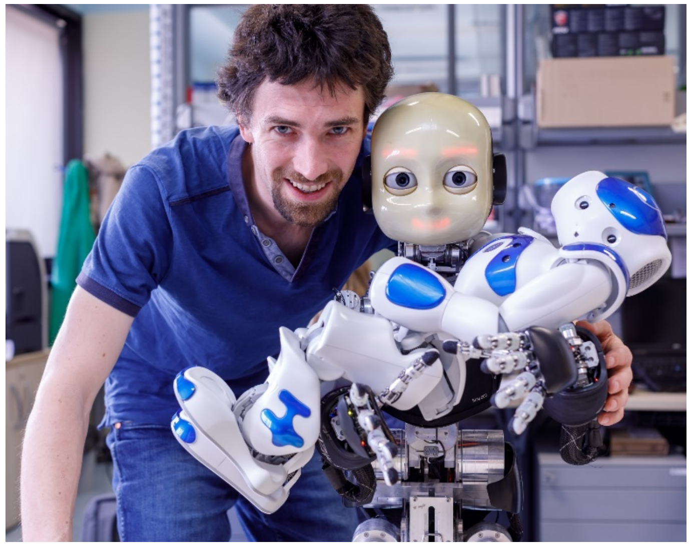
Cybernetics and Artificial Intelligence
Introduction into the course

Matěj Hoffmann & Tomáš Svoboda,
2019



Admin, rules of the game

- weekly: 2 hours lectures, 2 computer labs, 5 individual work (reading, coding)
- at the end: ~35 hours wrapping up - preparing for exam.

Intensive term work may save time at the end.

- https://cw.fel.cvut.cz/wiki/courses/be5b33kui/start
  - program
  - grading
  - literature …

literature, resources

- we recommend a few (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 you recommend new ones

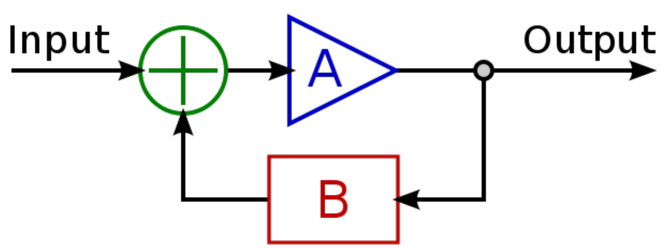
Cybernetics

- “The word *cybernetics* comes from Greek κυβερνητική (*kybernētikḗ*), 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"



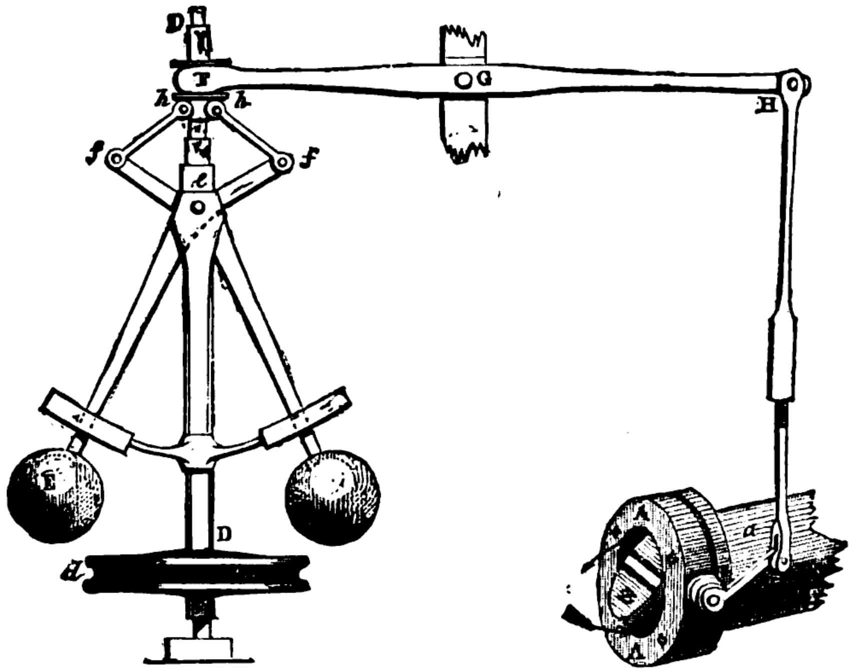


FIG. 4.—*Governor and Throttle-Valve.*

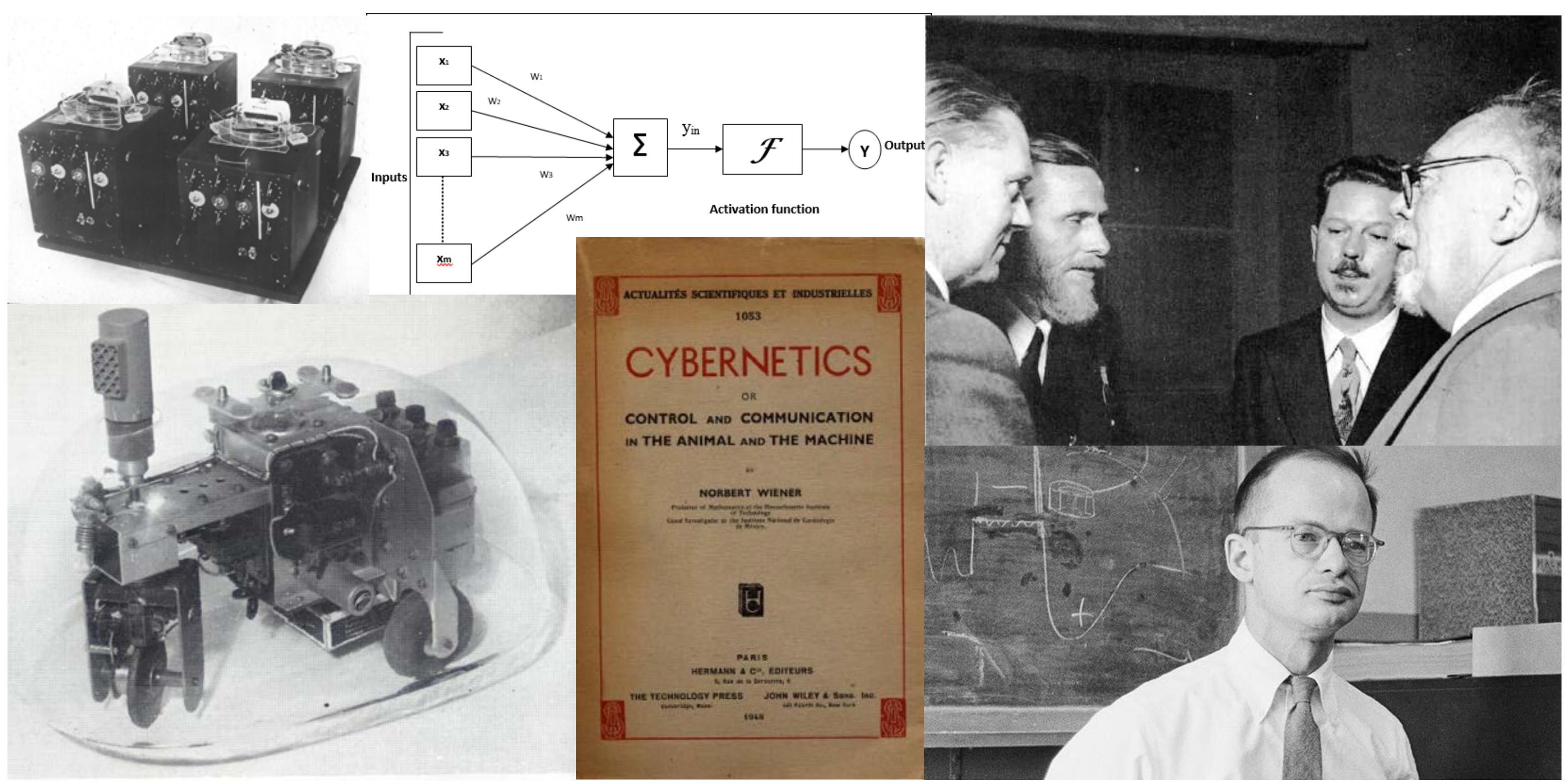
https://en.wikipedia.org/wiki/Centrifugal_governor#/media/File:Centrifugal_governor.png
https://en.wikipedia.org/wiki/Negative_feedback

William Ross Ashby: An introduction to cybernetics

- W. R. Ashby (1903 – 1972) – English psychiatrist
- Book: An introduction to cybernetics (1957)
  - Excerpts from Table of contents:
    - Part I: Mechanism
      - Coupling systems, feedback, stability, disturbance, equilibrium black box…
    - Part II: Variety
      - Constraint, Transmission (through a channel), Markov chain, Entropy, Noise…
    - Part III: Regulation and control
      - Error-controlled regulator, Markovian regulation, Games and strategies, Amplifier…

