Cybernetics and Artificial Intelligence
Introduction into the course

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Admin, rules of the game

- 2+2+5+(~35) - weekly: 2 hours lectures, 2 computer labs, 5 individual work (reading, coding), ~35 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

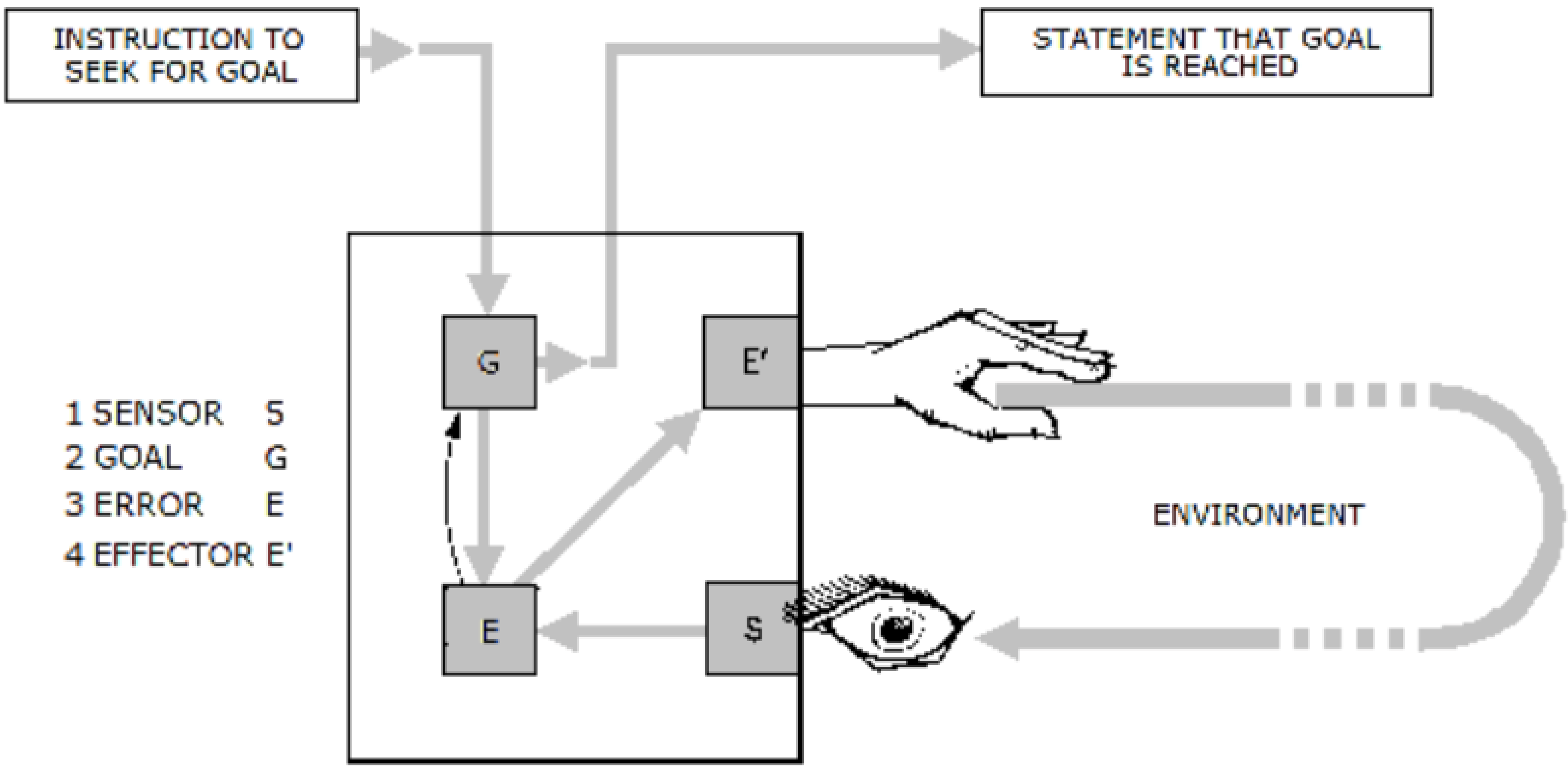
- we recommend a few
- on-line materials abundant - you can find by yourself, responsibility is (always) yours
- ask us if unsure
- we appreciate you recommend new ones

cybernetics and AI

- Norbert Wiener (1948). Cybernetics: Or Control and Communication in the Animal and the Machine.
- 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.

