Cybernetics and Artificial Intelligence
Introduction into the course

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Admin, rules of the game

- An overview is at the course webpage:
  - CZ: https://cw.fel.cvut.cz/wiki/courses/b3b33kui/start
  - EN: https://cw.fel.cvut.cz/wiki/courses/be5b33kui/

  - Program (lectures / labs), assessment, literature…

- Weekly workload: 1 lecture (1.5 hours), 1 computer lab (1.5 hours), individual work (reading, coding) ~ 5 hours
- At the end: ~35 hours wrapping up - preparing for exam.

  Intensive term work may save time at the end.

literature, resources

- we recommend a few:
  CZ: https://cw.fel.cvut.cz/wiki/courses/b3b33kui/literatura
  EN: https://cw.fel.cvut.cz/wiki/courses/be5b33kui/literature

- on-line materials abundant - you can find by yourself, responsibility is (always) yours

- ask us if unsure

- we appreciate if you recommend new ones

Cybernetics

- “The word *cybernetics* comes from Greek κυβερνητική (*kybernētiké*), meaning "governance", i.e., all that are pertinent to κυβερνάω (*kybernáō*), the latter meaning "to steer, navigate or govern", hence κυβέρνησις (*kybérnēsis*), meaning "government", is the government while κυβερνήτης (*kybernḗtēs*) is the governor or "helmperson" of the "ship". ” source: https://en.wikipedia.org/wiki/Cybernetics
- Norbert Wiener (1948). Cybernetics Or Control and Communication in the Animal and the Machine. **~ def. of cybernetics**
- William Grey Walter (1949). Building autonomous robots as an aid to study animal behavior.
- William Ross Ashby (1956). An introduction to cybernetics.
- then development continued but different names/wording on the two sides of “iron curtain”.
- Pask, Gordon (1972). "Cybernetics". Encyclopædia Britannica.

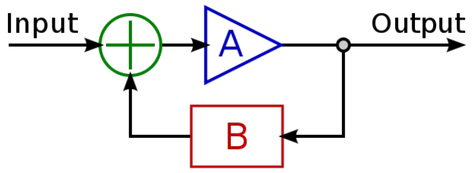
Systems with feedback

Centrifugal (Watt's) governor

- A centrifugal governor is a specific type of governor with a feedback system that controls the speed of an engine by regulating the amount of fuel (or working fluid) admitted, so as to maintain a near-constant speed. It uses the principle of proportional control.

- invented by Christiaan Huygens and used to regulate the distance and pressure between millstones in windmills in the 17th century
- **James Watt** adapted one to control his **steam engine** where it regulates the admission of steam into the cylinder(s)

- ~ "negative feedback"



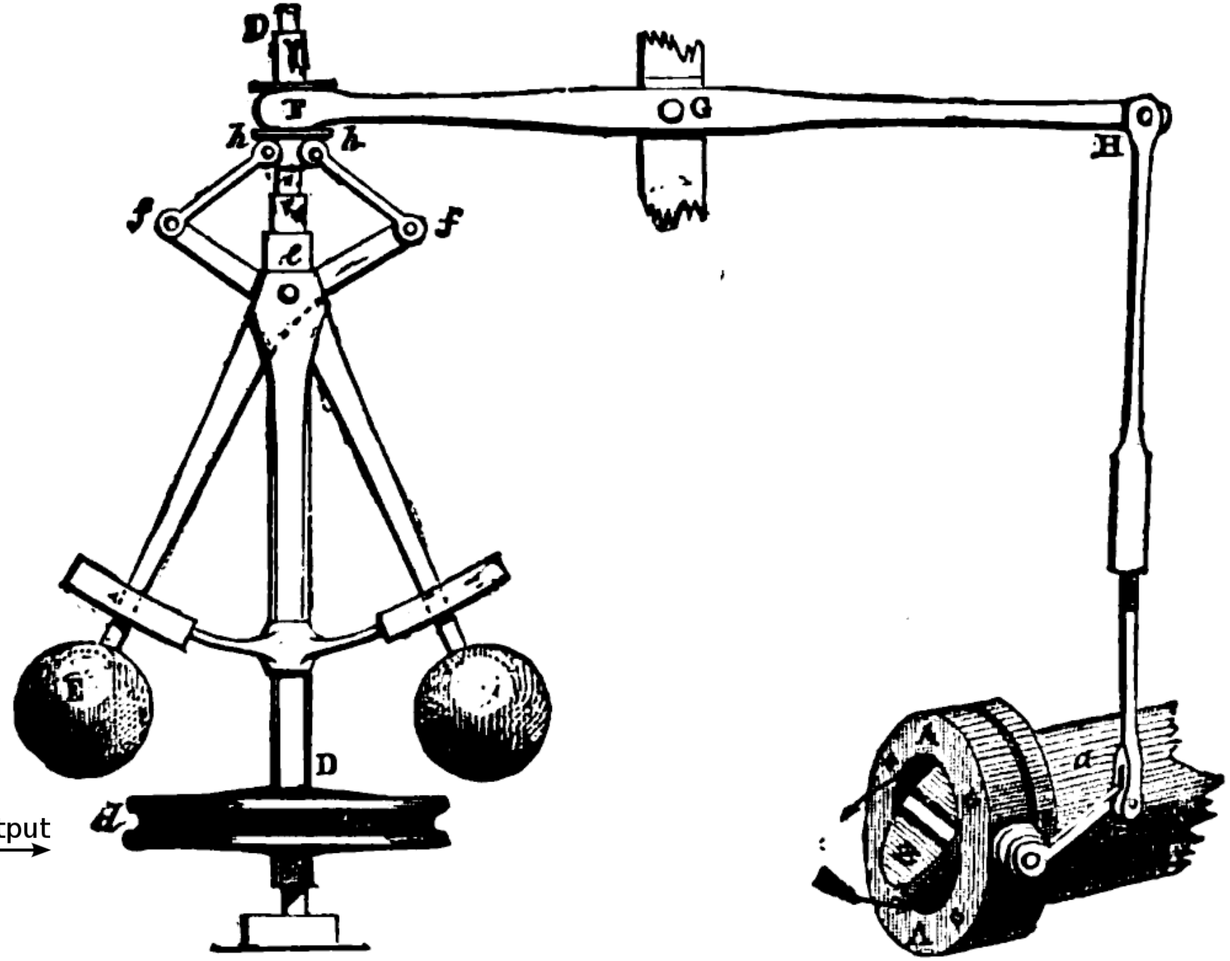
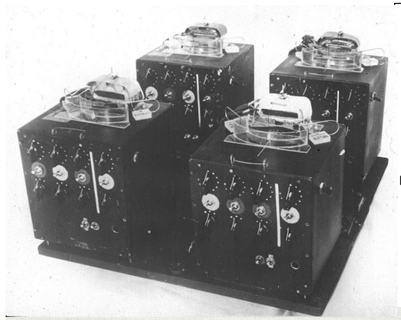