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

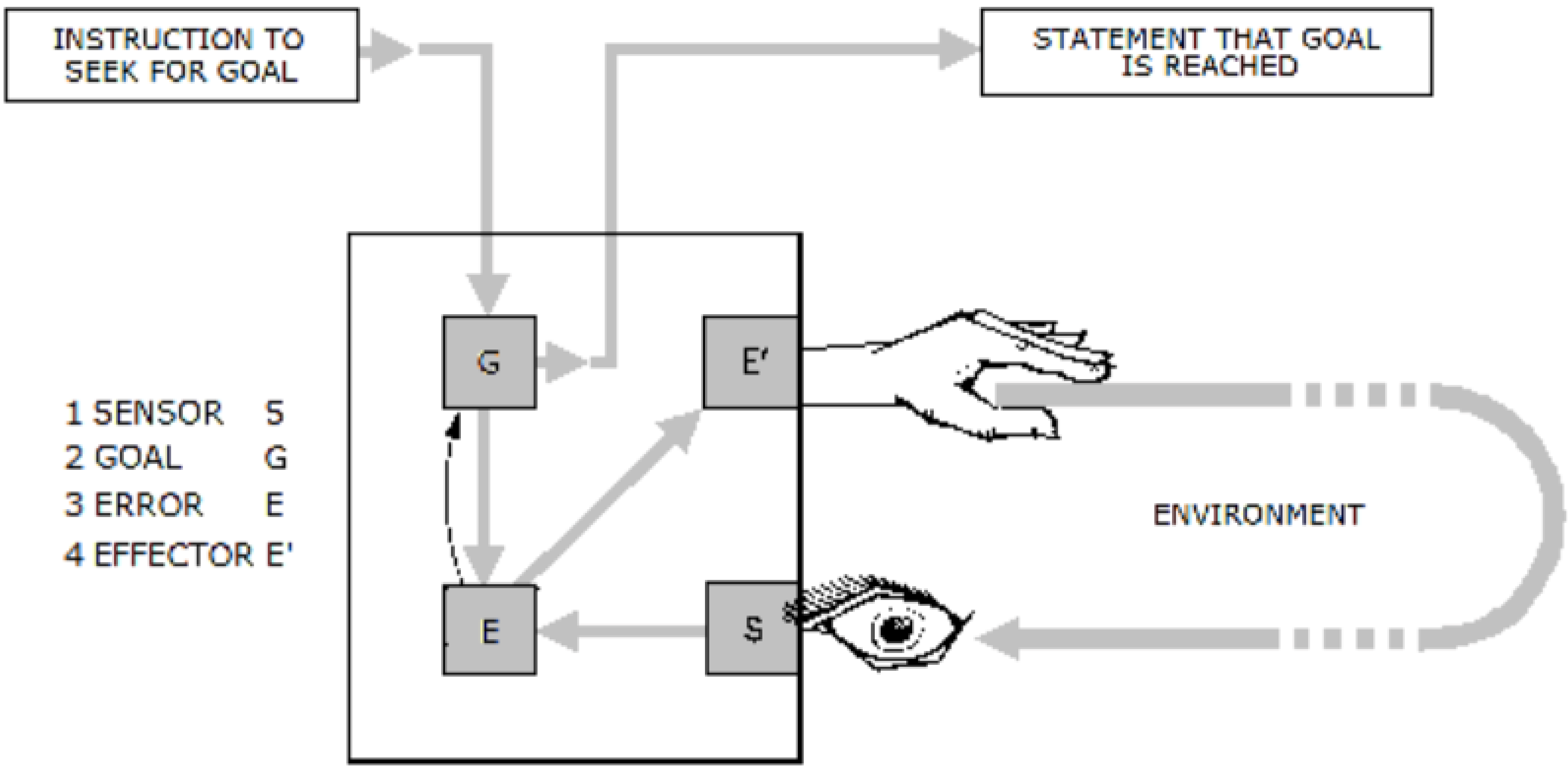
Grey Walter’s tortoises

- video

2nd order cybernetics

- Heinz von Foerster (1968-1975)
  - Cybernetics of “observing systems” rather than “observed systems”
- Biology: Humberto Maturana and Franscisco Varela influenced by cybernetic concepts
  - “autopoiesis” – self-generating, self-maintaining structure in living systems

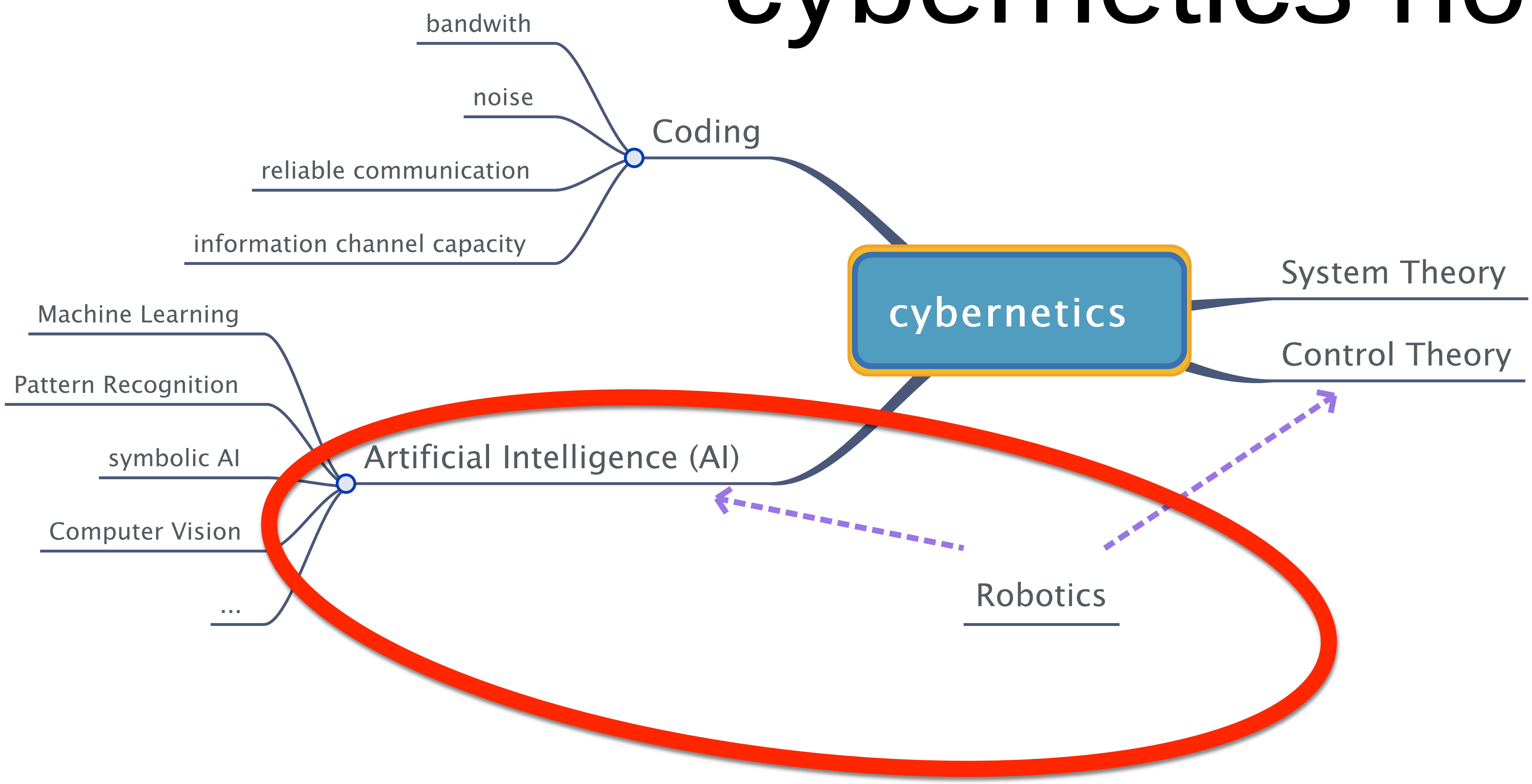
goal-directed system



A SIMPLE 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

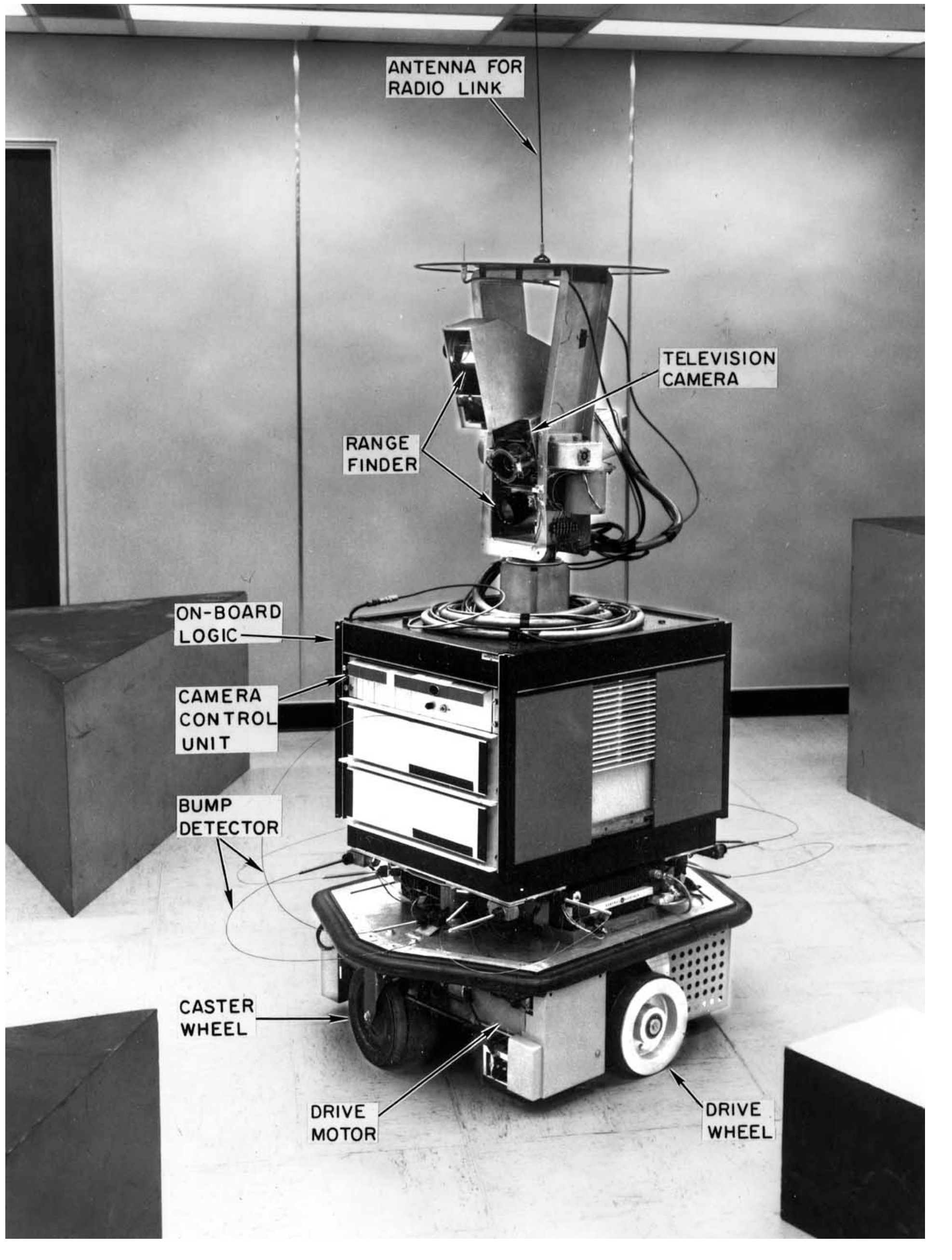
- 1956 - onwards: Artificial Intelligence
  - 1956 Dartmouth Conference / McCarthy coins term “artificial intelligence” / first running AI program (Logic Theorist)
  - from middle ‘50s to late ’80s : ‘**Classical AI**’ (e.g. Newell, Simon, McCarthy)
    - human cognition = a set of ‘rational activities’ (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 middle of ’80s: rising unsatisfaction with using ‘Classical AI’ in robotics
  - far from the expectations of the founders (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

