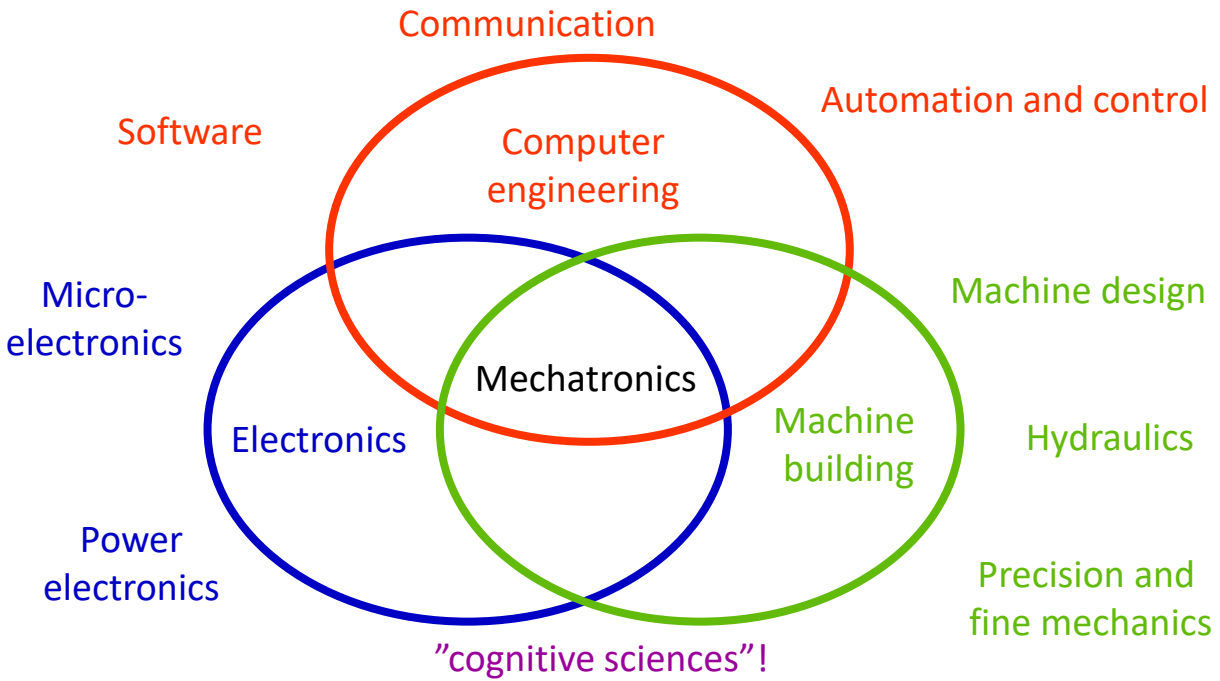
Mechatronics integrates sciences



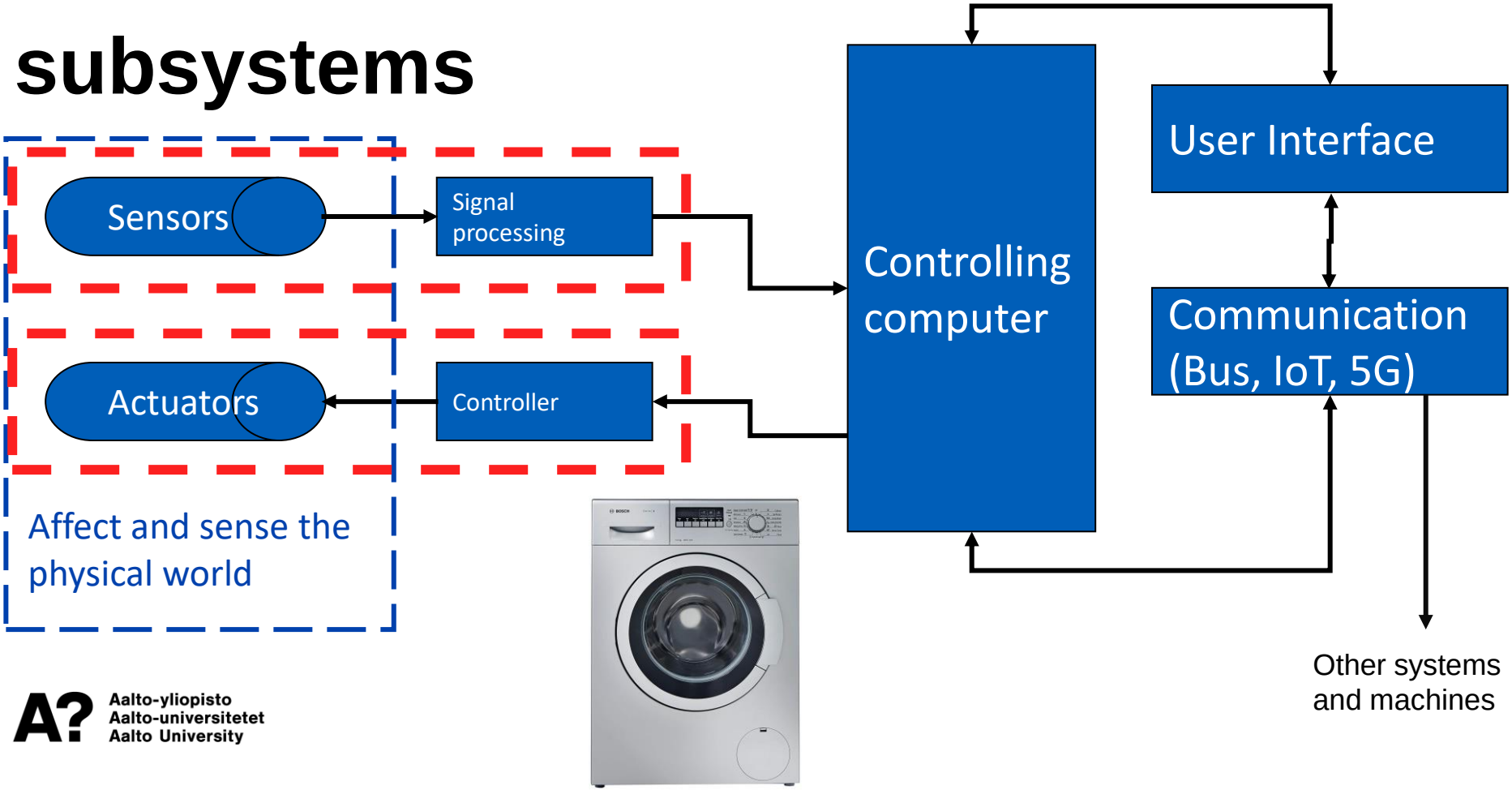
- French standard NF E 01-010 gives the following definition:

  “approach aiming at the synergistic integration of mechanics, electronics, control theory, and computer science within product design and manufacturing, in order to improve and/or optimize its functionality".