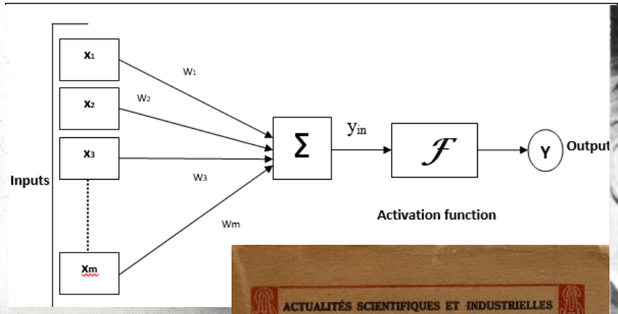
FIG. 4.—*Governor and Throttle-Valve.*

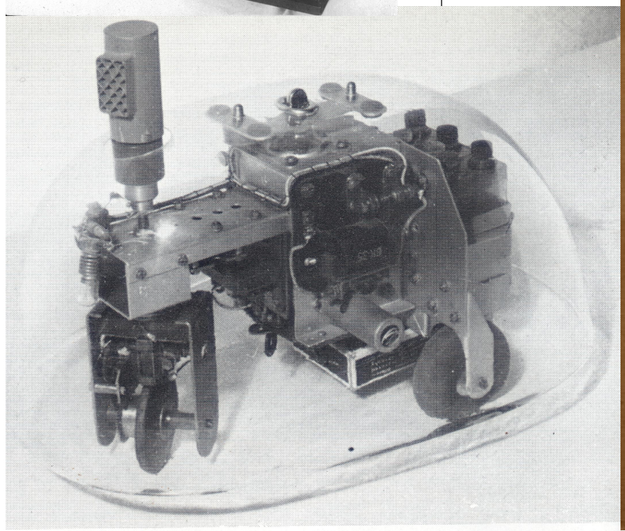
https://en.wikipedia.org/wiki/Centrifugal_governor#/media/File:Centrifugal_governor.png
https://en.wikipedia.org/wiki/Negative_feedback

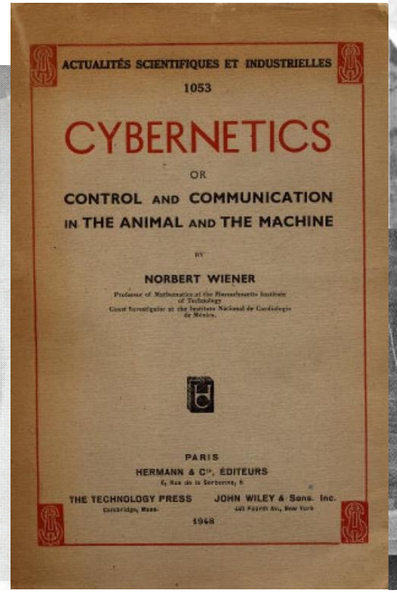
Middle ’40s: Cybernetics - modelling intelligence through machines (Wiener 1948, von Neumann 1948)

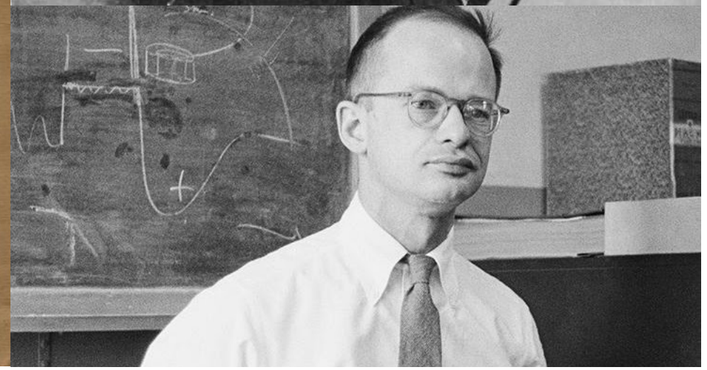
- early ideas of embodiment and modeling neurophysiological processes in the 1940s (McCulloch, Pitts 1946 - formal neuron; Ross Ashby - Homeostat; Grey Walter - tortoise robots)
- 1946 - 1953 Macy Conferences on Cybernetics







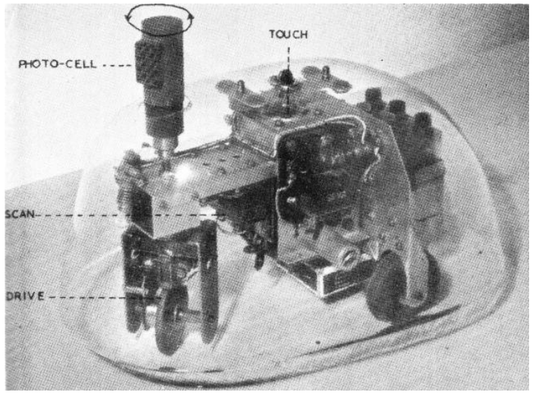




Slide source: Hagen Lehmann

William Grey Walter (1910-1977)

- English neurophysiologist and roboticist
- Work on EEG, conditioning, etc.
- “Robotic tortoises” (1948-49)
  - Autonomous robots with touch and light sensors
  - Simple “brain” (2 “neurons”)
  - “tortoises” influenced a number of roboticists (Hans Moravec, Rodney Brooks, etc.)
  - “descendants”: robotic vacuum cleaners