Historical Notes on Artificial Intelligence

From Classical AI Onwards

Shakey - video

Slide source: Hagen Lehmann

problem: machine control in unstructured environment

TRADR Amatrice video

2016 Amatrice (Italy) earthquake, deployment of the TRADR system, http://www.tradr-project.eu

(our) pictures of the game

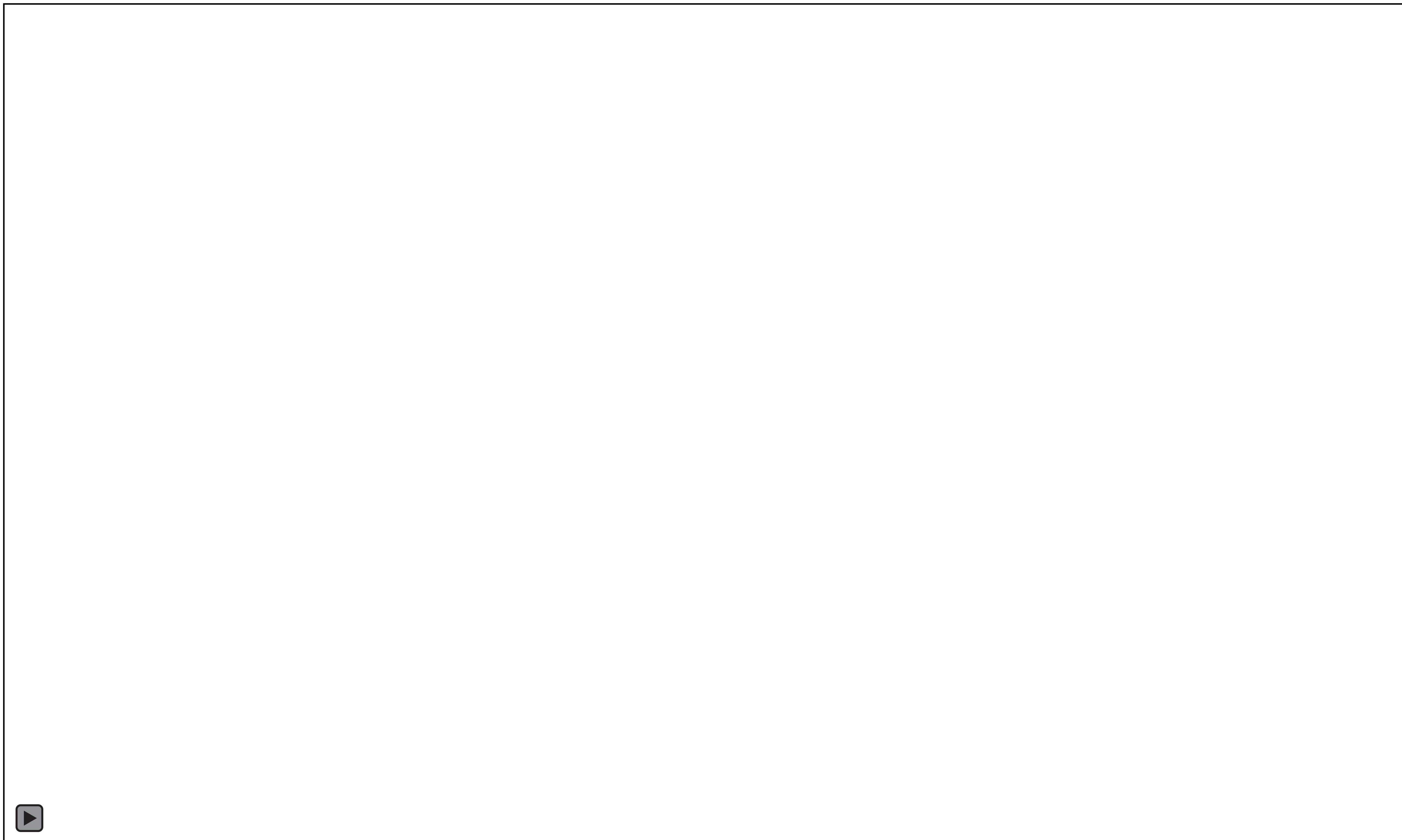
VRAS videos

http://www.tradr-project.eu, http://www.nifti.eu, https://cyber.felk.cvut.cz/category/department/cmp/vras/

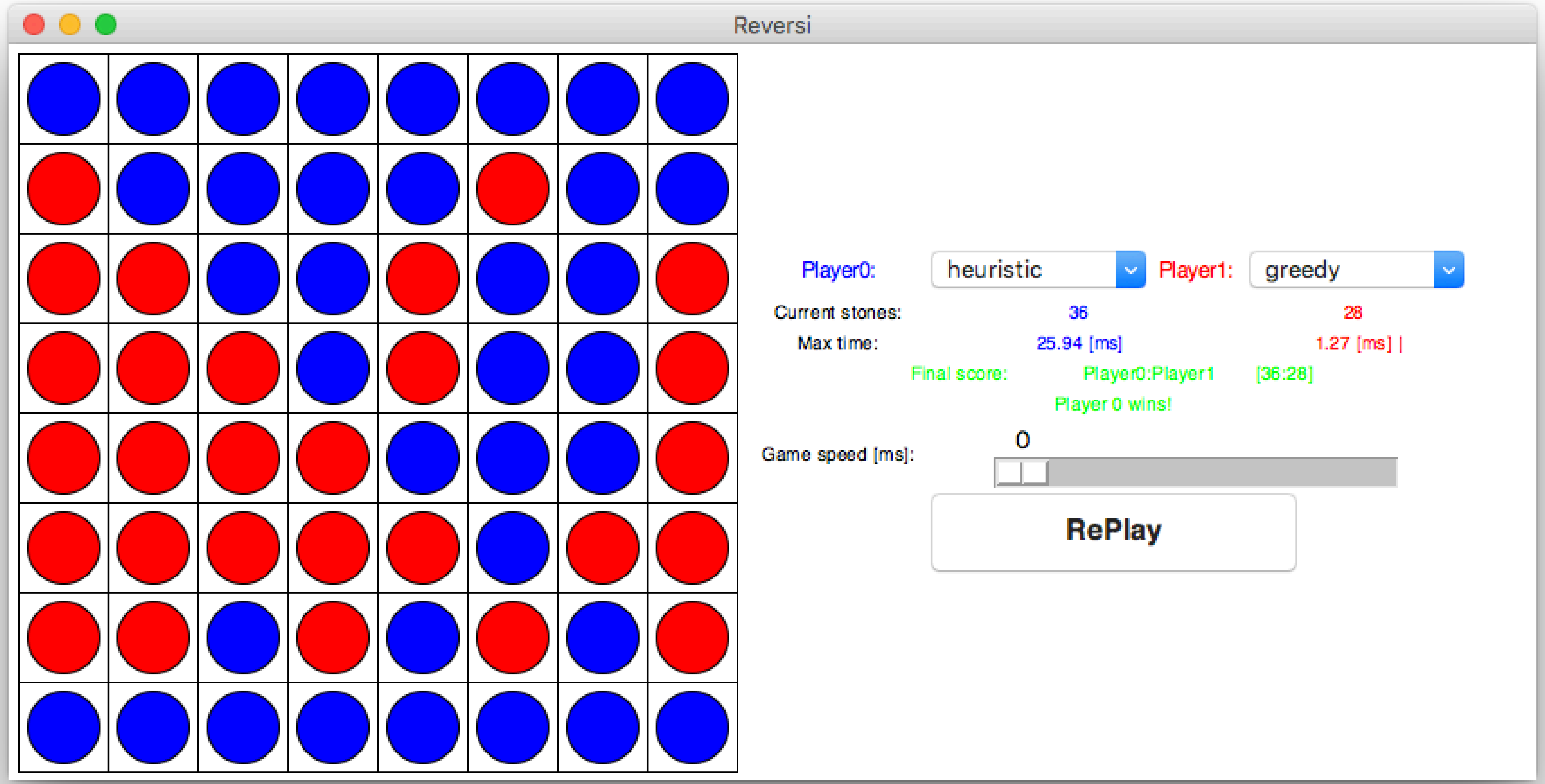
essentials - course content

- solving problems by search
- sequential decisions under uncertainty - how to search when actions are unreliable, but known
- reinforcement learning - learning from final successes and failures
- essentials from machine learning - bayesian decisions, classifiers, …