Grey Walter’s tortoises

goal-directed system



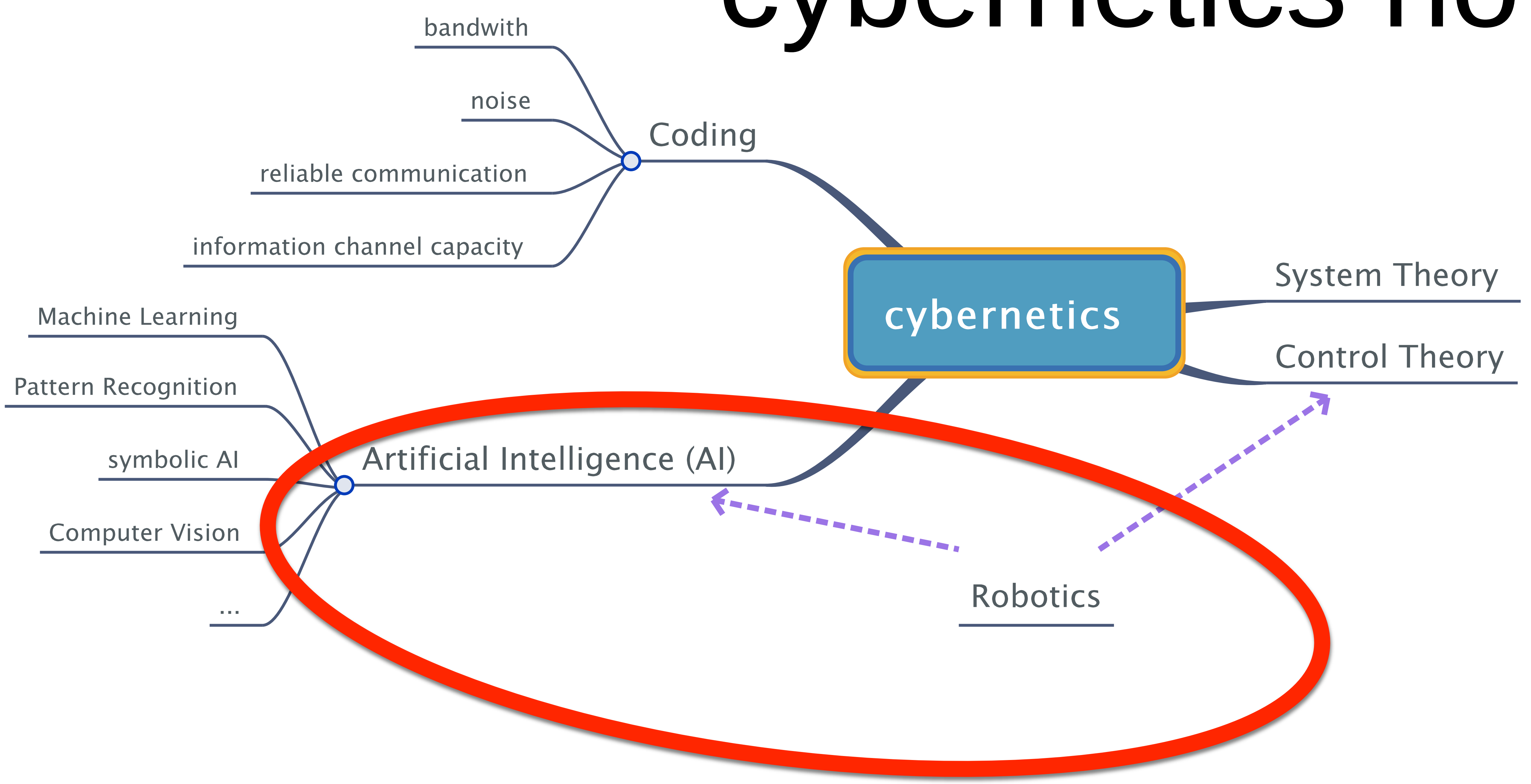
A SIMPLE GOAL-DIRECTED SYSTEM

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

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

cybernetics now



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