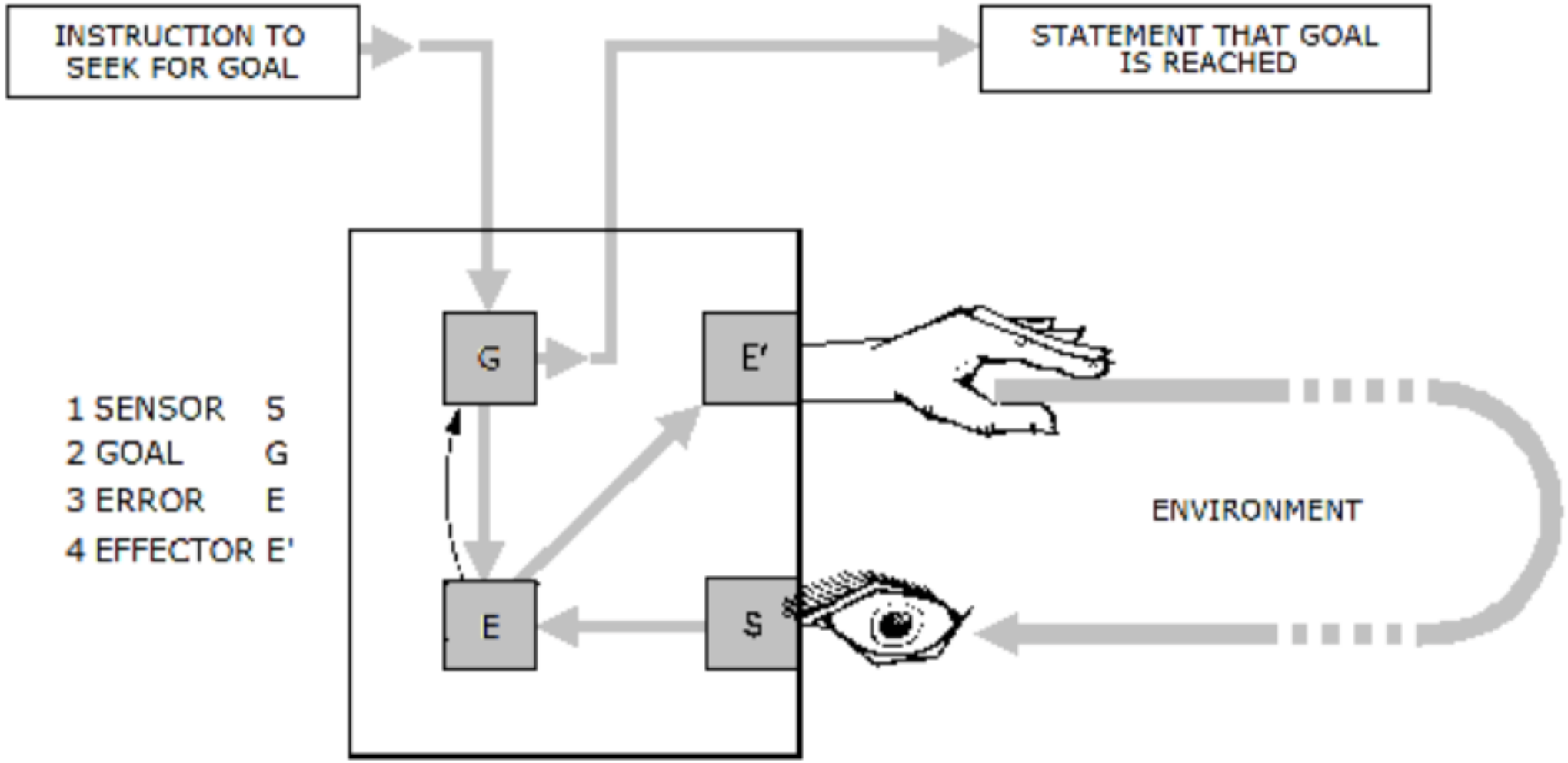


Slide source: Miloš Železný

Grey Walter’s tortoises

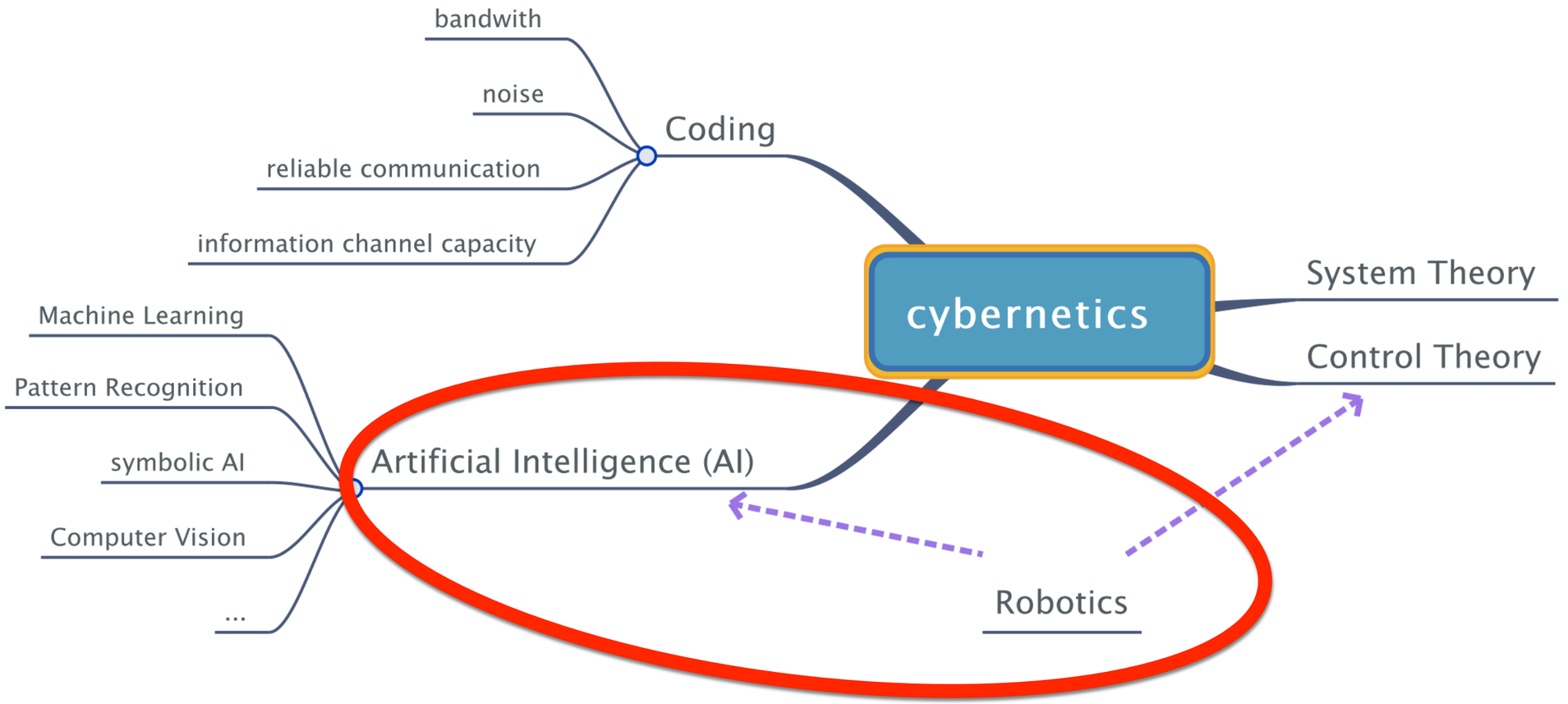
https://spectrum.ieee.org/tech-history/space-age/meet-roombas-ancestor-cybernetic-tortoise
https://youtu.be/lLULRlmXkKo

Course target: goal-directed system



Pask, Gordon (1972). "Cybernetics". Encyclopædia Britannica.

cybernetics now



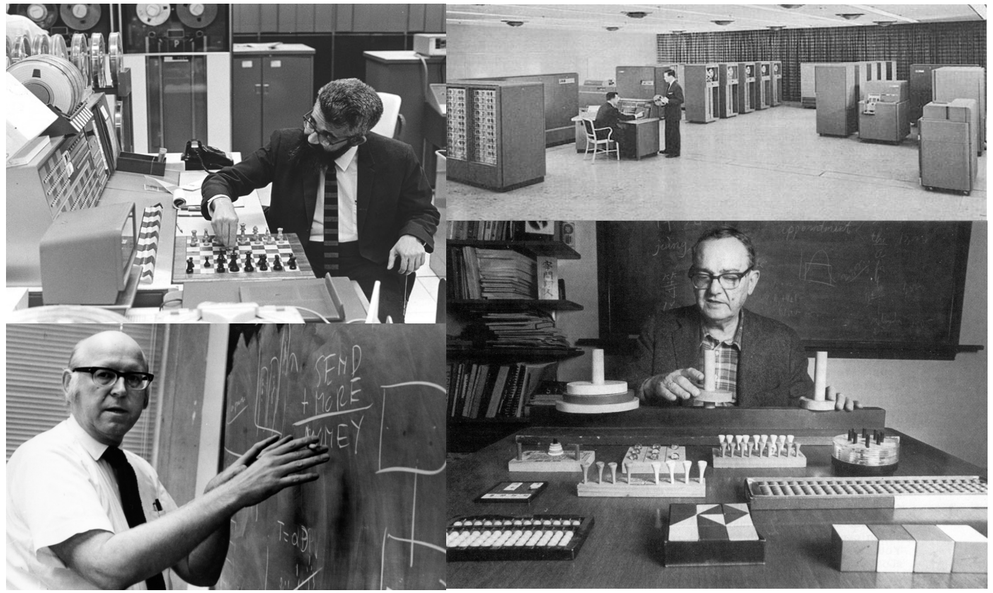
- our motivation from (intelligent) robotics
- yet basic concepts from cybernetics
- modern terminology will be used