Mechatronics as a field of technology



Mechatronic machine - subsystems



Mechatronic system: combustion engine

Sensors

Actuators

Engine Control Unit (ECU)

3 spark plug
9 throttle valve
fuel injection valve
5 coolant temperature sensor
6 knock sensor
7 engine speed and crankshaft reference sensor

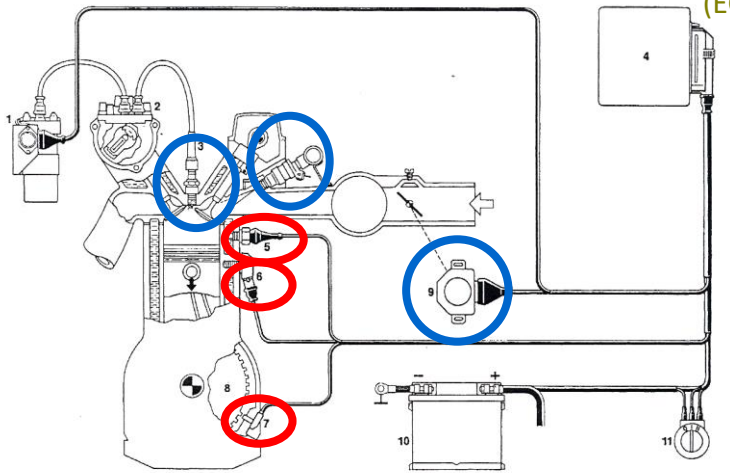


FIGURE 12.20 Schematic of an electronic ignition system with distributor: ignition coil (1), high-voltage distributor (2), spark plug (3), ECU (4), coolant temperature sensor (5), knock sensor (6), engine speed and crankshaft reference sensor (7), sensor wheel (8), throttle valve (9), battery (10), and ignition switch (11).

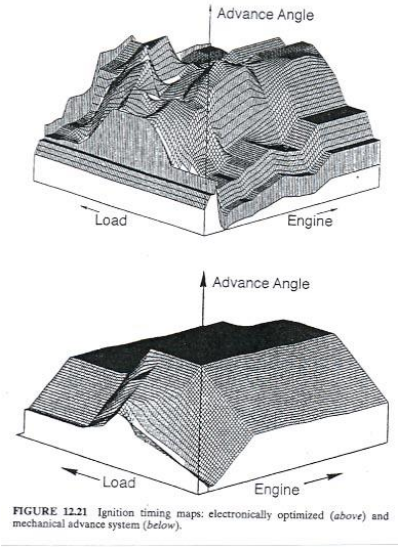


FIGURE 12.21 Ignition timing maps: electronically optimized (*above*) and mechanical advance system (*below*).

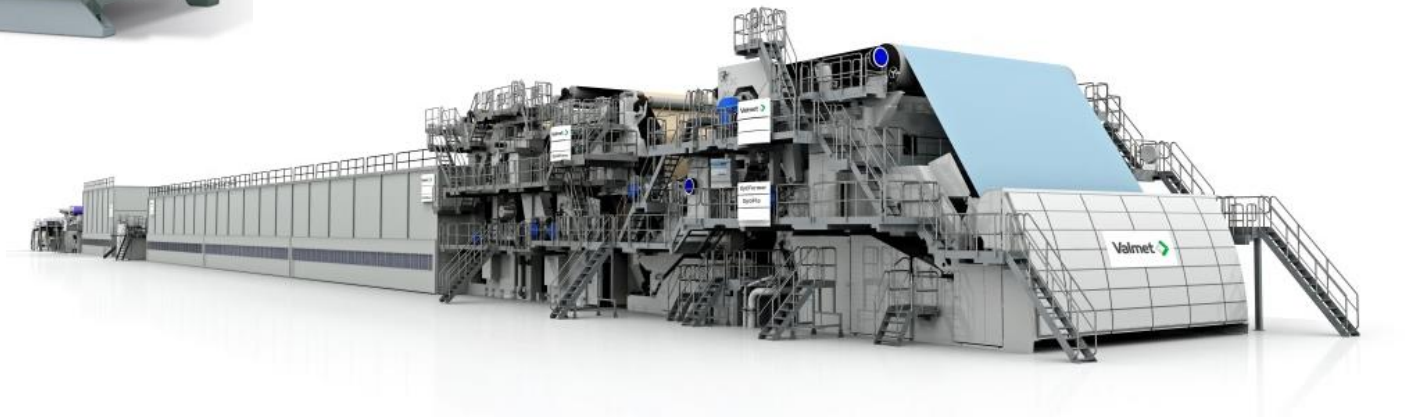
ECU

Mechanical

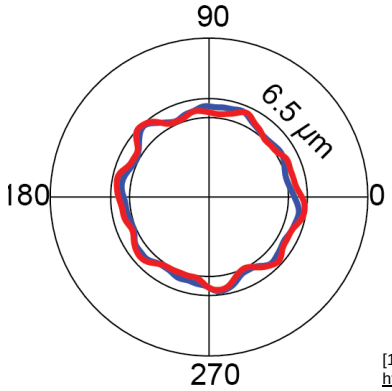
(Hirschlieb et al., Robert Bosch GmbH. In: Ronald Jurgen, Automotive Electronics Handbook)