problem: machine control in unstructured environment

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

(our) pictures of the game

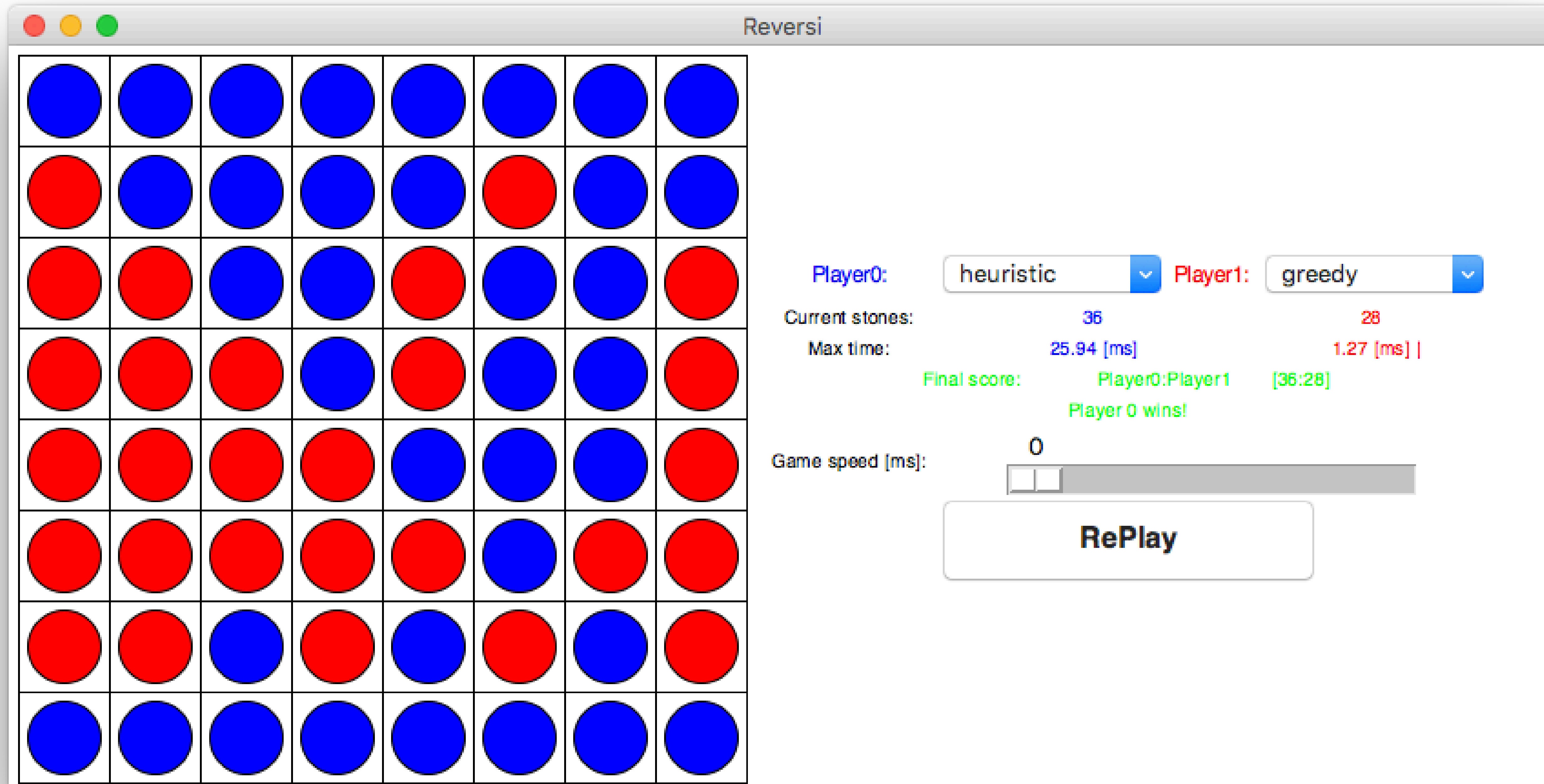
http://www.tradr-project.eu, http://www.nifti.eu, https://cyber.felk.cvut.cz/category/department/cmp/vras/