Birth of Artificial Intelligence

- 1956 - onwards: Artificial Intelligence

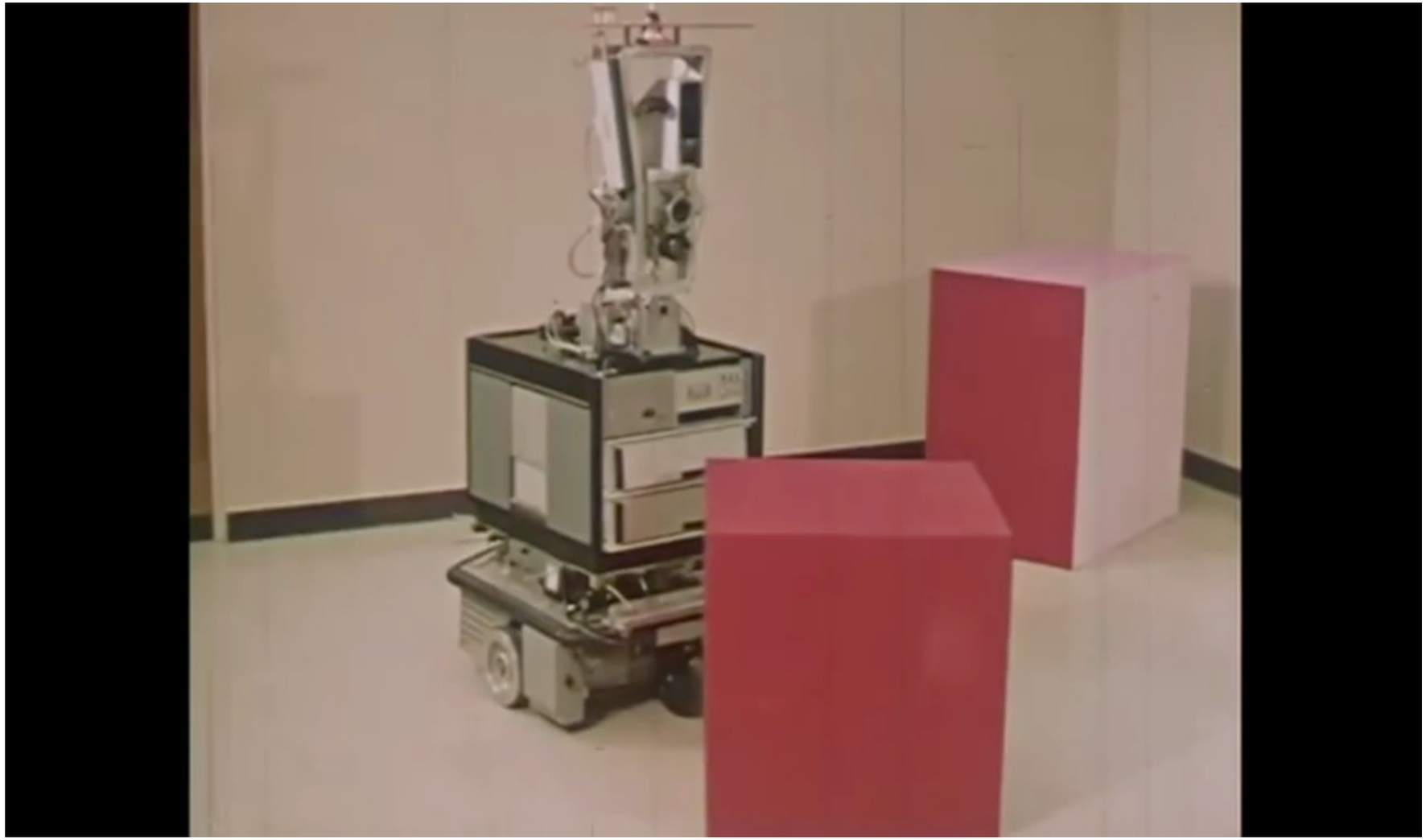
- 1956 Dartmouth Conference / McCarthy coins term “artificial intelligence” / first running AI program (Logic Theorist)
  - from middle ‘50s to late ’80s : ‘**Classical AI**’ (e.g. Newell, Simon, McCarthy)
    - human cognition = a set of ‘rational activities’ (reasoning, language, formal games…);
    - intelligent artifacts = programs for computers

Classical AI = modelling “high level” capabilities (mainly) through computer programs detached from robotic bodies



Slide source: Hagen Lehmann

Historical Notes on Artificial Intelligence
From Classical AI Onwards

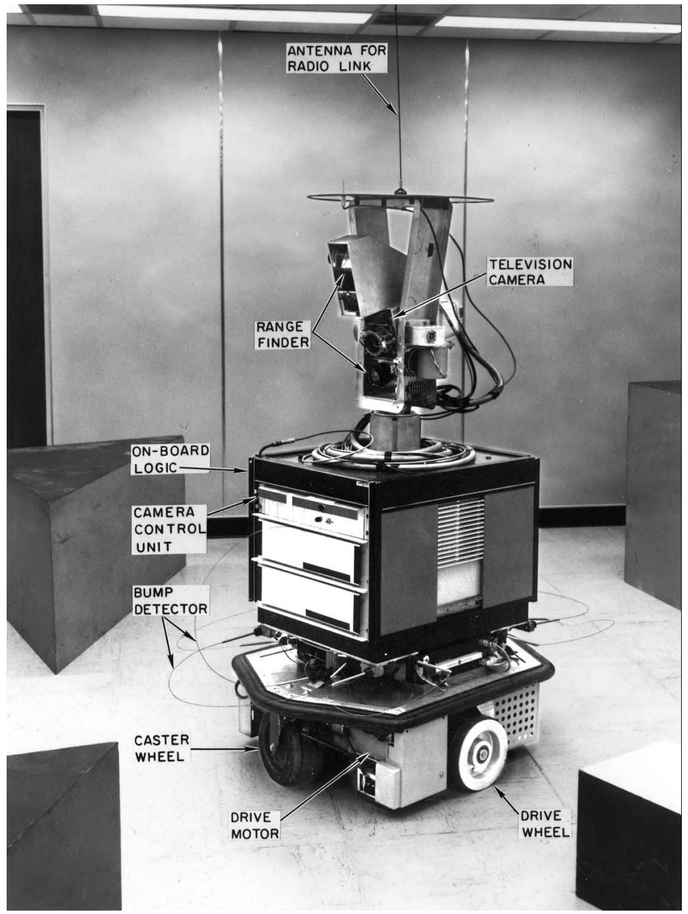


Robot Shakey (1966-1972), https://youtu.be/7bsEN8mwUB8

Slide source: Hagen Lehmann

Historical Notes on Artificial Intelligence

- from middle of 1980s: rising dissatisfaction with using ‘Classical AI’ in robotics
  - far from the expectations of the founders (Herbert A. Simon in '60s: by the end of the ‘80s, machines capable of human mental work)
  - even simple tasks for humans represented big challenges (traversing between rooms)
  - growing interest in probability and bio-inspired techniques