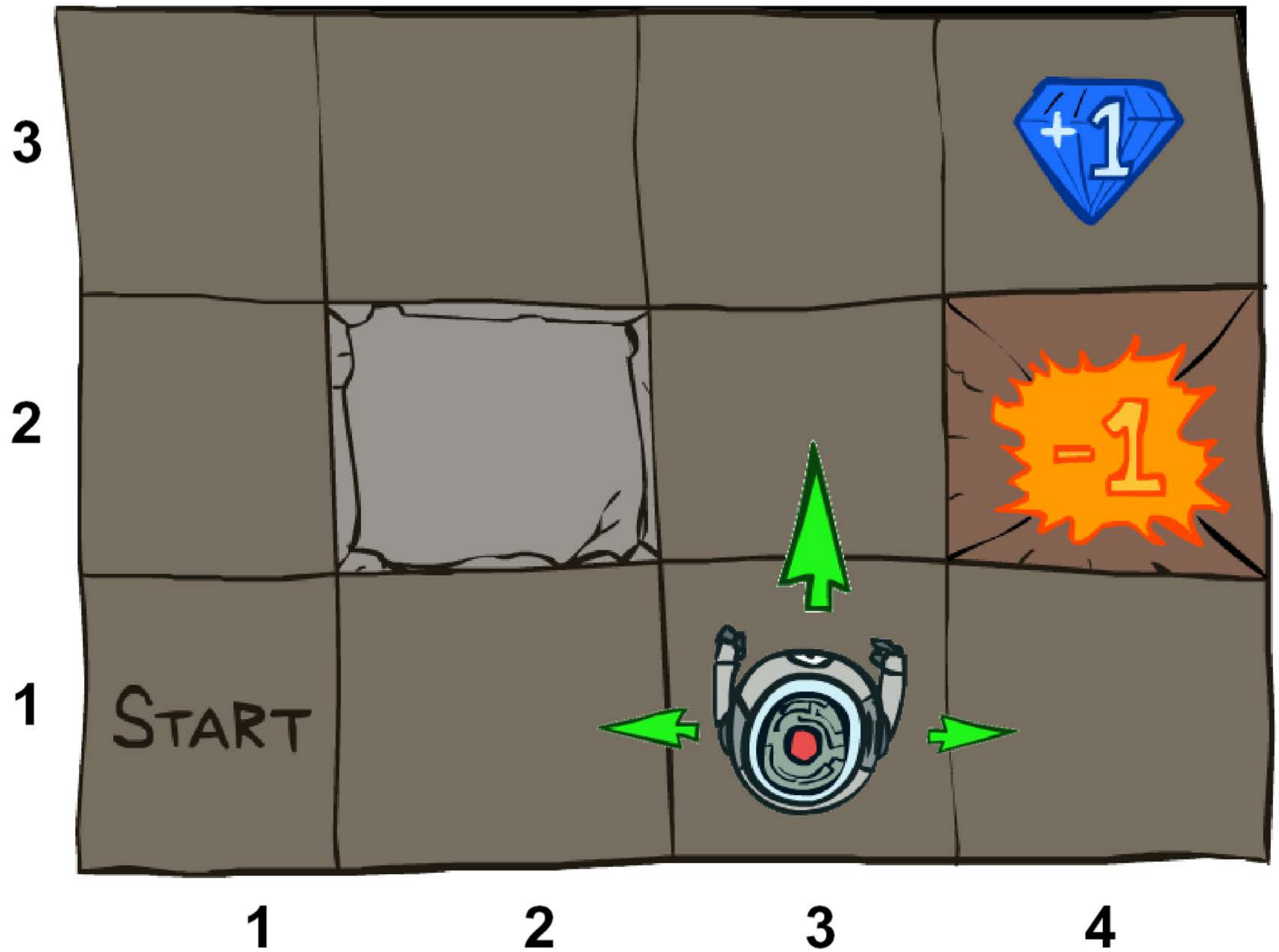
search, …, and beyond



Someone is playing against us



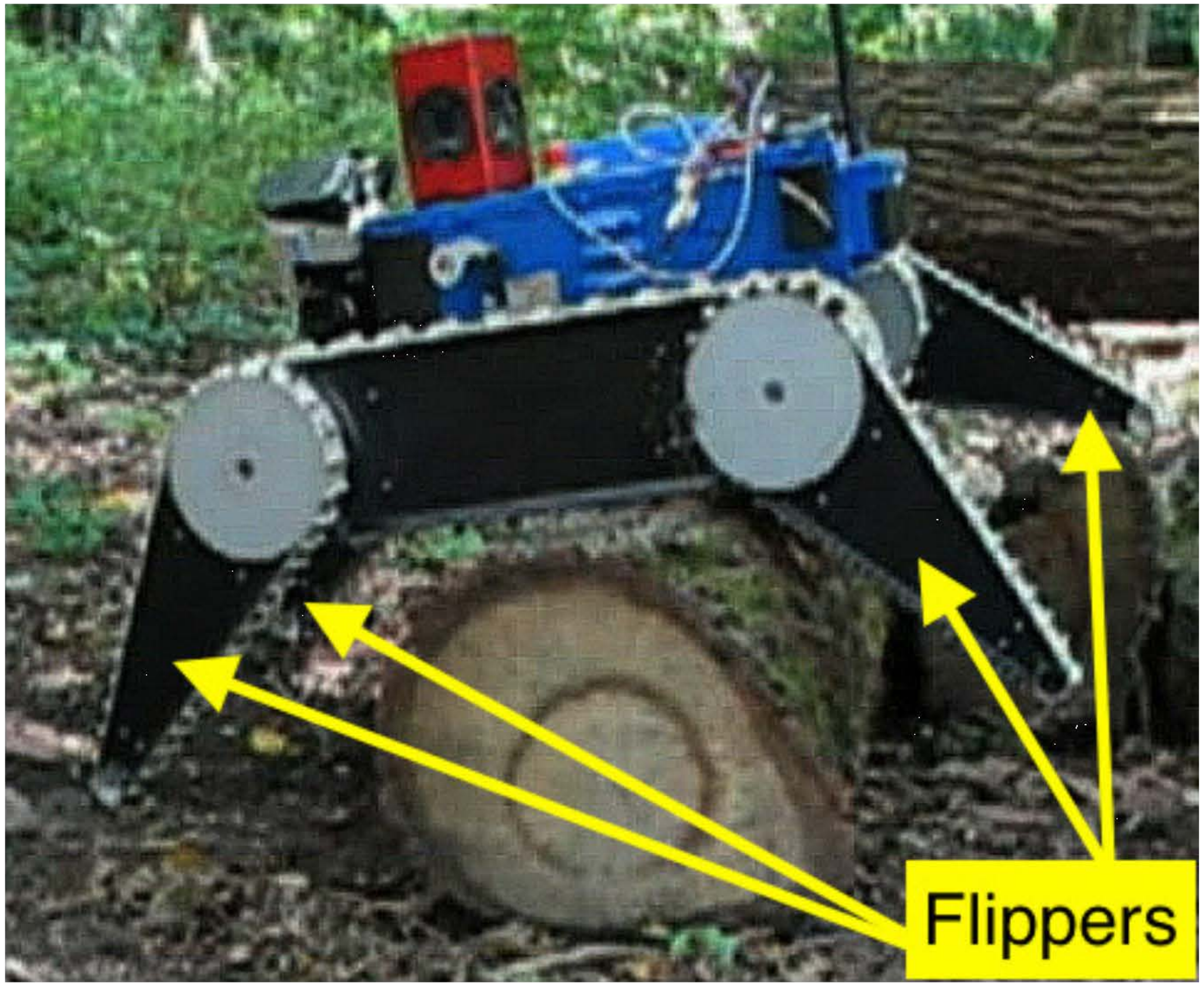
A robot may not always obey the commands