essentials - course content

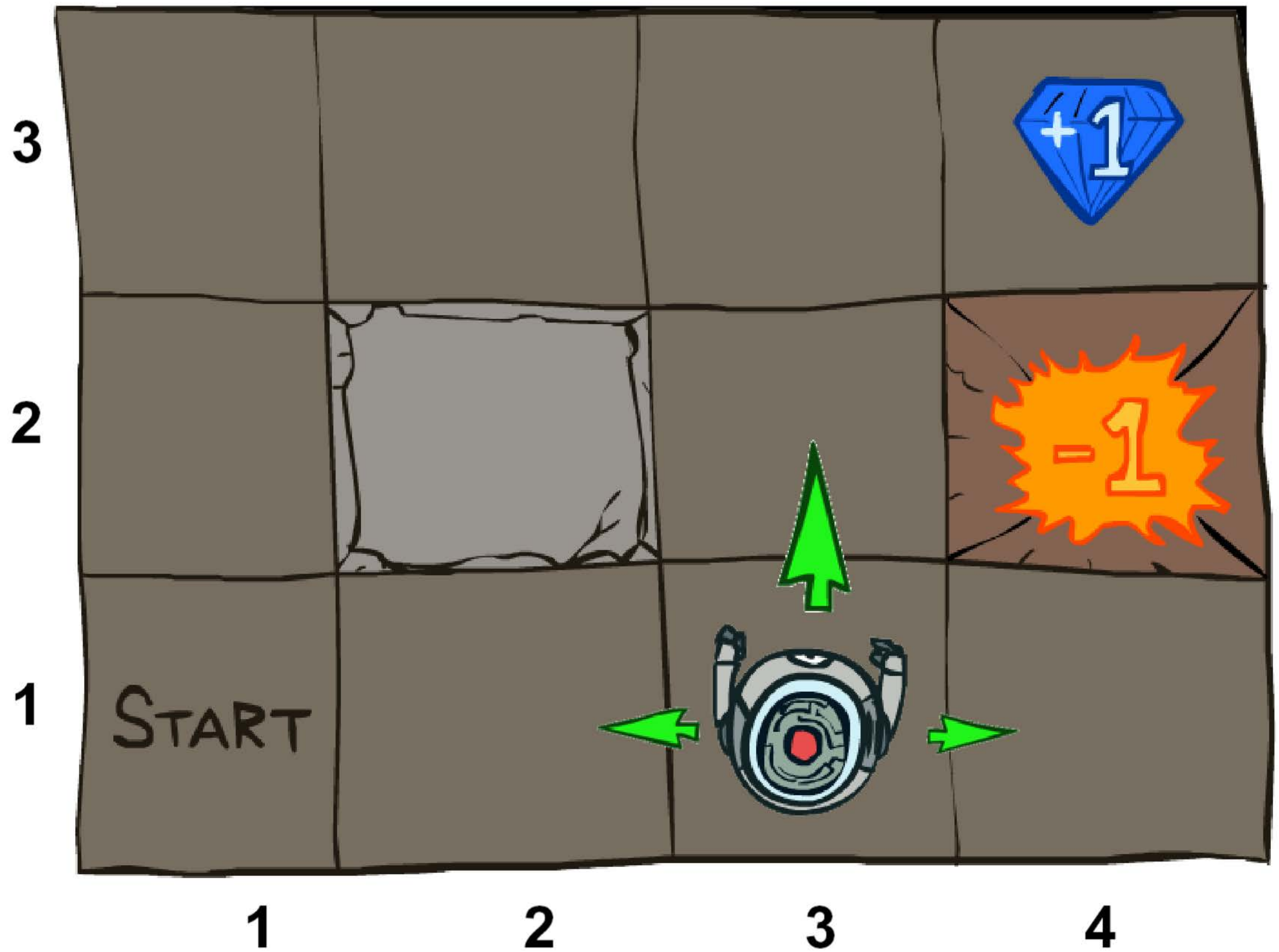
- solving problems by search
- sequential decisions under uncertainty - how to search when actions are unreliable, but known
- reinforcement learning - learning from final successes and failures
- essentials from machine learning - bayesian decisions, classifiers, …