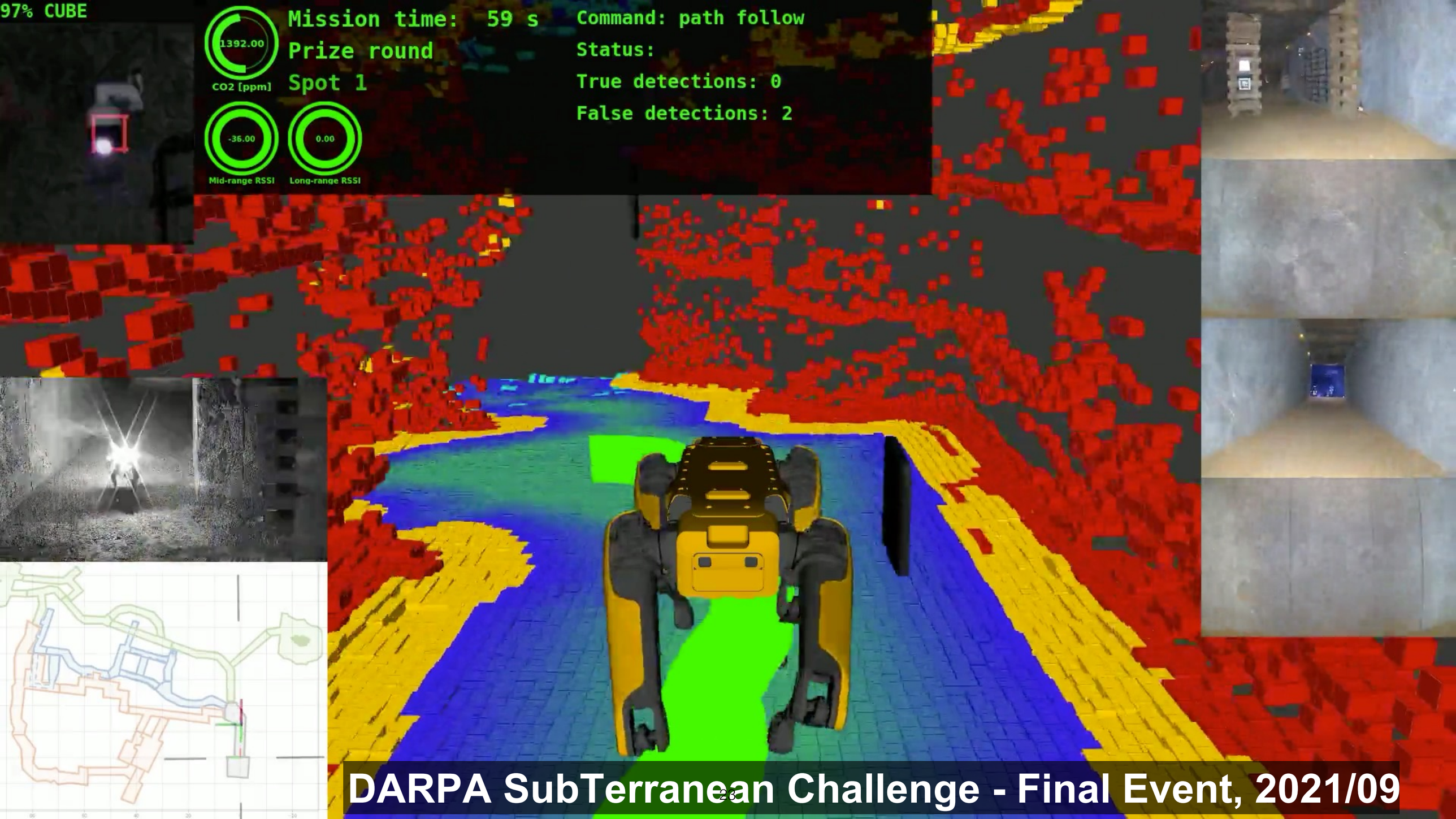
Slide source: Hagen Lehmann


Mirandola 2012 earthquake

Amatrice 2016

FACULTY OF ELECTRICAL ENGINEERING CTU IN PRAGUE

DARPA SubTerranean Challenge - Urban Circuit, 2020/02


97% CUBE
1392.00
CO2 [ppm]
Mission time: 59 s
Prize round
Spot 1
Command: path follow
Status:
True detections: 0
False detections: 2
-36.00
Mid-range RSSI
0.00
Long-range RSSI
DARPA SubTerranean Challenge - Final Event, 2021/09