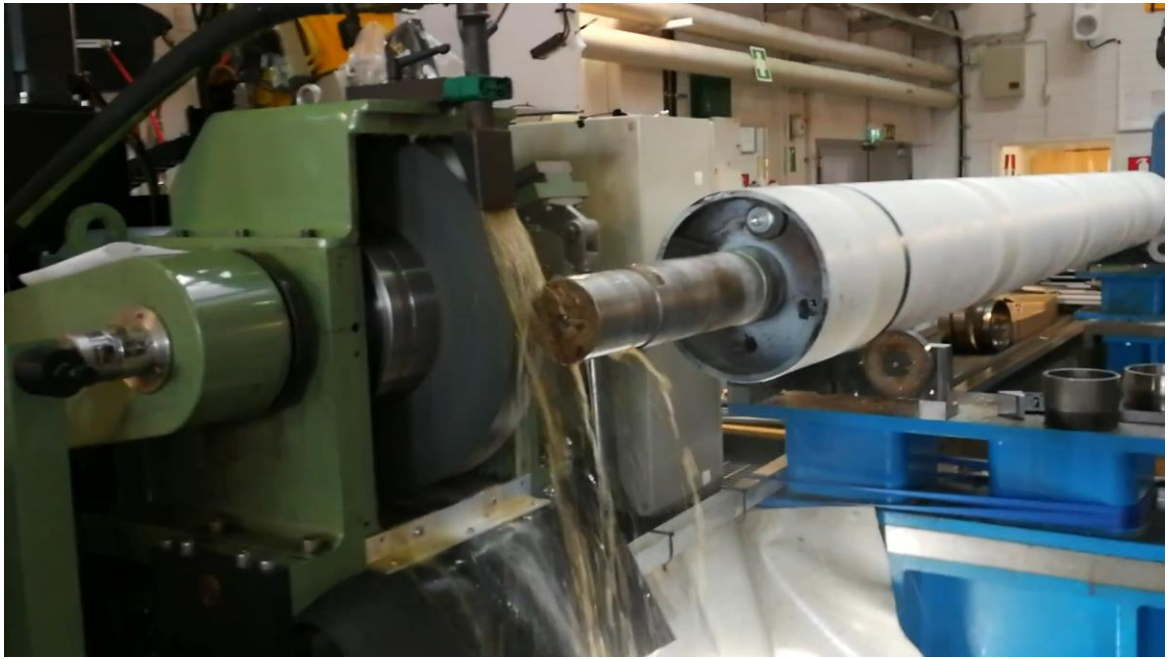
Home mechatronics

Industrial mechatronics



Mechatronics in industrial research





[1] *Uncertainty analysis of phase and amplitude of harmonic components of bearing inner ring four-point roundness measurement.* Viitala, R et al. Precision Engineering 54 (2018), 118-130. https://doi.org/10.1016/j.precisioneng.2018.05.008

[2] *Subcritical vibrations of a large flexible rotor efficiently reduced by modifying the bearing inner ring roundness profile.* Viitala, R et al. Mechanical Systems and Signal Processing 110 (2018), 42-58. https://doi.org/10.1016/j.ymssp.2018.03.010

[3] *Minimizing the bearing inner ring roundness error with 3D grinding to reduce rotor subcritical response*. Viitala, R. CIRP Journal of Manufacturing Science and Technology 30 (2020), 140-148. https://doi.org/10.1016/j.cirpj.2020.05.002

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PONSSE
A logger's best friend

Vehicle mechatronics

Medical mechatronics

Robot can perform surgery on beating heart

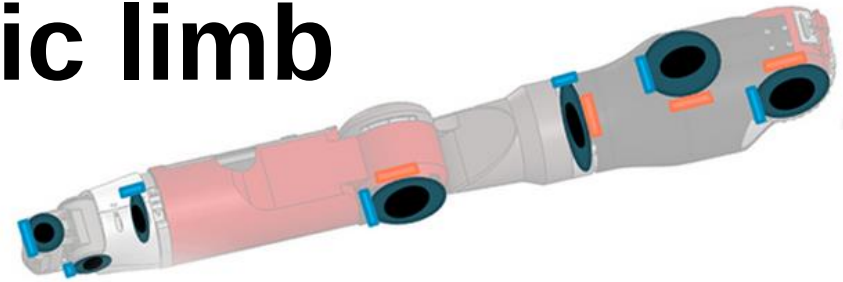
Kyle Sherer | April 13th, 2009

Waseda University's heart rate compensation system allows beating hearts to be operated on as if they were motionless.