search, …, and beyond

Someone is playing against us

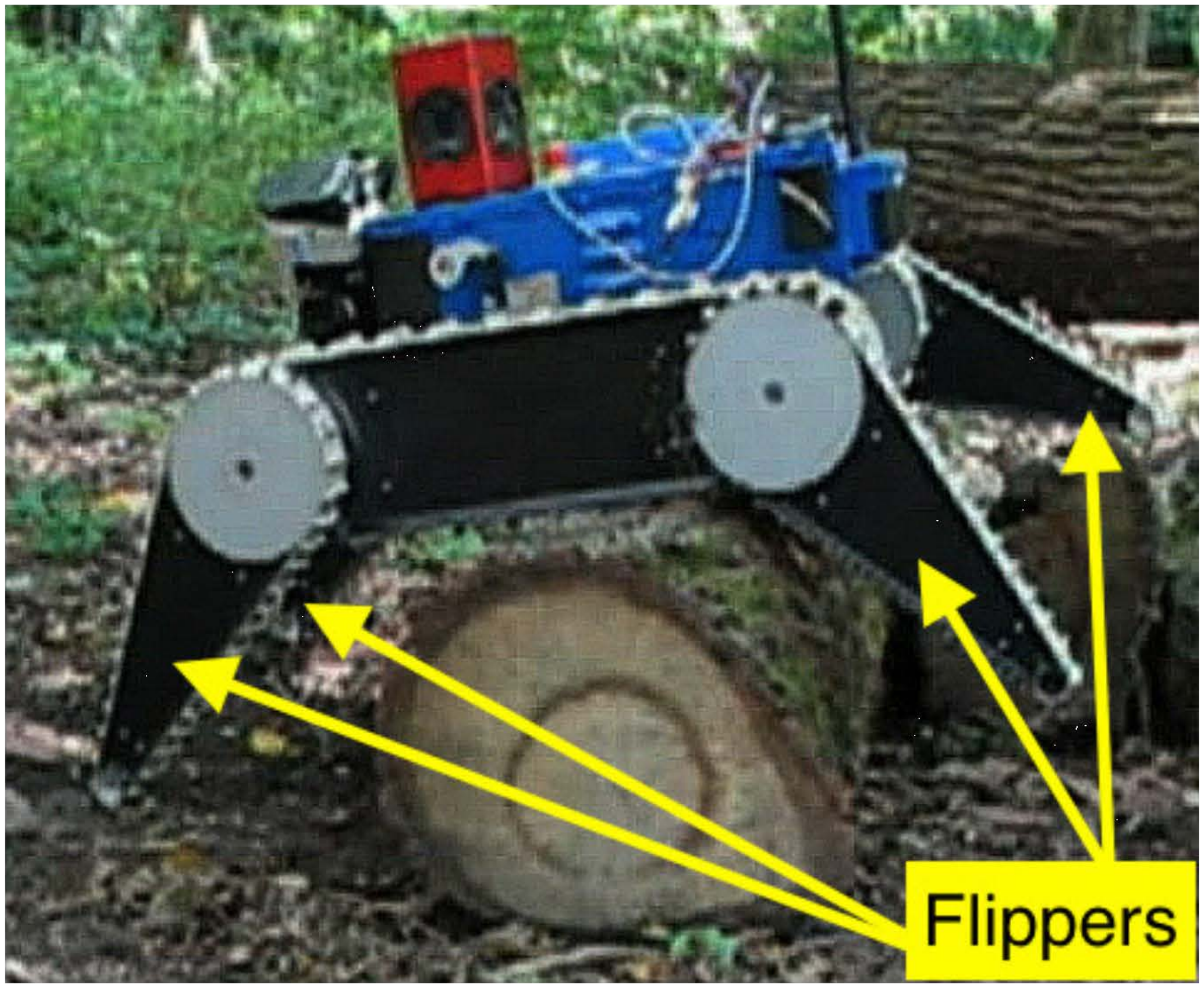