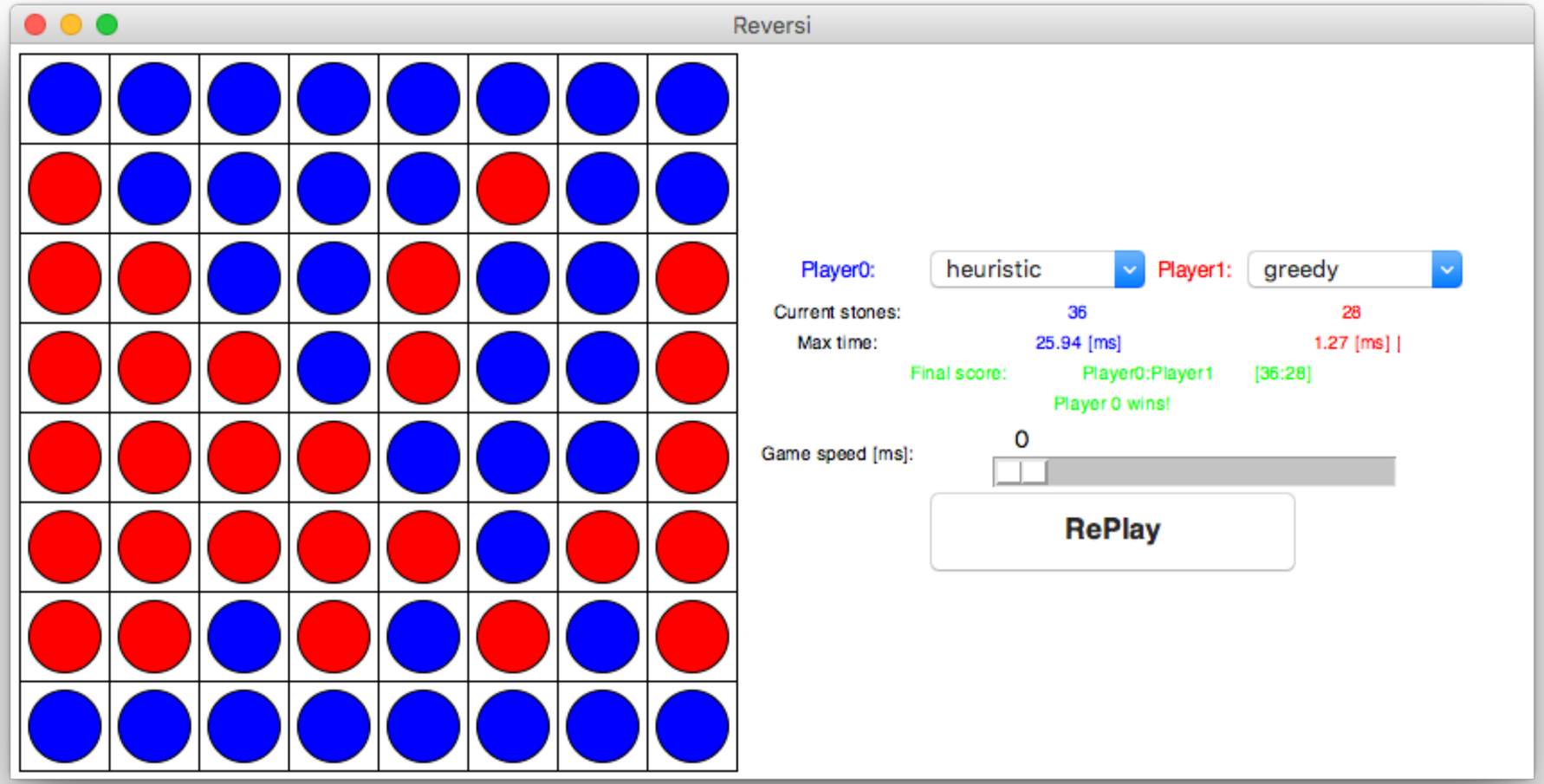
Essentials - course content

- solving problems by **search**
- **sequential decisions** under uncertainty
  - how to search when environment model is known, but action outcomes are unreliable
- reinforcement **learning**
  - map/model unavailable
  - world needs to be explored through interaction
  - learning from final successes and failures
- essentials from **machine learning** - Bayesian decisions, classifiers, …

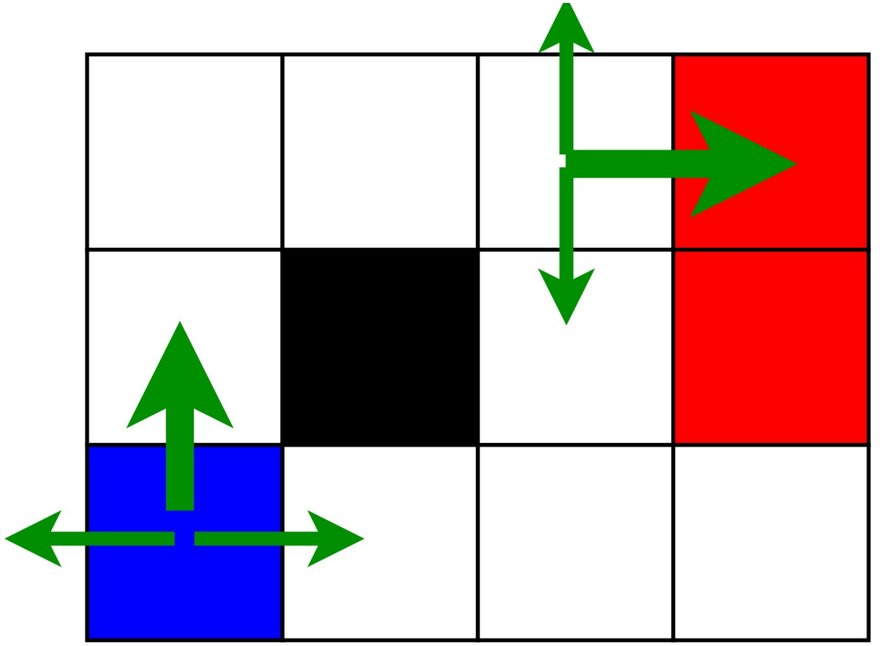
search, …, and beyond

https://youtu.be/tLrc2NiGzRc

Someone is playing against us

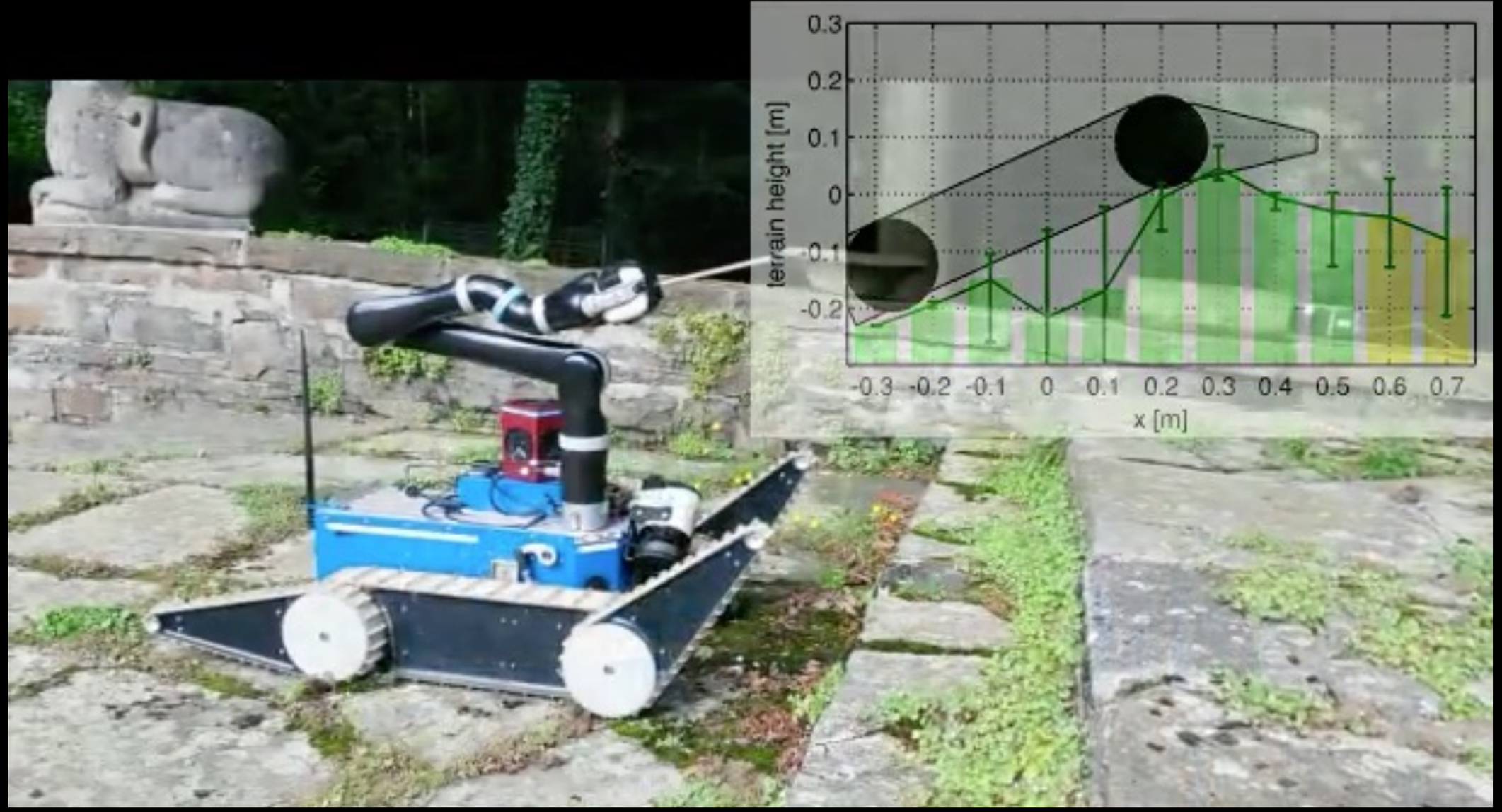


- Walls block movement – agent/robot stays in place.
- Actions do not always go as planned.
- Agent receives rewards each time step:
  - Small "living" reward/penalty.
  - Big rewards/penalties at the end.
- Goal: maximize sum of (discounted) rewards