Medical mechatronics: Prostheses

Medical mechatronics: Prostheses

Modular prosthetic limb

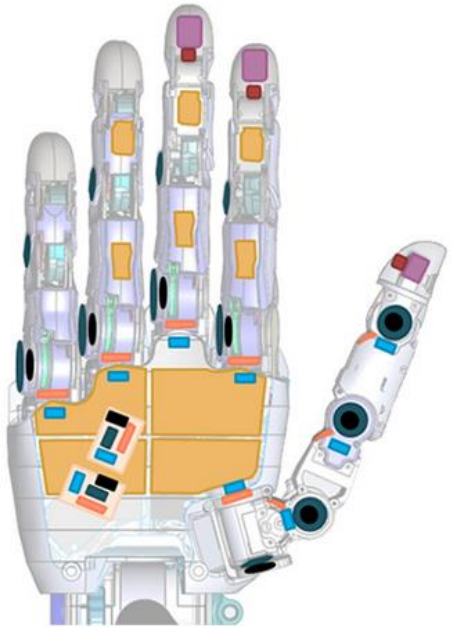


17 brushless DC motors

CAN bus communication

Mass 4.8 kg

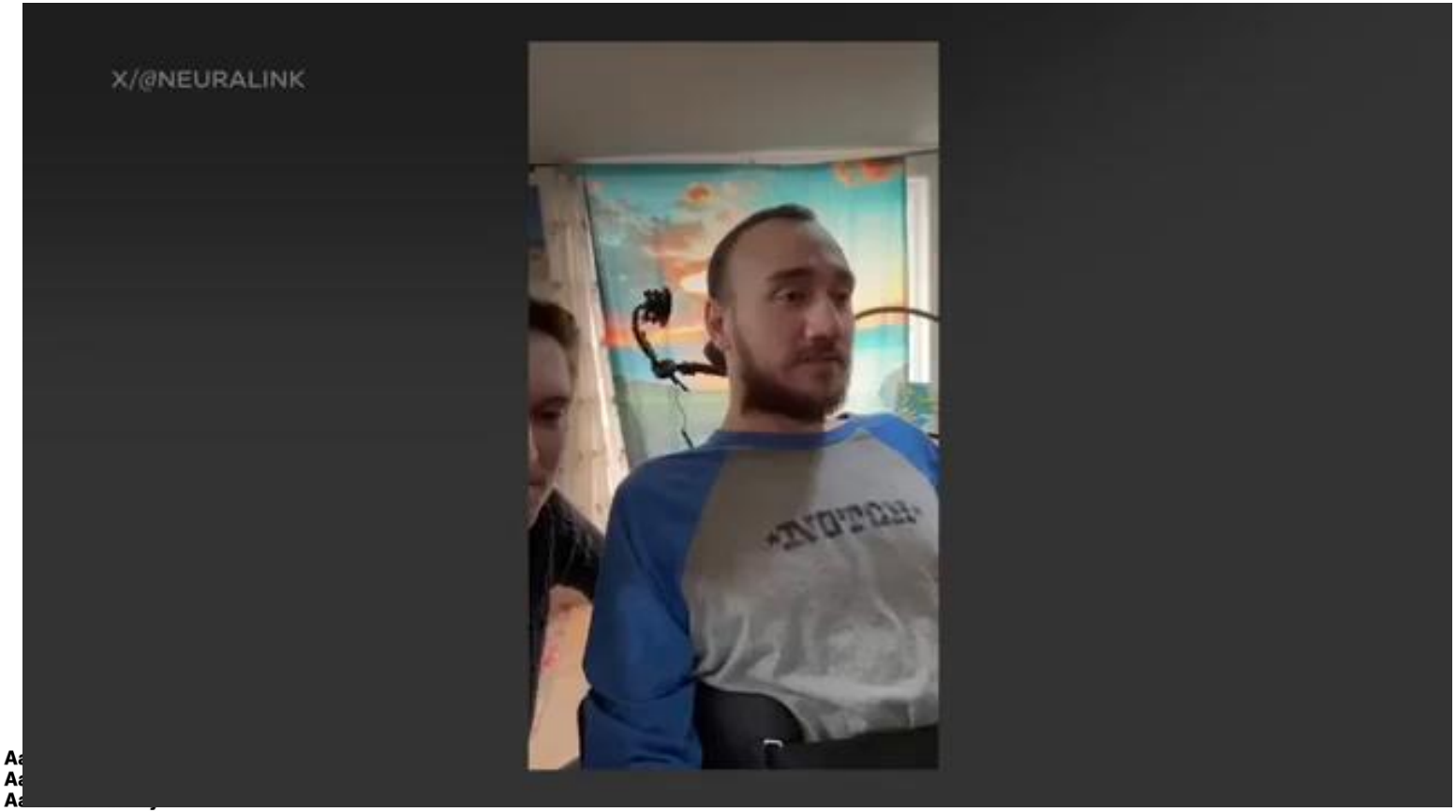
Payload 15.9 kg



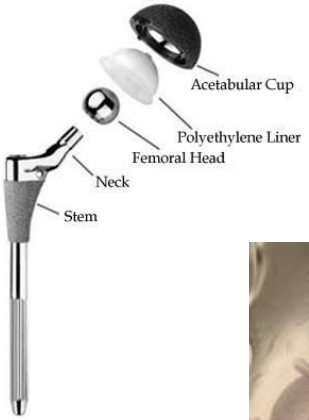
Key	Sensor	Number
	Absolute Position Sensor	21
	Contact Sensor	10
	Torque Sensor	14
	Joint Temperature Sensor	17
	3-Axis Acclerometer	3
	3-Axis Force Sensor	3
	Additional Sensors	41
	▪ Incremental rotor position (x17) ▪ Drive voltage (x17) ▪ Upperarm drive current (x7)	

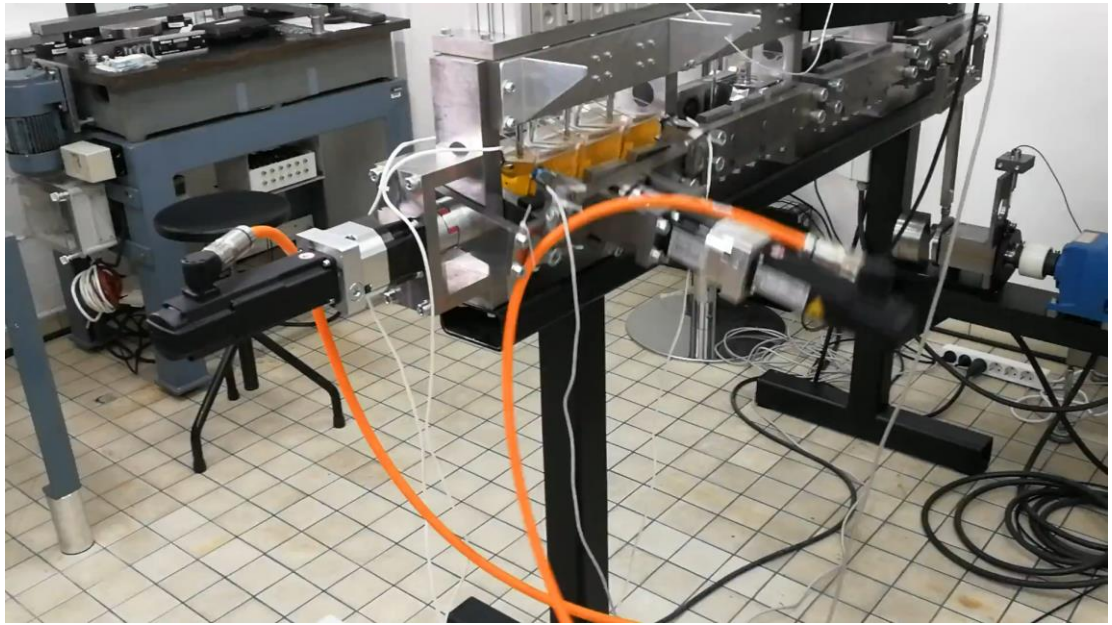
http://www.jhuapl.edu/prosthetics/scientists/mpl.asp

Medical mechatronics: Neuralink



Mechatronics in medical research





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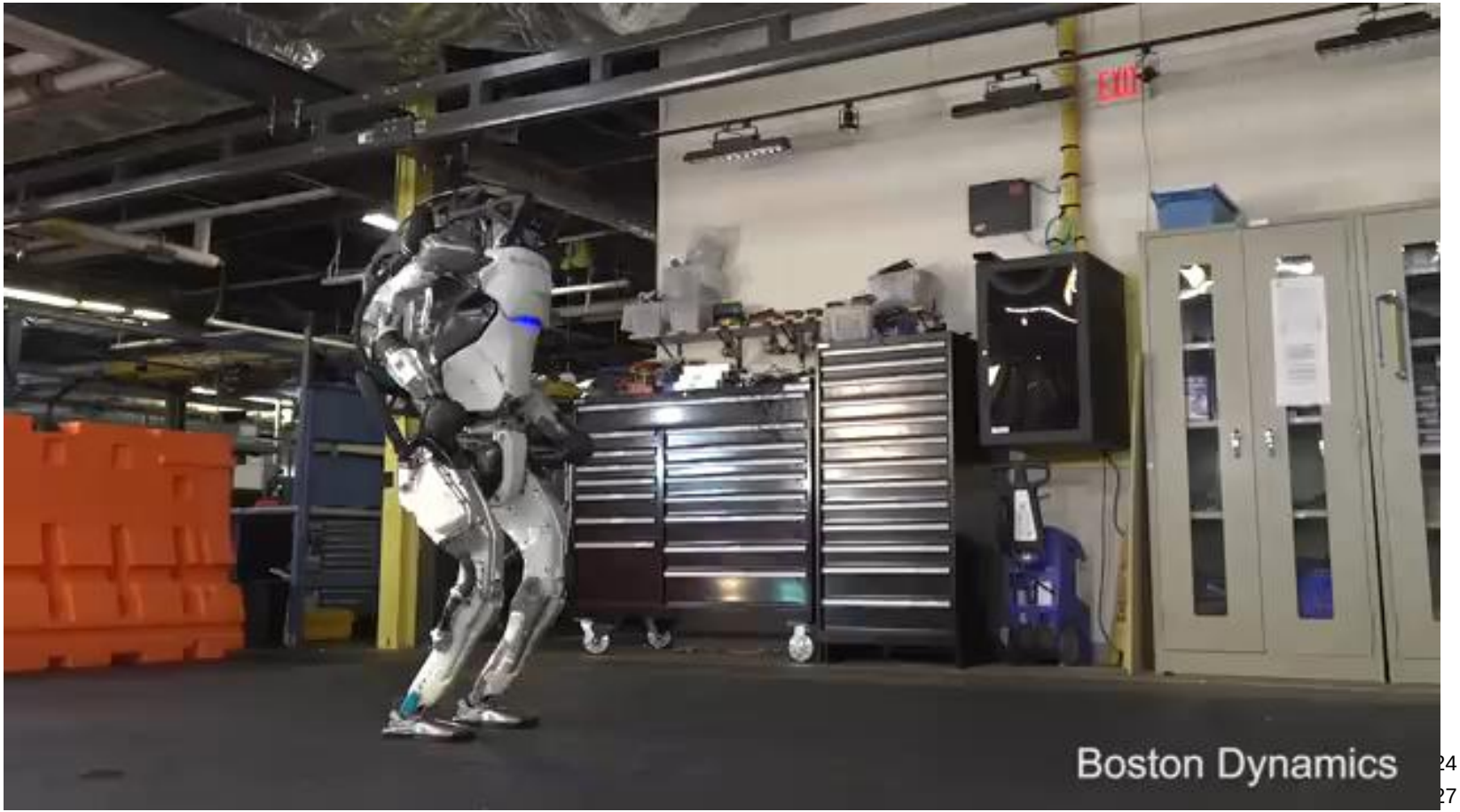
Effect of random variation of input and various daily activities on wear in a hip joint simulator. Viitala, R; Saikko, V. Journal of Biomechanics 106 (2020), 109831. https://doi.org/10.1016/j.jbiomech.2020.109831