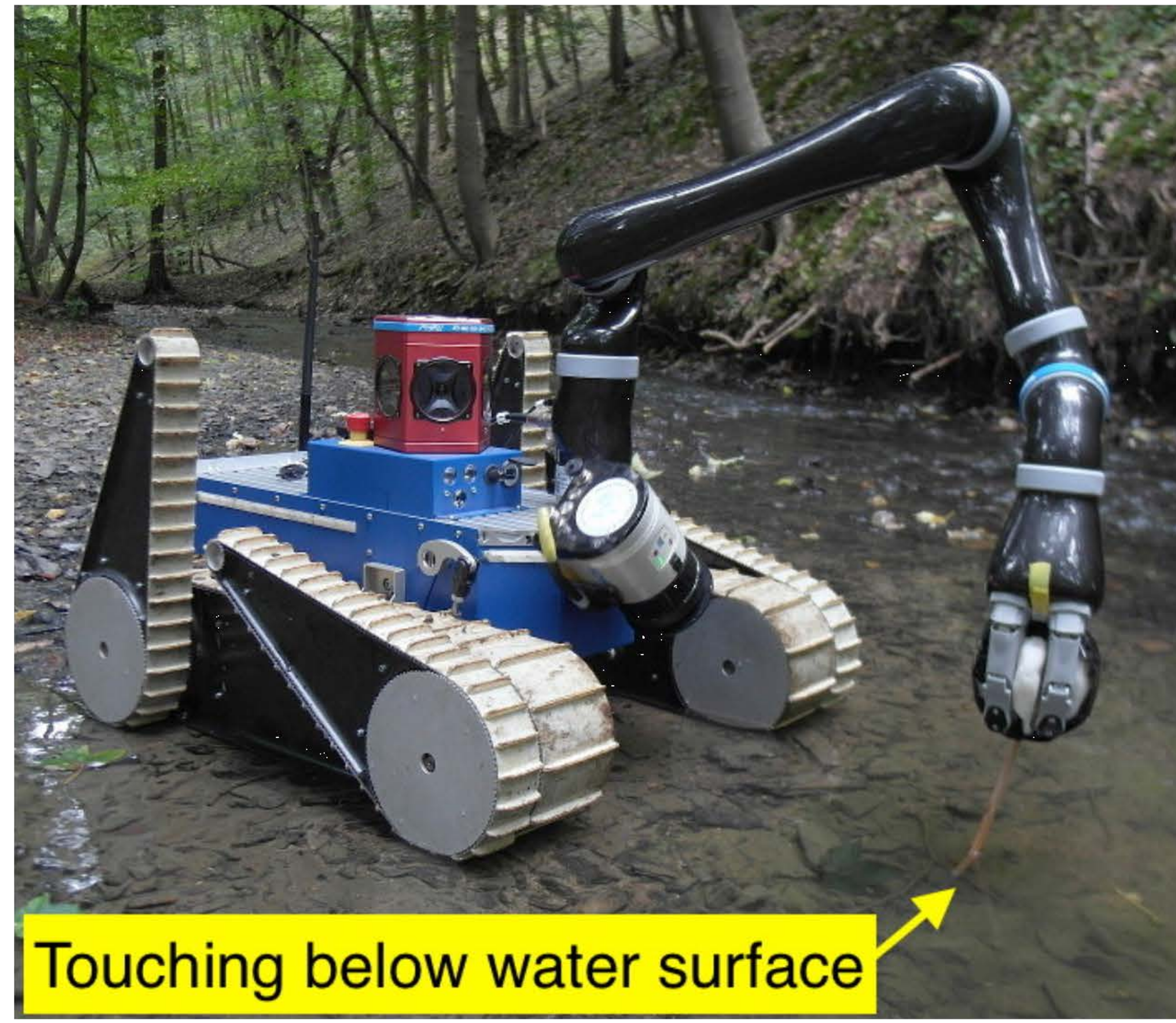
A robot may not always obey the commands