OBYTNÝ VŮZ

https://youtu.be/JyonGazRoTk



M. Pecka, K. Zimmermann, M. Reinstein, and T. Svoboda. Controlling Robot Morphology from Incomplete Measurements. In *IEEE Transactions on Industrial Electronics*, Feb 2017, Vol 64, Issue: 2

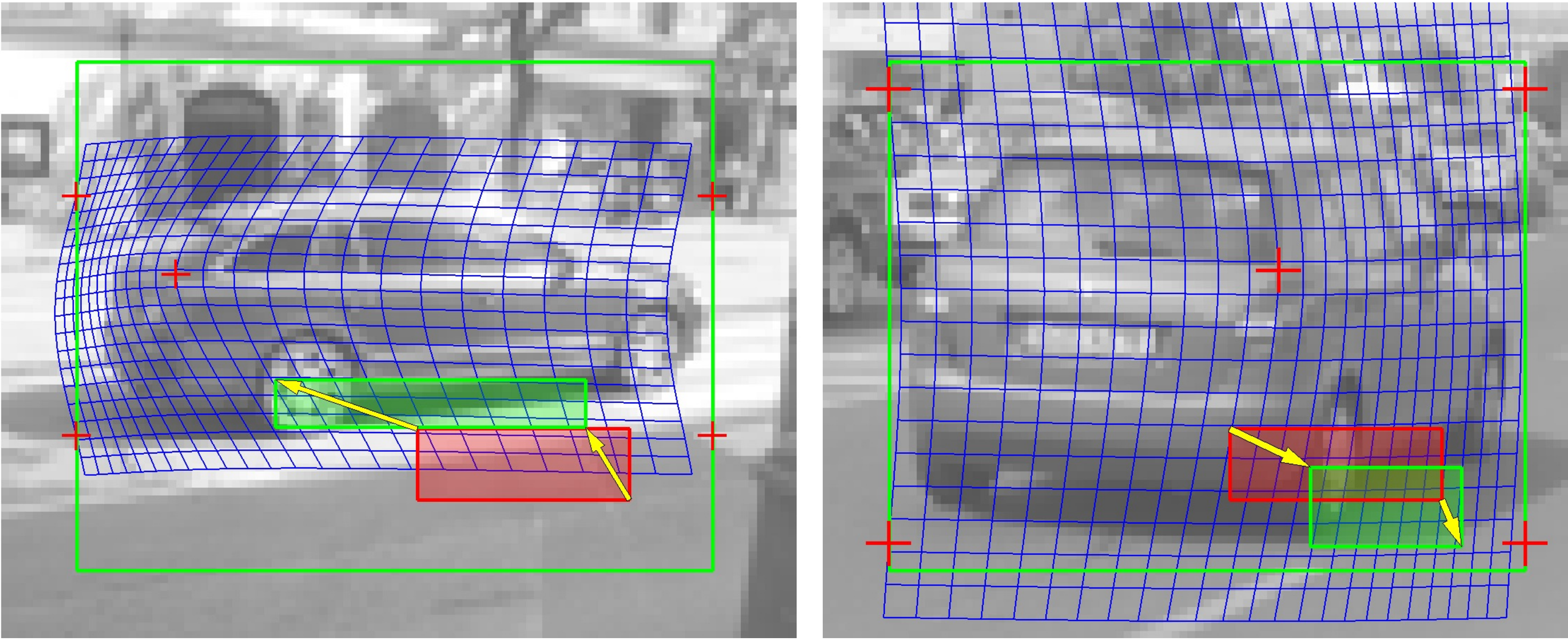
V. Šalanský, V. Kubelka, K. Zimmermann, M. Reinstein, T. Svoboda. Touching without vision: terrain perception in sensory deprived environments. CVWW 2016