Robotics

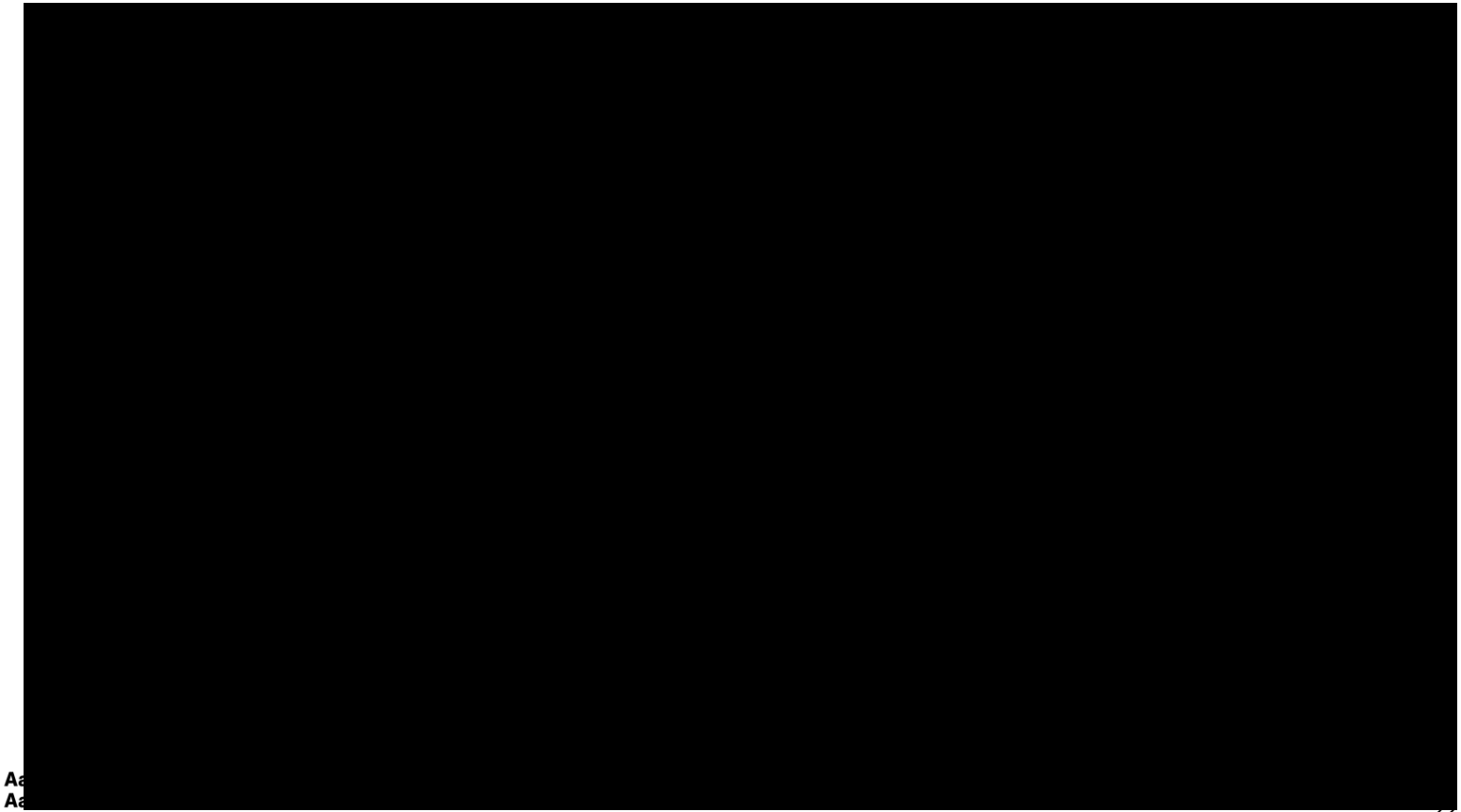


A?