joint exploration and segmentation

(reinforcement) learning for the robot control



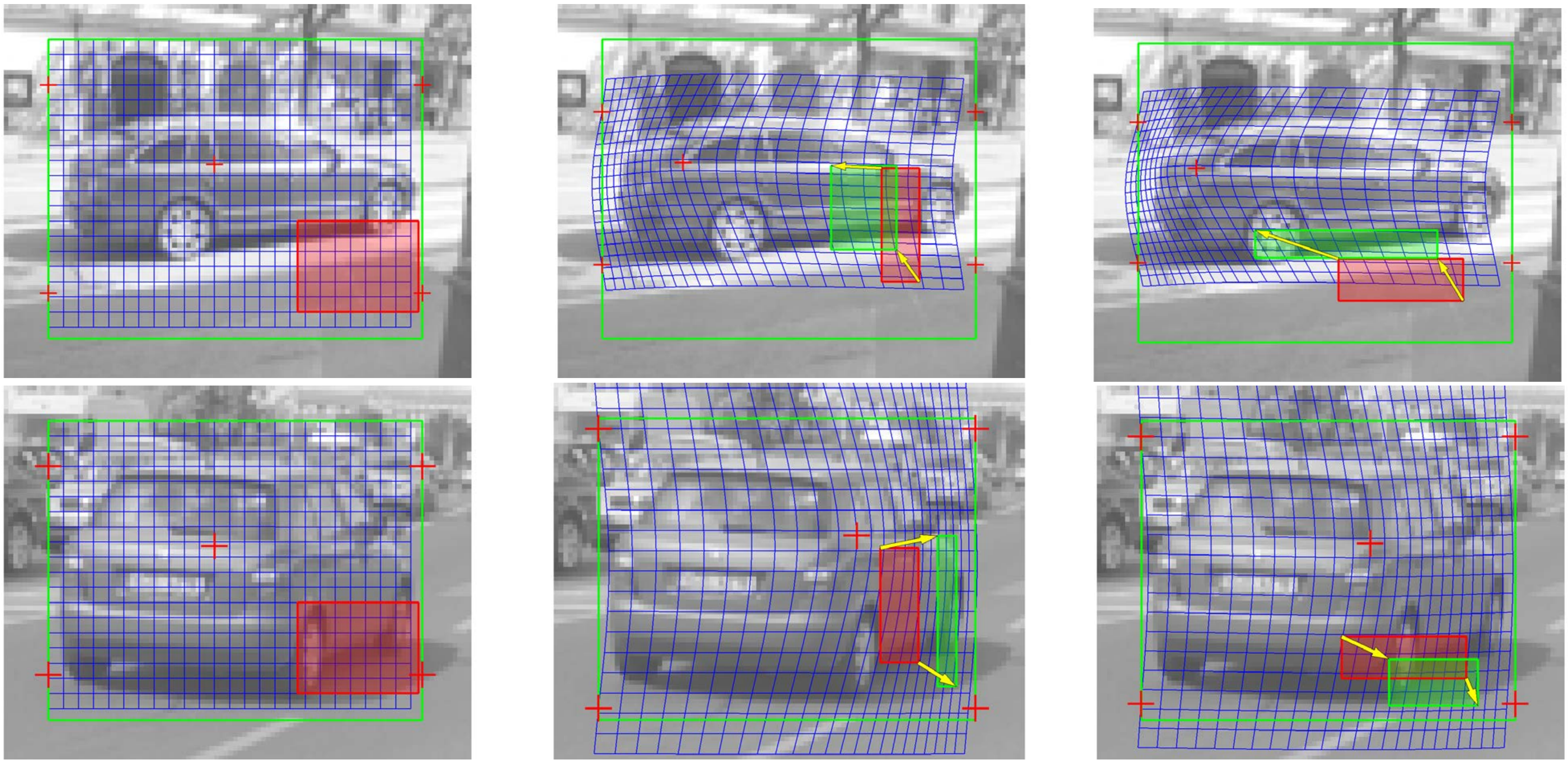


M. Pecka, K. Zimmermann, M. Reinstein, and T. Svoboda. Controlling Robot Morphology from Incomplete Measurements. In *IEEE Transactions on Industrial Electronics*, Feb 2017, Vol 64, Issue: 2, pp. 1773-1782

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

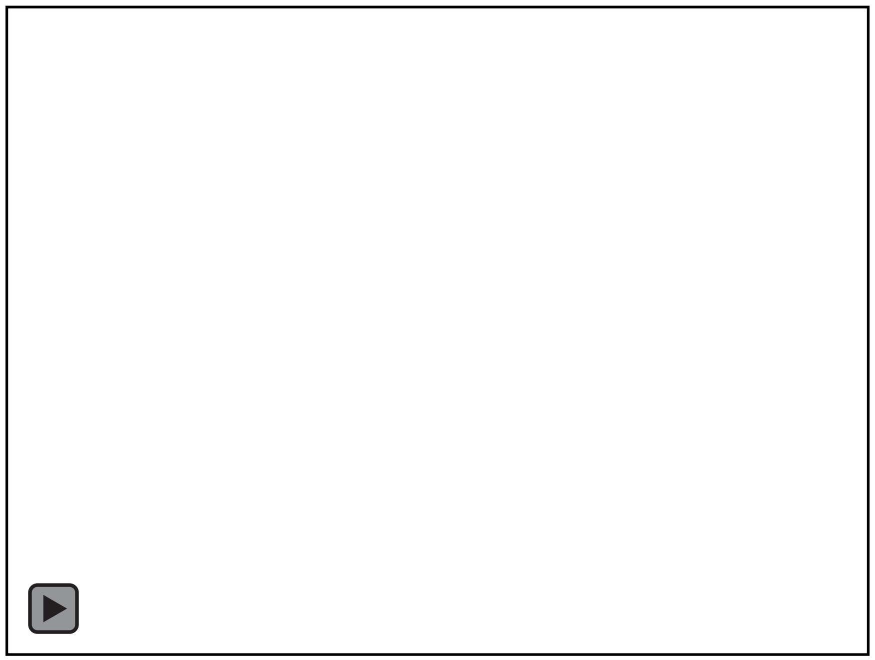
object detection - deforming for better detection/recognition