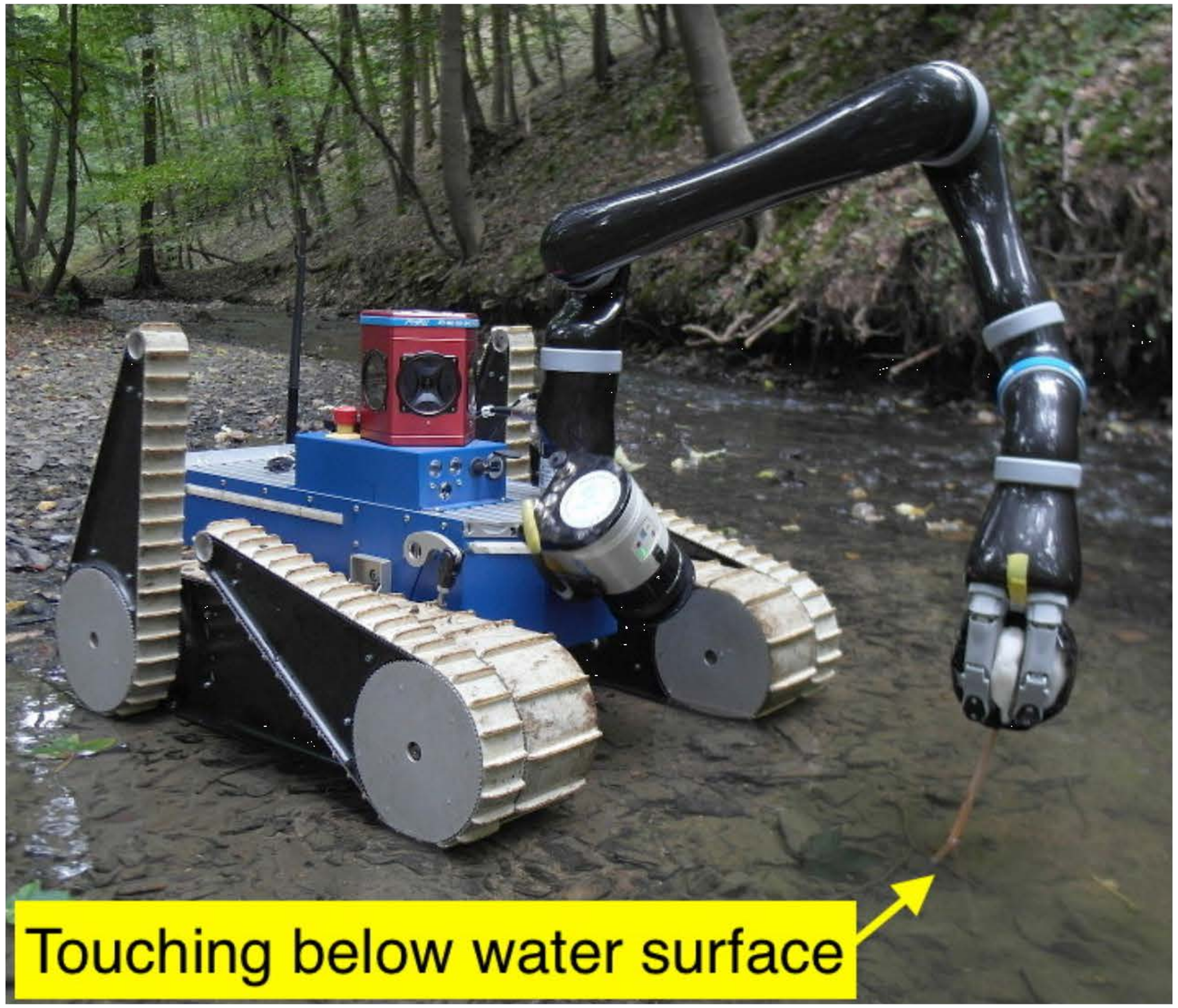


joint exploration and segmentation

TRADR victims video

(reinforcement) learning for the robot control



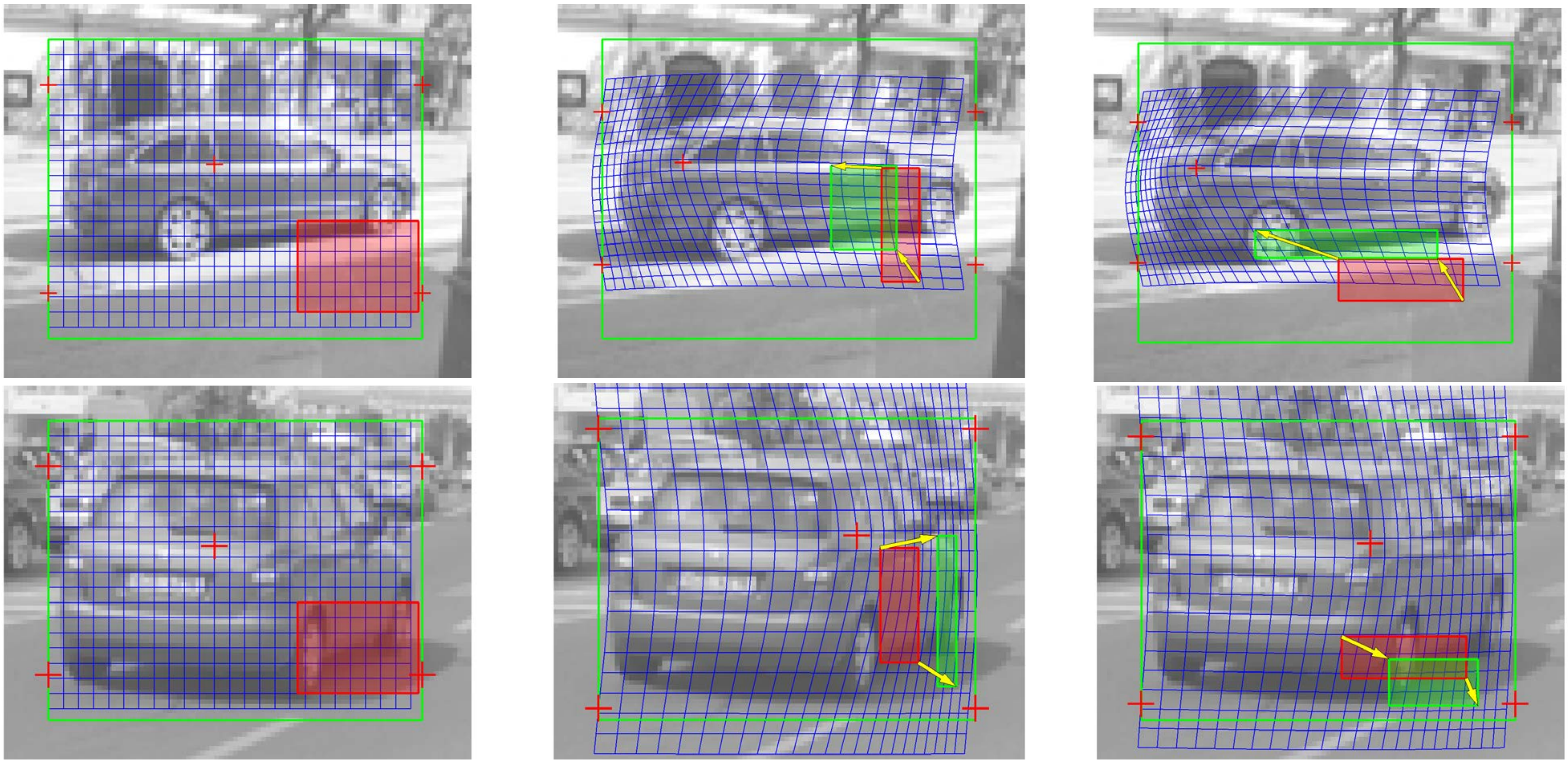


M. Pecka, K. Zimmermann, M. Reinstein, and T. Svoboda. Controlling Robot Morphology from Incomplete Measurements. In *IEEE Transactions on Industrial Electronics*, Feb 2017, Vol 64, Issue: 2, pp. 1773-1782

V. Kubelka, L. Oswald, F. Pomerleau, F. Colas, T. Svoboda, and M. Reinstein. Robust data fusion of multi-modal sensory information for mobile robots. In *Journal of Field Robotics*, June 2015, Vol 32, Issue: 4

reinforcement learning

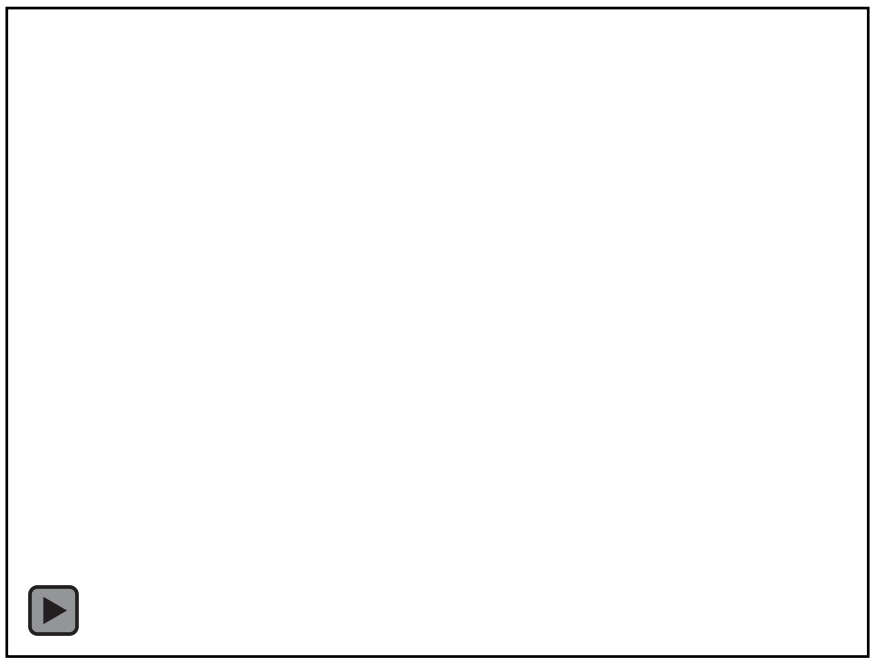
object detection - deforming for better detection/recognition

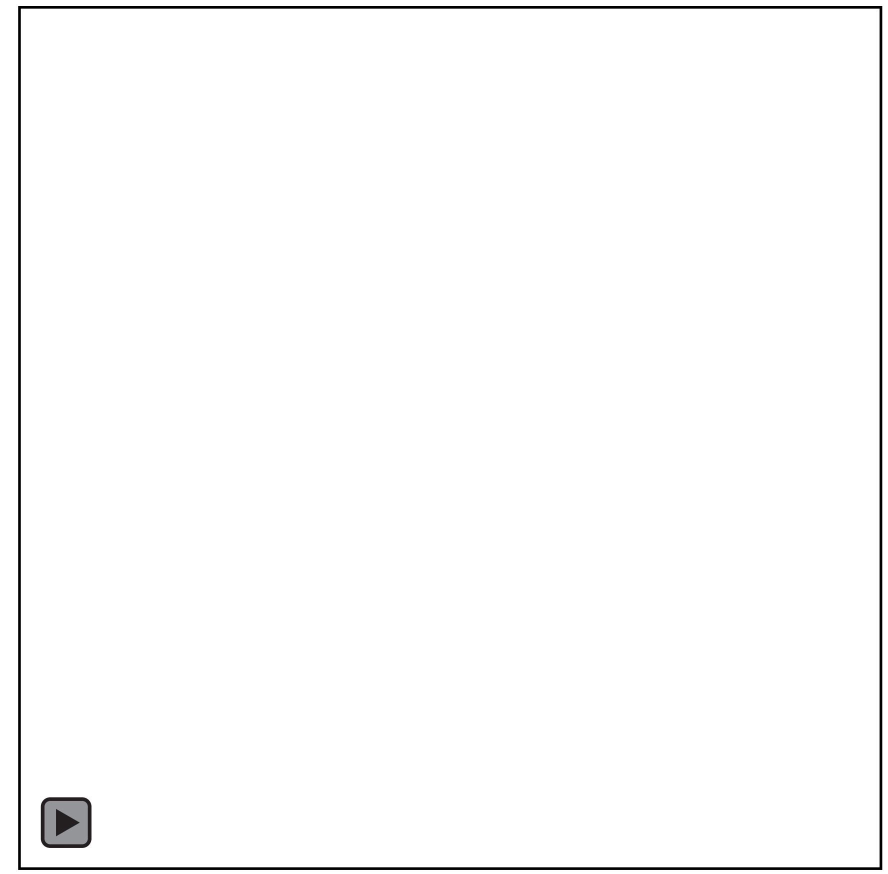


K. Zimmermann, D. Hurych, T. Svoboda. Non-Rigid Object Detection with Local Interleaved Sequential Alignment (LISA). In *IEEE Transactions on Pattern Analysis and Machine Intelligence*, [April 2014, Vol 36, Issue 4]


raw image (kyoCA02/50)
lateral view angle (−75,+75) [deg]