Actuators: fast

Actuators: strong

Actuators: fast and precise



Actuators

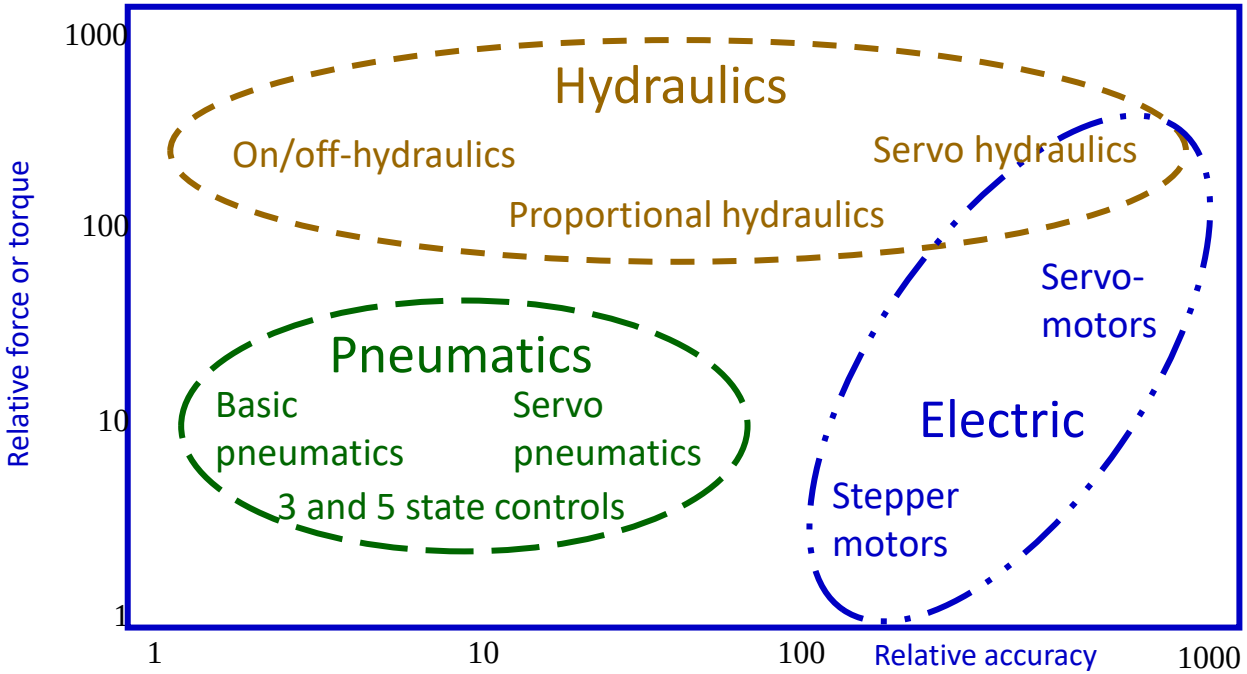
Electric actuators

- DC and AC motors, solenoids, voice coils
- Active materials (piezoelectric, electrostrictive etc)
- Microelectromechanical (MEMS) actuators

Fluid power

- Hydraulic actuators
- Pneumatic actuators

Fields of application

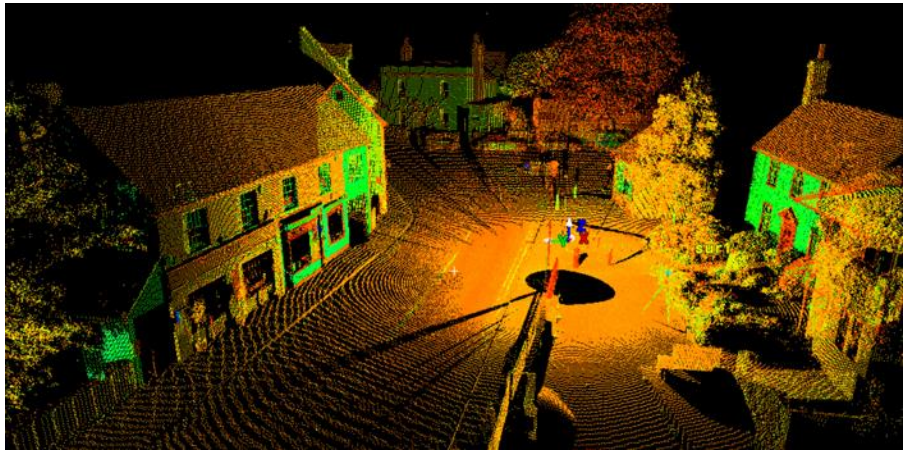


Sensors: mapping

Sensors: inertial

A?

Sensors



Position

- Very basics:
  Potentiometer, Encoder, LVDT etc.
- 1D/2D/3D laser, radar
- Stereo vision

Acceleration, force, torque, magnetic field, temperature

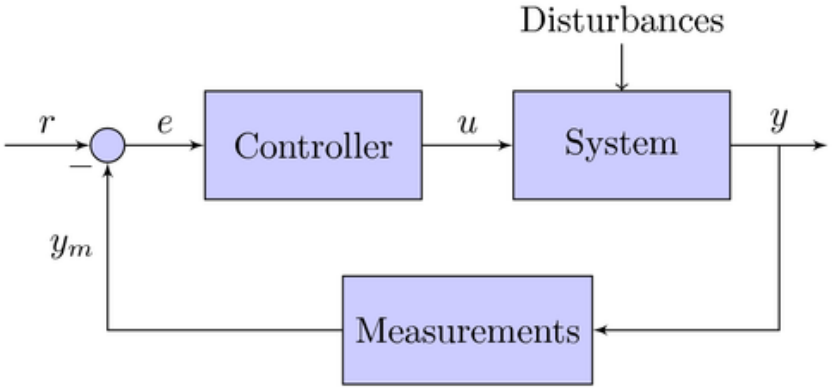
Measurement systems and electromagnetic interference

Control

Control

Control systems

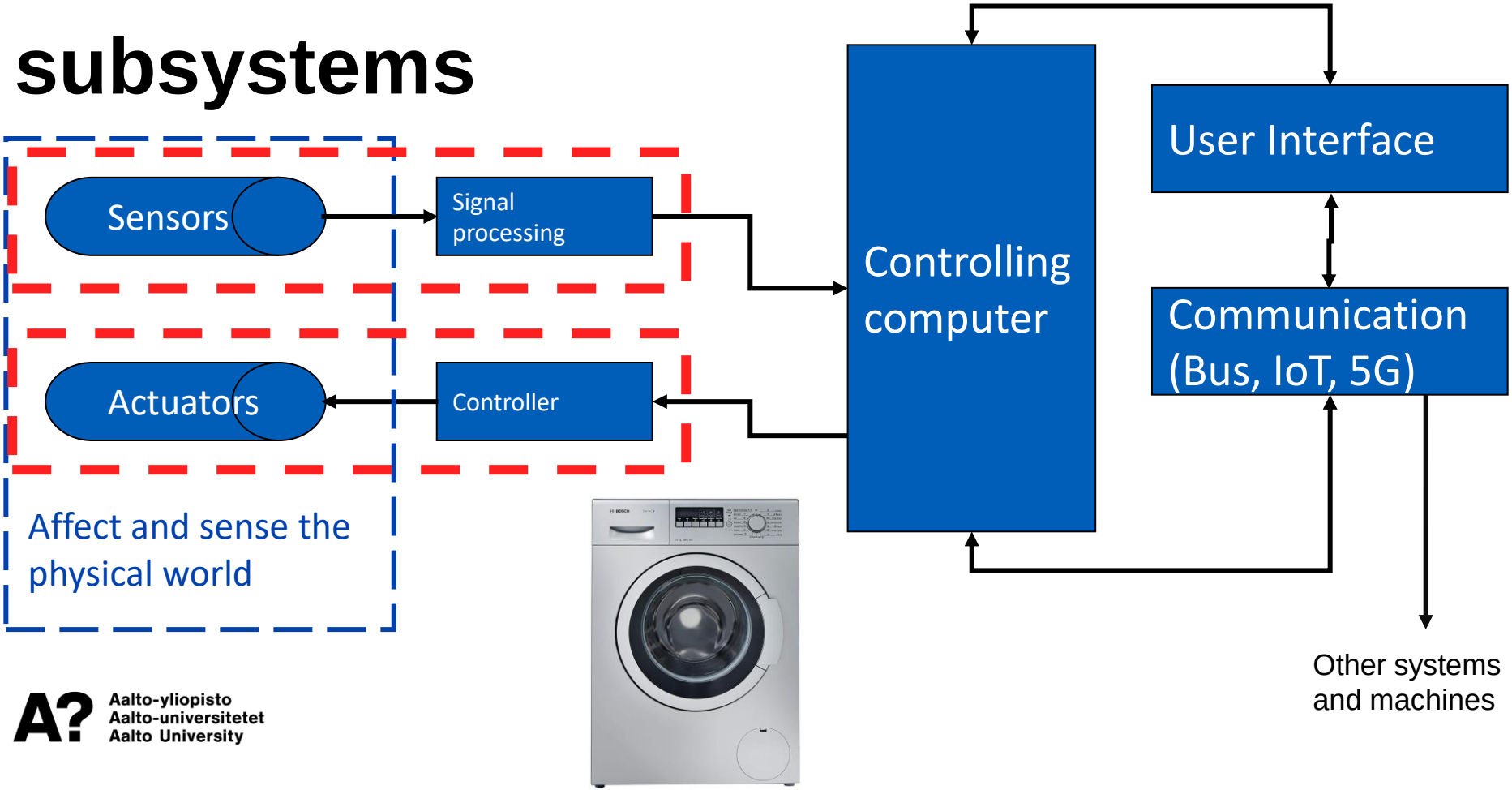
- Modeling system dynamics
- Feedback control, open loop control
- Controllers, PID, model based etc.