learning, classification, …

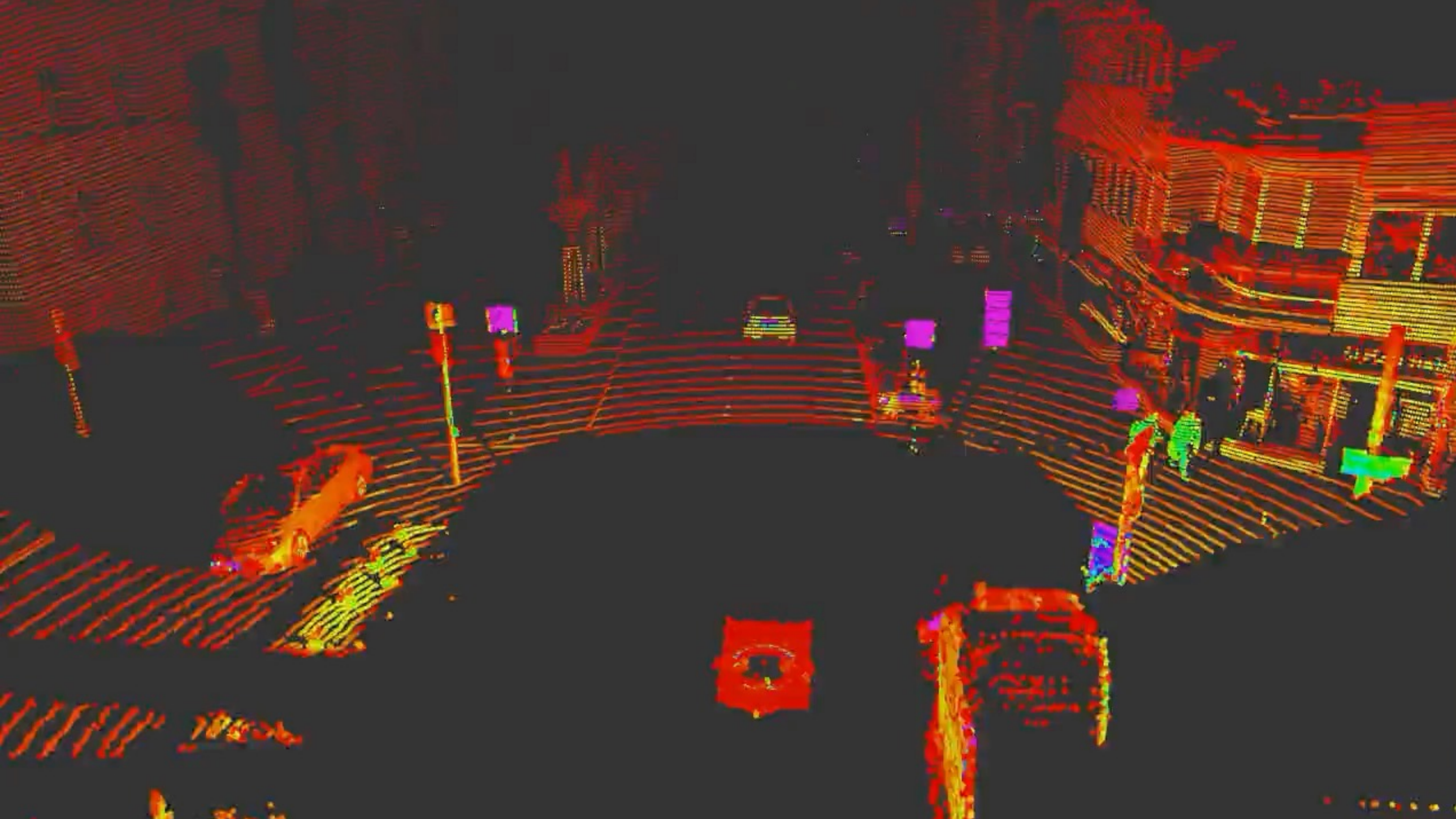
https://youtu.be/lla_GVeQMvA

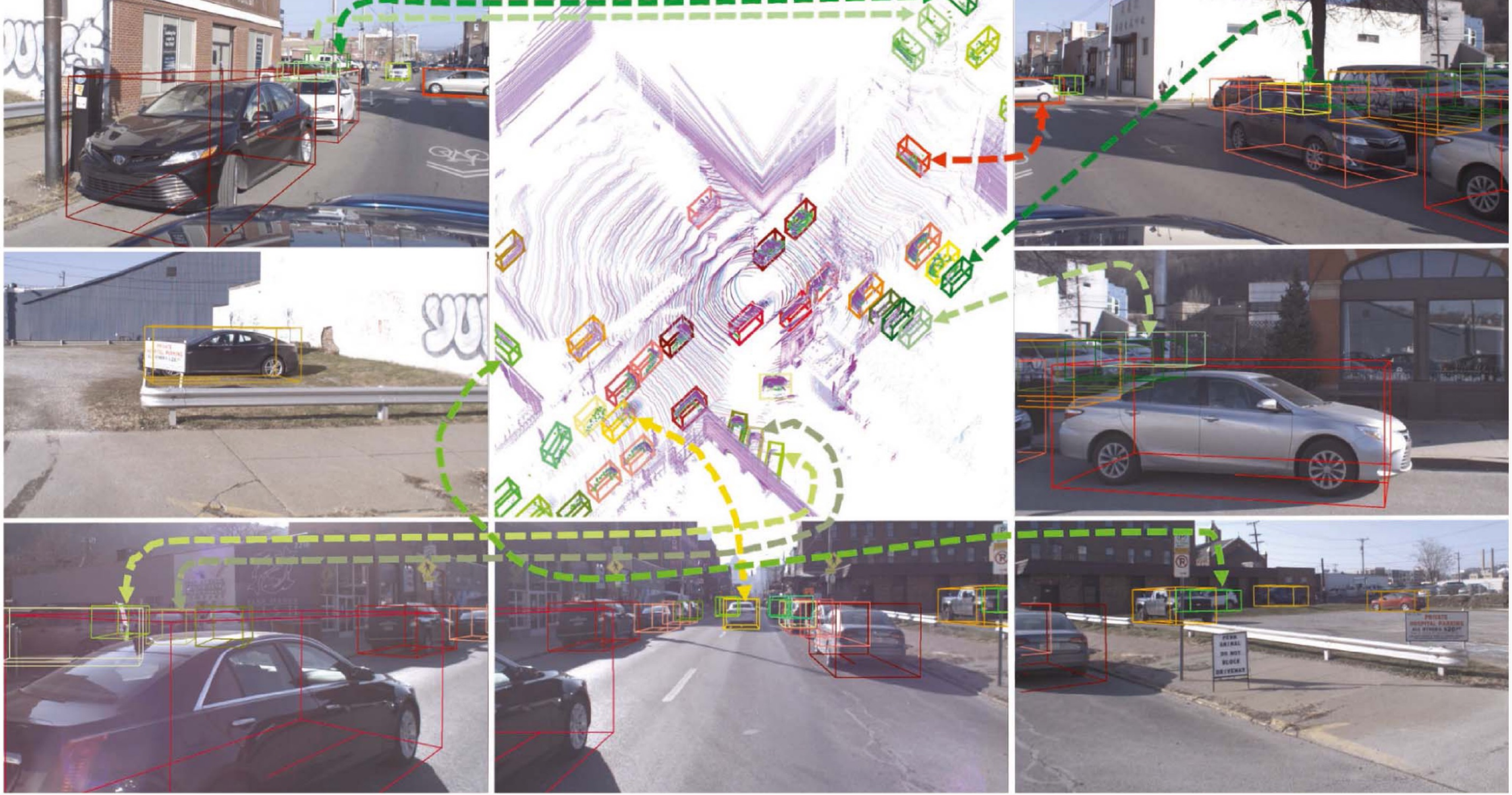
$\frac{x}{\text{cm}}$	XS (0–100)	S (100–125)	M (125–150)	L (150–175)	XL (175–200)	XXL (200-∞)	Σ
$P(x\|\text{male})$	0.05	0.15	0.2	0.25	0.3	0.05	**1**
$P(x\|\text{female})$	0.05	0.1	0.3	0.3	0.25	0.0	**1**

object detection - deforming for better detection/recognition



K. Zimmermann, D. Hurych, T. Svoboda. Non-Rigid Object Detection with Local Interleaved Sequential Alignment (LISA). In *IEEE Transactions on Pattern Analysis and Machine Intelligence*, April 2014, Vol 36, Issue 4

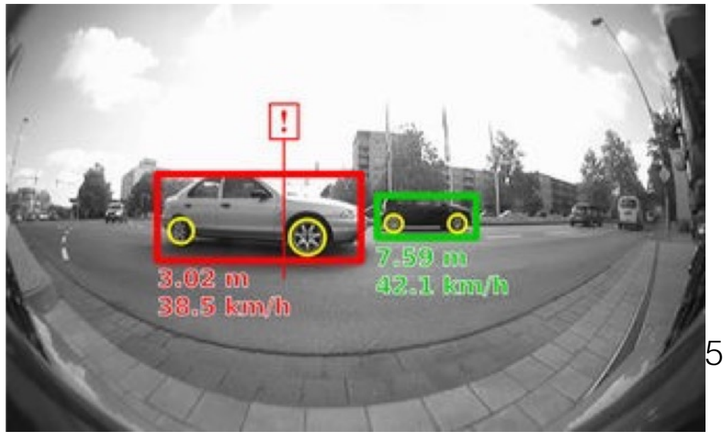




A. H. Gebrehiwot, P. Vacek, D. Hurych, K. Zimmermann, P. Perez, T. Svoboda. Teachers in Concordance for Pseudo-Labeling of 3D Sequential Data. *IEEE Robotics and Automation Letters*, February 2023, Vol 8, Issue 2

Course emphasis on problem solving

- (problem) analysis
- formalize the problem
- solution - algorithm
- implementation/computation
- verification/testing



Student projects

- Bachelor project / thesis, paid summer internship…
- Check:
  - https://cyber.felk.cvut.cz/research/groups-teams/vras/ - Student topics
  - https://sites.google.com/site/matejhof/student-projects/open-and-ongoing

Summary

- What is cybernetics?
- Our target: a goal directed machine
- Thinking about state(s)

Literature and resources for this lecture & further reading

- History of Cybernetics:
  - 1948, Norbert Wiener: *Cybernetics: Or Control and Communication in the Animal and the Machine*. Paris, (Hermann & Cie) & Camb. Mass. (MIT Press) 2nd revised ed. 1961.
  - 1956, William R. Ashby: *An Introduction to Cybernetics*, Chapman & Hall.
- In Czech:
  - Romportl, J. (2013). *Kapitoly z historie kybernetiky*.
  - Vysoký, P. (1998). Padesát let kybernetiky, Vesmír 77, 626, 1998/11