learning, classification, …

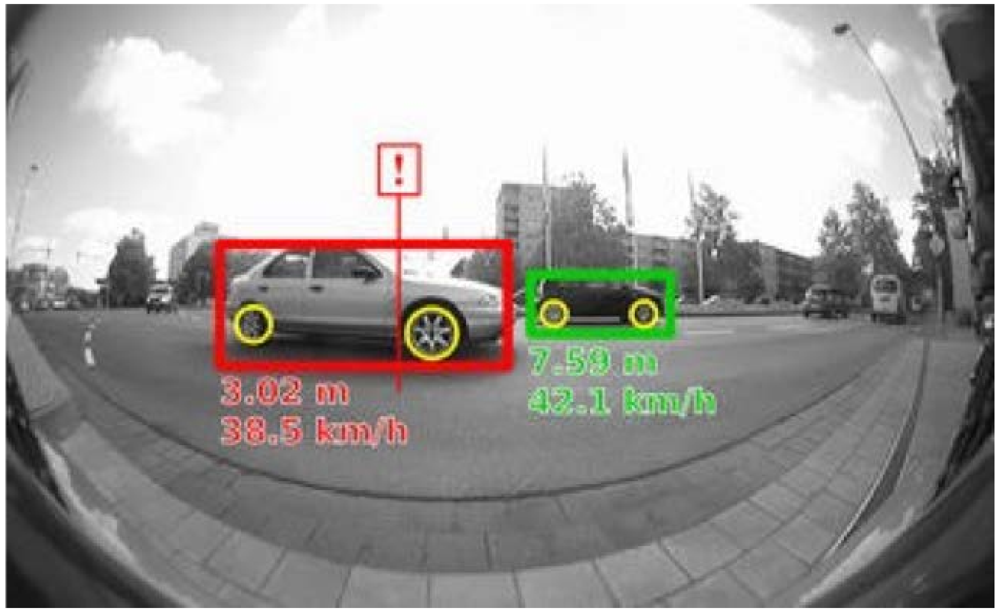




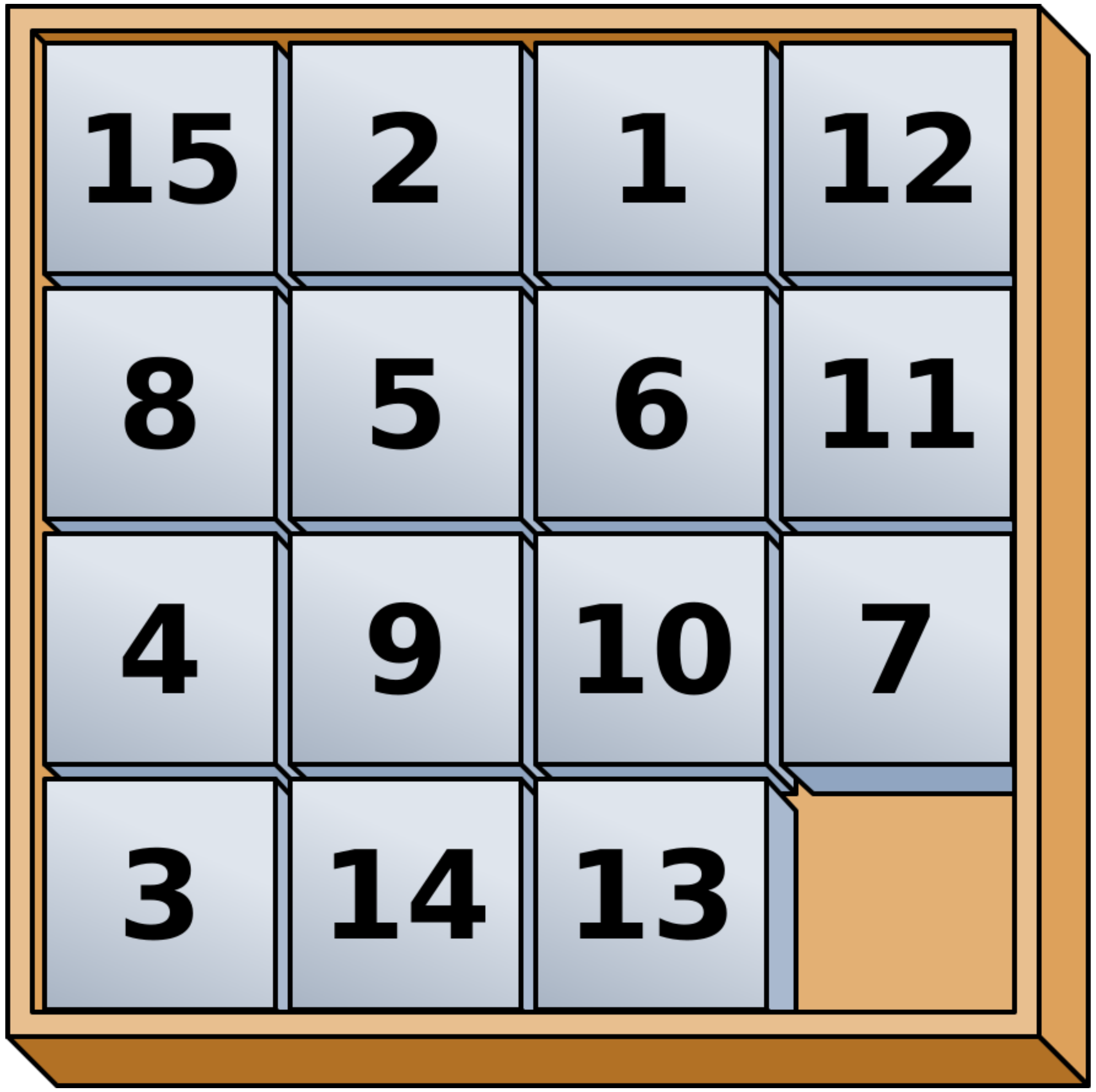
x cm	XS (0–100)	S (100–125)	M (125–150)	L (150–175)	XL (175–200)	XXL (200-∞)	Σ
$P(x\|\text{male})$	0.05	0.15	0.2	0.25	0.3	0.05	**1**
$P(x\|\text{female})$	0.05	0.1	0.3	0.3	0.25	0.0	**1**