Control devices and their interfaces

- Microcontrollers, Programmable Logic Devices (PLC), PCs
- Communication

Mechatronic machine - subsystems



Course practicalities

Learning outcomes

The student

1. is able to describe the general structure of a mechatronic system and the structure and properties of the most common sensors and actuators.
2. is able to select, dimension and interface suitable sensors, actuators and control devices for a simple mechatronic system.
3. knows multiple everyday and some special applications for mechatronic systems.
4. has the ability to discover the operating principle of a mechatronic system that they have not encountered before.
5. is able to discover information from multiple sources, such as internet, concerning mechatronic systems and their design.

Content

Must know

- General structure of mechatronic system
- How to select and dimension components for mechatronic systems
- How to describe a mechatronic system
- Analog vs. Digital

Should know

- Physical operating principles of multiple sensors and actuators
- Measurement systems, aliasing and discrete sampling
- Control theory (PID-control)

Nice to know

- Examples of mechatronic devices and their operating principles
- Microcontroller programming

MyCourses and Zoom

- **MyCourses is used for**
  - Course information
  - Course related news
  - Publishing lecture slides and recordings
  - Publishing, submitting and grading exercises
  - Publishing exercise and course results
  - Feedback throughout the course
- **Web address mycourses.aalto.fi**

- **Zoom is used for**
  - Broadcasting and recording the lectures
  - No interaction through zoom

Lectures

- **Tuesdays 10:15-12:00 in K1/213a**
- **Thursdays 10:15-12:00 in K1/216**

#	Date	Topic
1	22.10.	Intro
2	24.10.	DC and stepper motors
3	29.10.	Position sensors
4	31.10.	AC motors, modeling mechatronic systems
5	5.11.	Control systems
6	7.11.	Hydraulic actuators (visiting lecturer)
7	12.11.	Measurement systems
8	14.11.	Other sensors
9	19.11.	Other actuators
10	21.11.	Microcontrollers (visiting lecturer)
11	26.11.	Digital control devices

Exercises

Mon 14.15-16.00 & Thu 12.15-14.00 in Y430

- Minimum 50% of exercise points required to pass the course
- Read ”Exercise and MyCourses instructions” before starting to do the exercises! All the encountered formatting, error etc. cases documented there during the 9 previous realizations of this course
- PDF-report is the main document for grading, if that is required. Make the report so, that it is understandable as such. Matlab and Simulink files are just a plus, which can be used if there is a tiny error in the code. Any tool can be used for PDF-report generation: Matlab report generator, word, latex…

All weekly exercise rounds are equally weighed in the end grading

- Includes 1 point per round for feedback

New exercise rounds published on Tuesdays

DL next week’s Tuesday 10:00

- Late submissions will not be accepted, since the solutions are published simultaneously with the DL
- All the tasks will be submitted to MyCourses, handwritten submissions will not be accepted

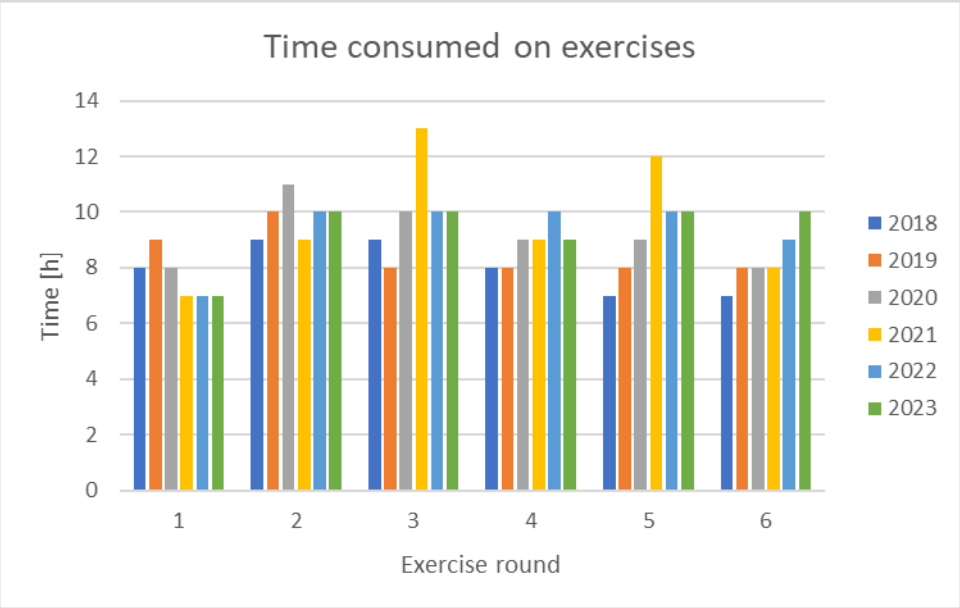
The solutions can be discussed with the assistants in Y430 during the exercise sessions. The solutions document will be available in MyCourses after the DL.

Exercises 2

ChatGPT and other generative AI: use in exercises is accepted in accordance with Aalto guidance

- **We have halved the points of essays (reduces their weight in the final evaluation)**
- **Rehearse writing yourself, because in the exam the use of chatGPT and other generative AI is prohibited and monitored!**

Reserve time to do the exercises!



Course book and material

Alciatore & Histand, Introduction to Mechatronics and Measurement Systems (McGraw-Hill, ISBN 0-07-125407-2)

- Can be found in the library

Not all information required to solve the exercises is given in lectures

- Use the book or other sources of information such as internet

Additional reading

- Mauri Airila, Mekatroniikka (in Finnish)
- Linklist in Other material (MyCourses)

Final exam

- **Thursday 12.12.2024 12-16 (course enrollment is sufficient to participate)**
- **Re-exams in January and May (separate enrollment in SISU)**
- **Computer based exam, similar to the exercises, locally arranged in computer classrooms**
  - The questions can be related to any course material
- **Any material allowed**
- **Communication between students prohibited**
- **ChatGPT and other generative AI strictly prohibited and monitored**
- **Based on the exercises, lectures, and the course book**
  - The importance order of the material considering successfull exam respectively

Grading

Grading 0 to 5 (0 = failed)

Exercises 50 % of course grade

- *50 % of points required to pass*

Final exam 50 % of course grade

- *40 % of points required to pass*

General

- **Remember to enroll in SISU**
- **Feedback is much appreciated (give it weekly)**
- **Course personnel**
  - *Lectures and responsible teacher:*
    D.Sc. (tech) Raine Viitala, raine.viitala@aalto.fi
    Assistant Professor, Mechatronics, ARotor

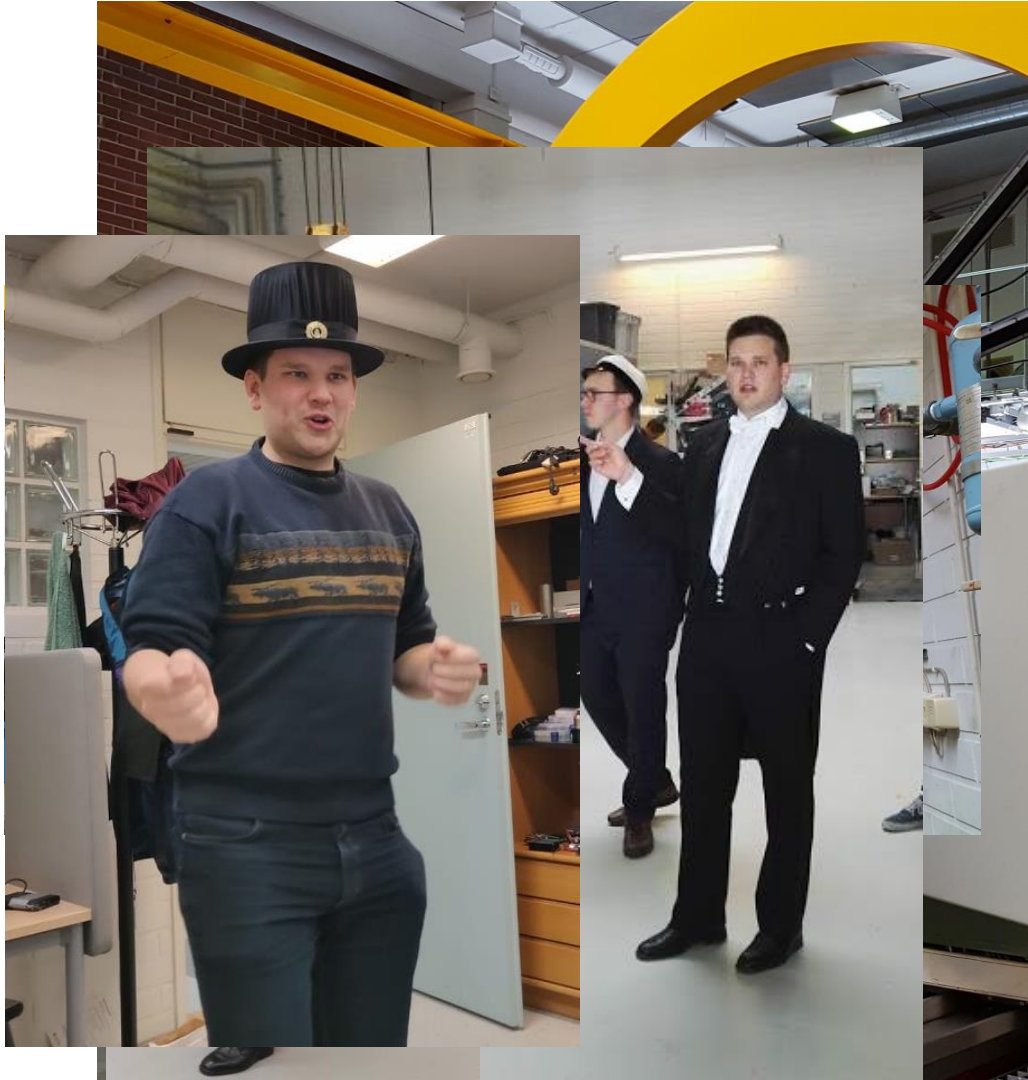
  - *Exercises, main assistant:*
    M.Sc. (tech) Samuli Rytömaa, samuli.rytomaa@aalto.fi
    Doctoral researcher, Mechatronics, ARotor

  - *Exercise sessions and grading: three student assistants*

Take it seriously…

Your studies

But remember to maintain a twinkle in your eye!



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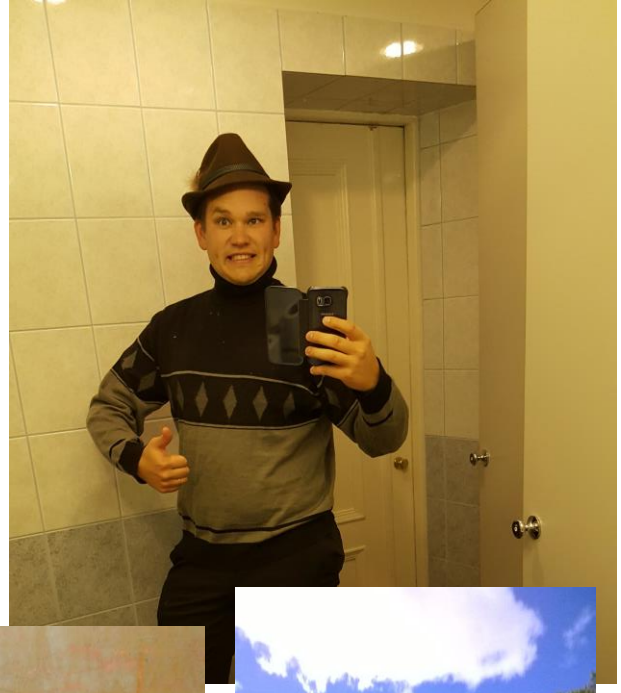
Finally

- **Remember to do something else!**
  - Nobody wants to be a one trick wonder!



Finally

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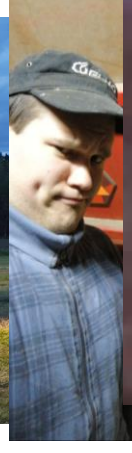

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Why mechatronic machines?

Better performance (engine control)

Optimization (washing machine: fast / best result / save energy)

Lower operating cost (reduce fuel consumption of a car)

Flexible and adaptable systems (self driving car)

Safety (dead man’s switches in machine tools, airbag)

Human comfort (vacuum cleaning robot)