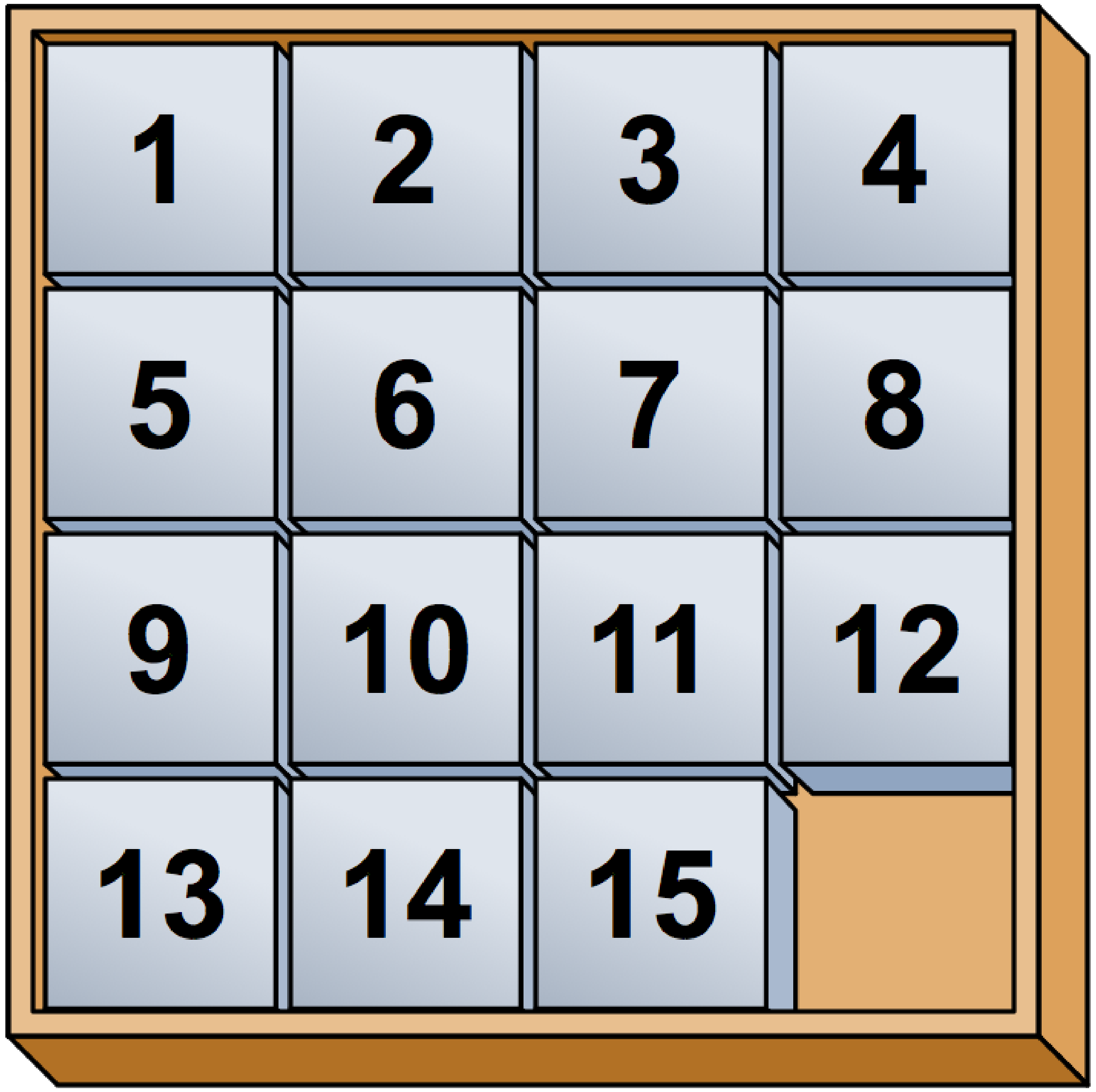
emphasis on problem solving

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



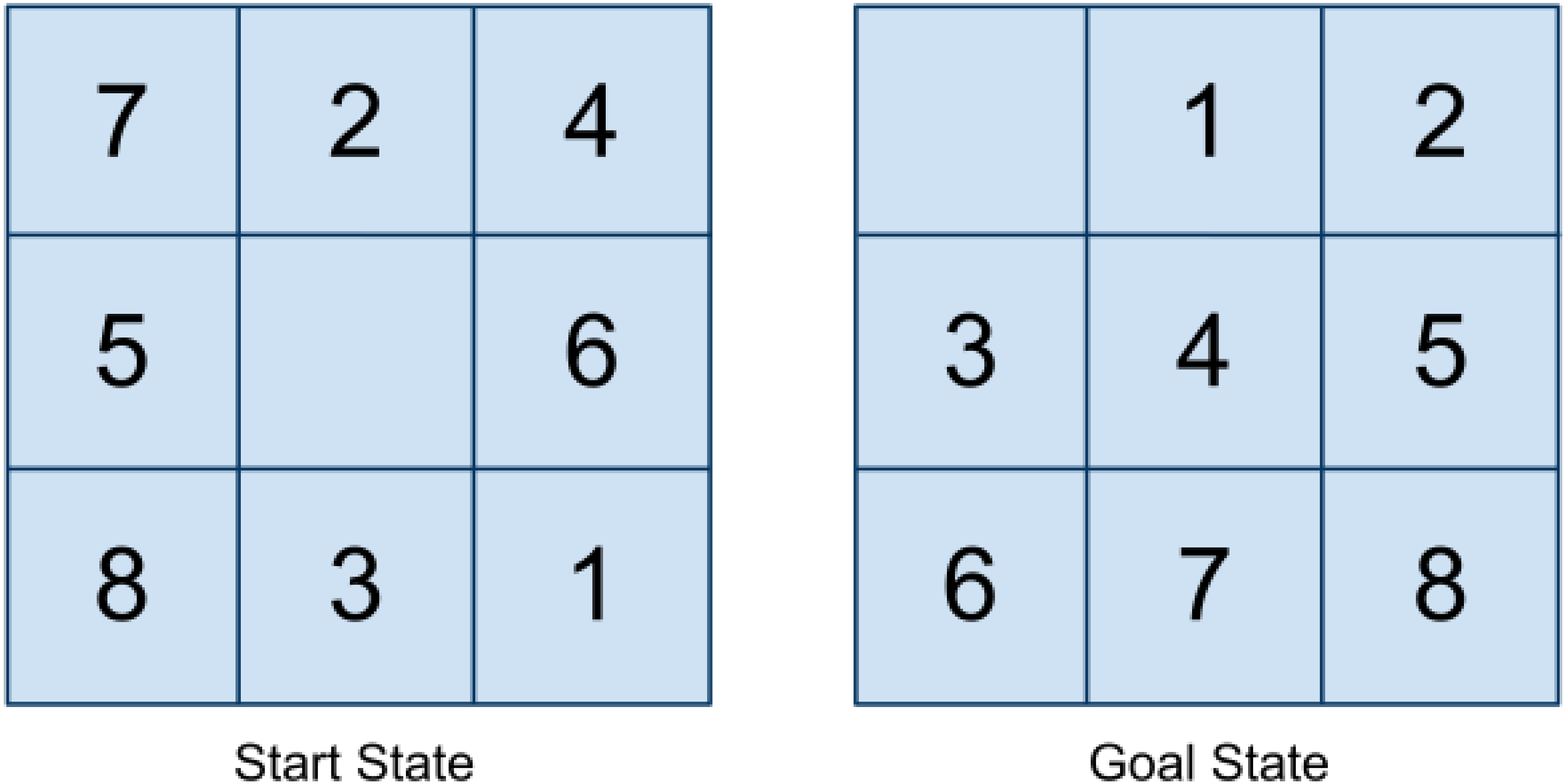
n-1 puzzle (here 16-1)



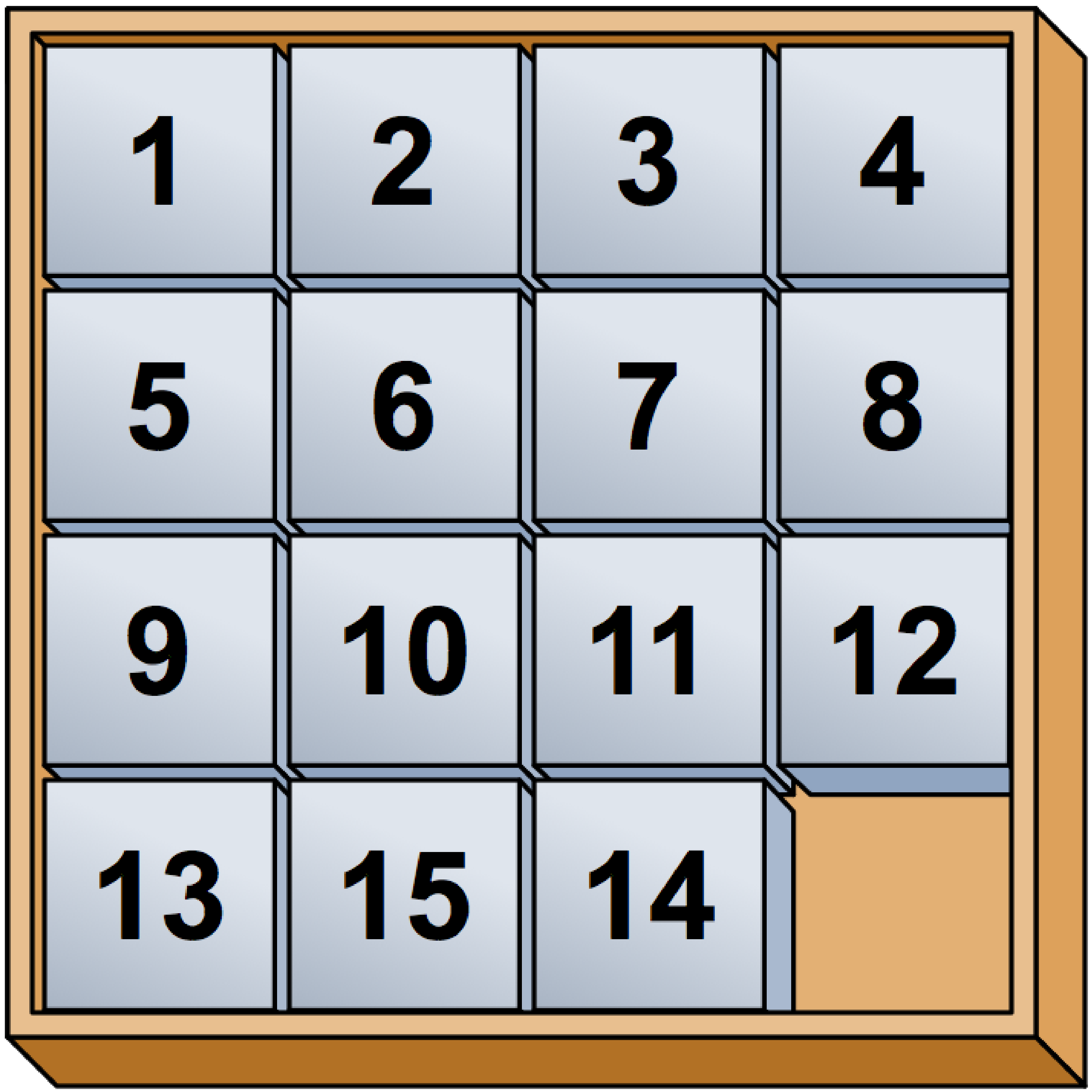


15-puzzle.svg:, Public Domain, https://commons.wikimedia.org/w/index.php?curid=28995093

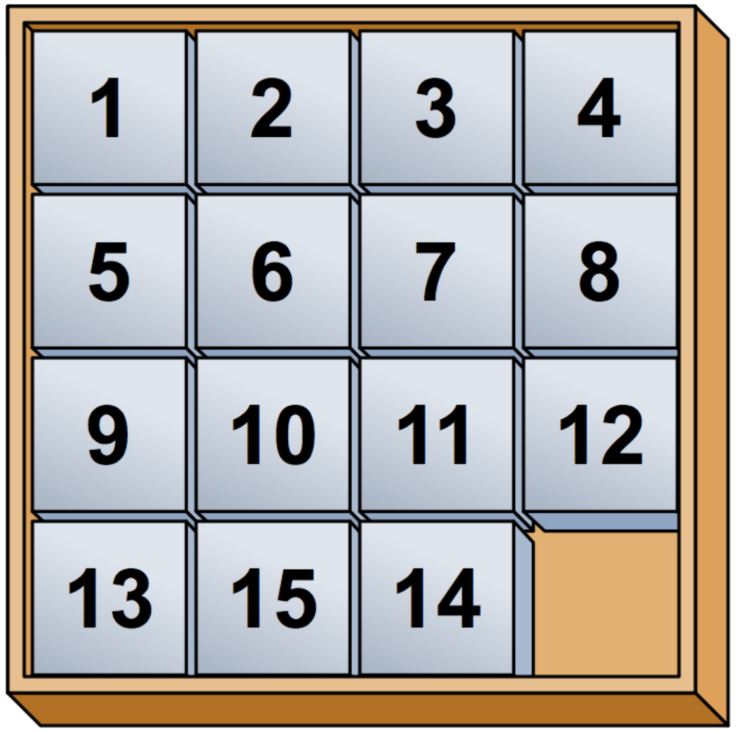
8-puzzle



almost(?) there …



states



- What is the state?
- How many states?
- Are all states solvable?
- Can we decide before actually solving it?

inversions

12	1	10	2
7	11	4	14
5		9	15
8	13	6	3

fig 4

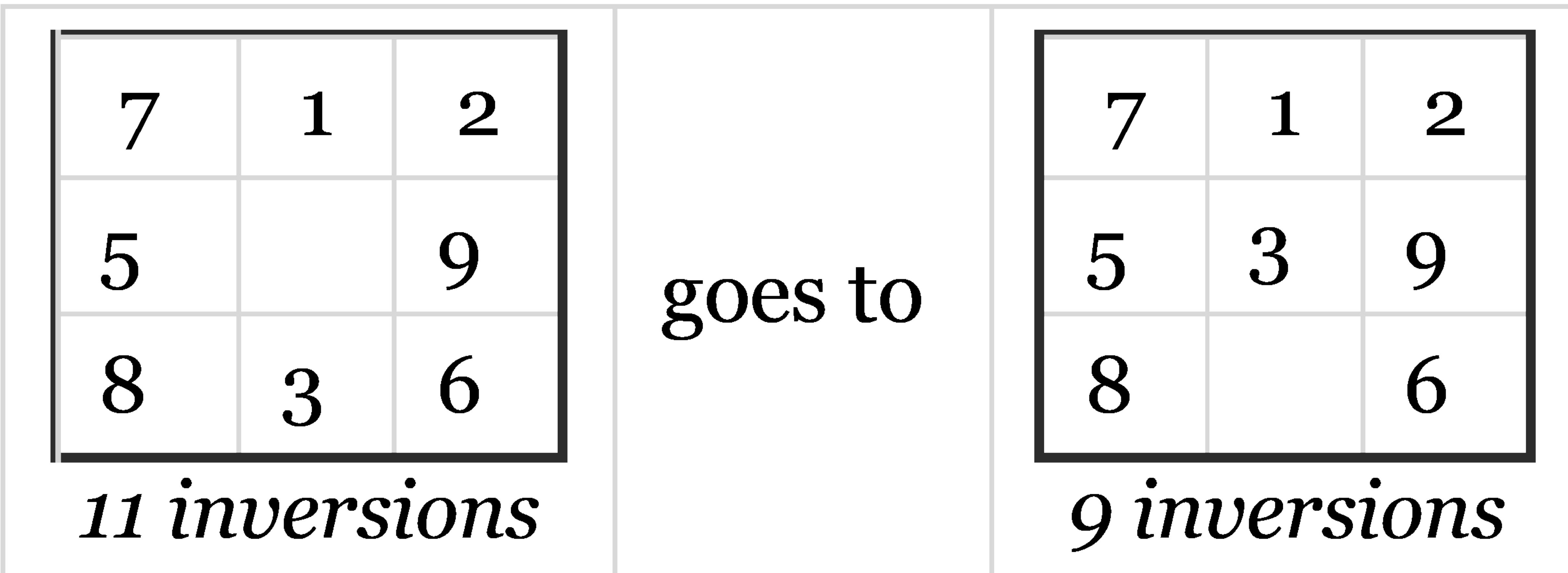
12	1	10	2	7	11	4	14	5		9	15	8	13	6	3

fig 5:
Tiles written in a row

inversion is when a tile precedes another tile with a low number

images from: Mark Ryan. Solvability of the Tiles Game

number of inversions during the search
odd size



- moving *left or right* does not change #inversions
- moving *up or down* does (passes even number of tiles)

parity of inversions (whether is odd or even) is an *invariant*

When is a state solvable?

invariant for the even sized tile

12	1	10	2
7	11	4	14
5		9	15
8	13	6	3

49 inversions
blank on even row from bot

goes to

12	1	10	2
7		4	14
5	11	9	15
8	13	6	3

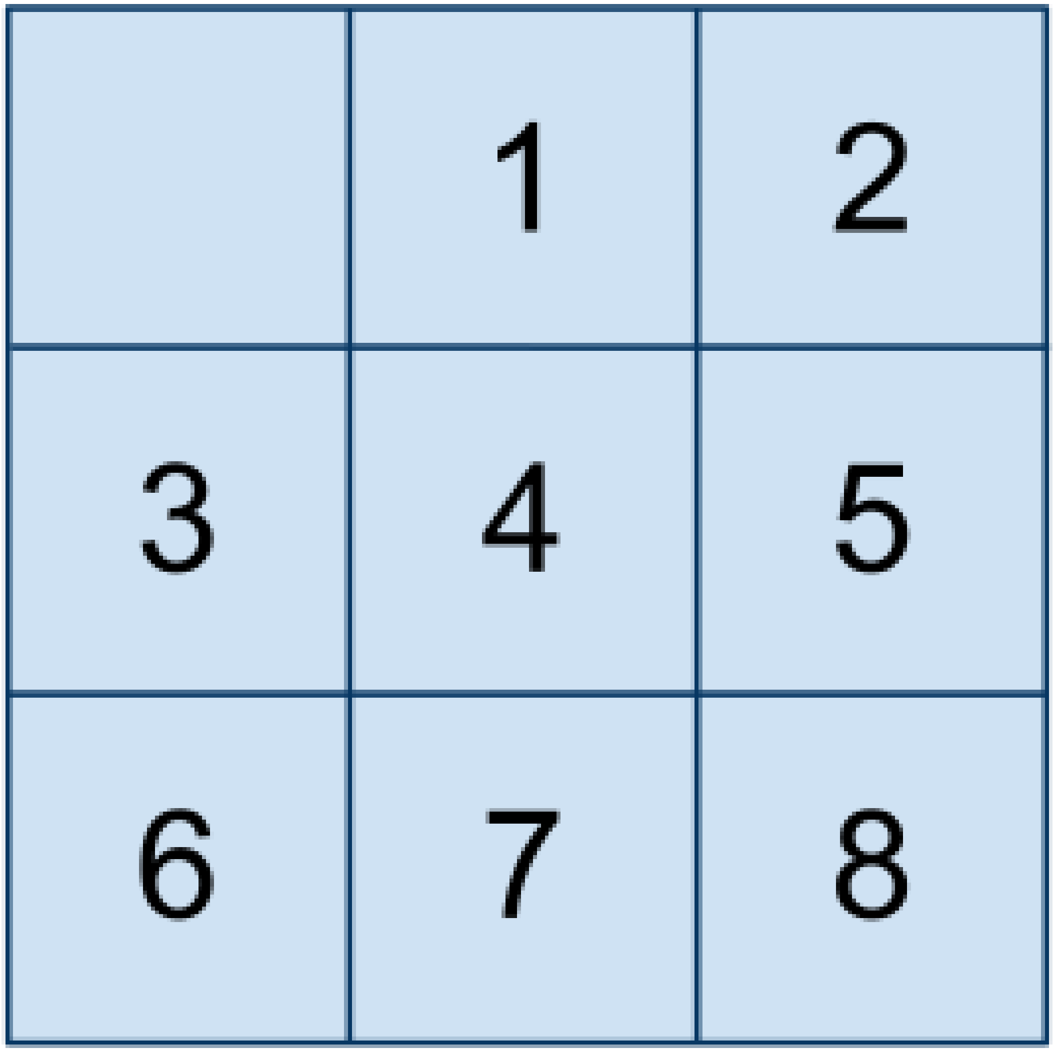
48 inversions
blank on odd row from bot

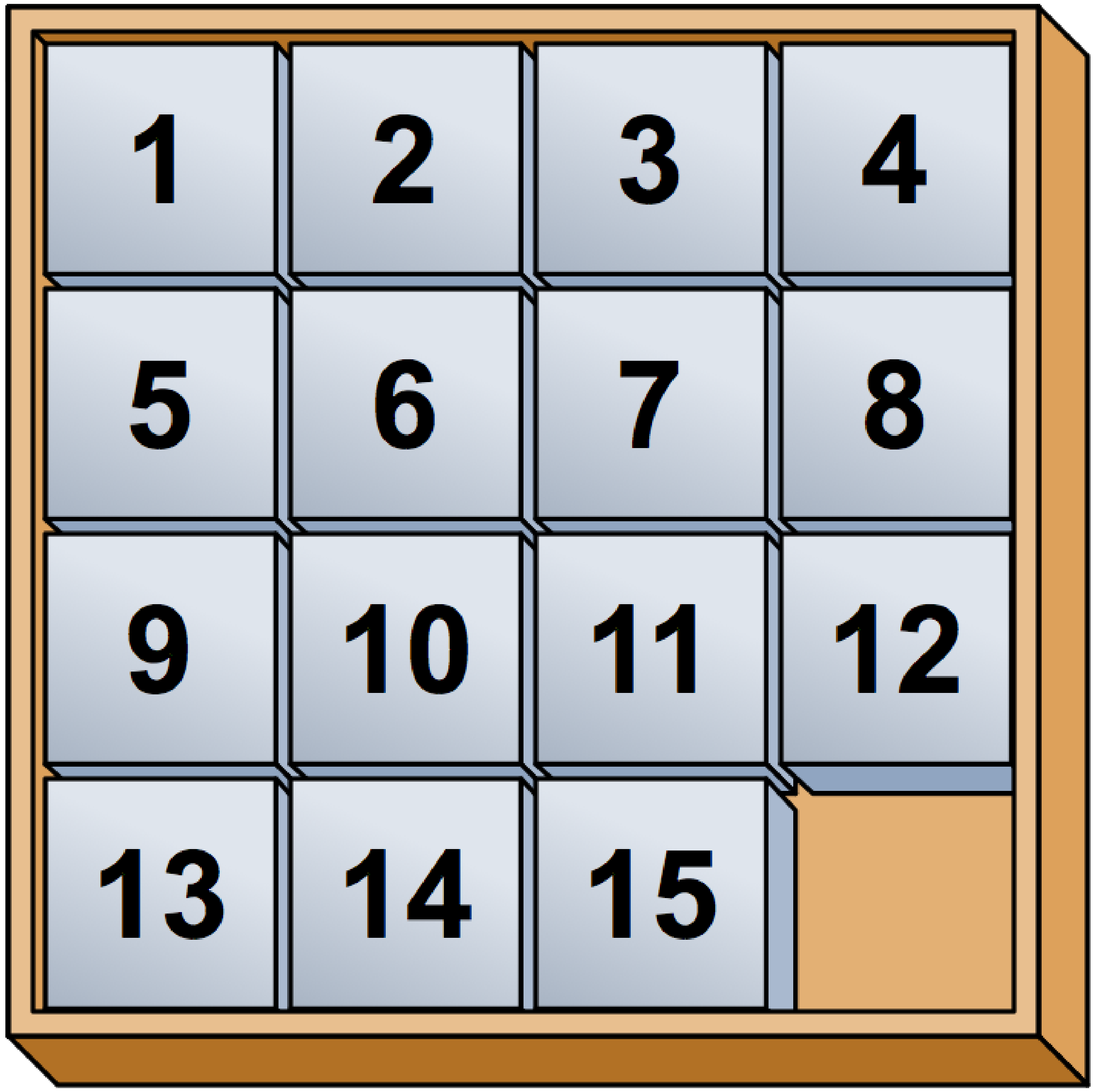
Moving a tile up or down:

- Passes an odd number of other tiles
- The row parity of the blank also changes (from odd to even, or from even to odd)

(#inversions even)==(blank on odd row from the bottom)

final states:





every solvable state

- If the width is odd, then every solvable state has an even number of inversions.

- If the width is even, then every solvable state has
  - an even number of inversions if the blank is on an odd numbered row counting from the bottom;
  - an odd number of inversions if the blank is on an even numbered row counting from the bottom;