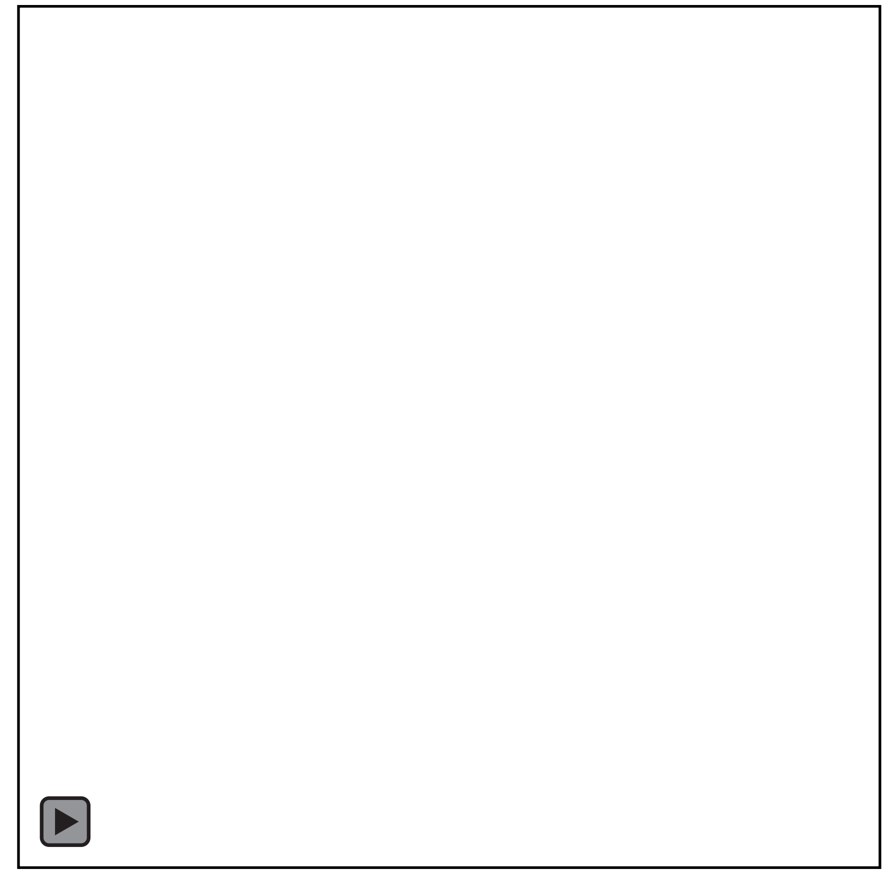


K. Zimmermann, D. Hurych, T. Svoboda. Non-Rigid Object Detection with Local Interleaved Sequential Alignment (LISA). In *IEEE Transactions on Pattern Analysis and Machine Intelligence*, April 2014, Vol 36, Issue 4


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

learning, classification, …

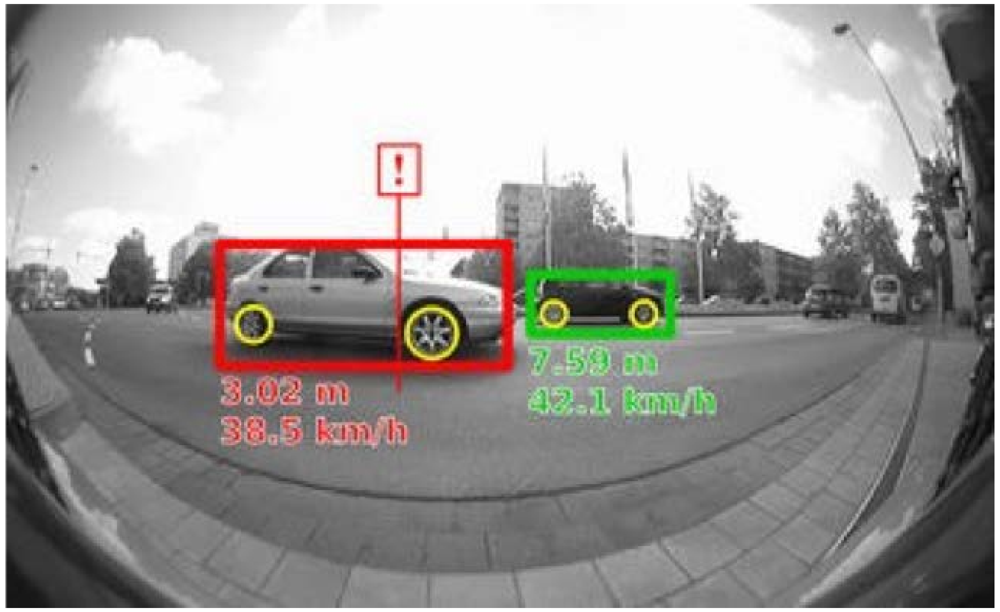




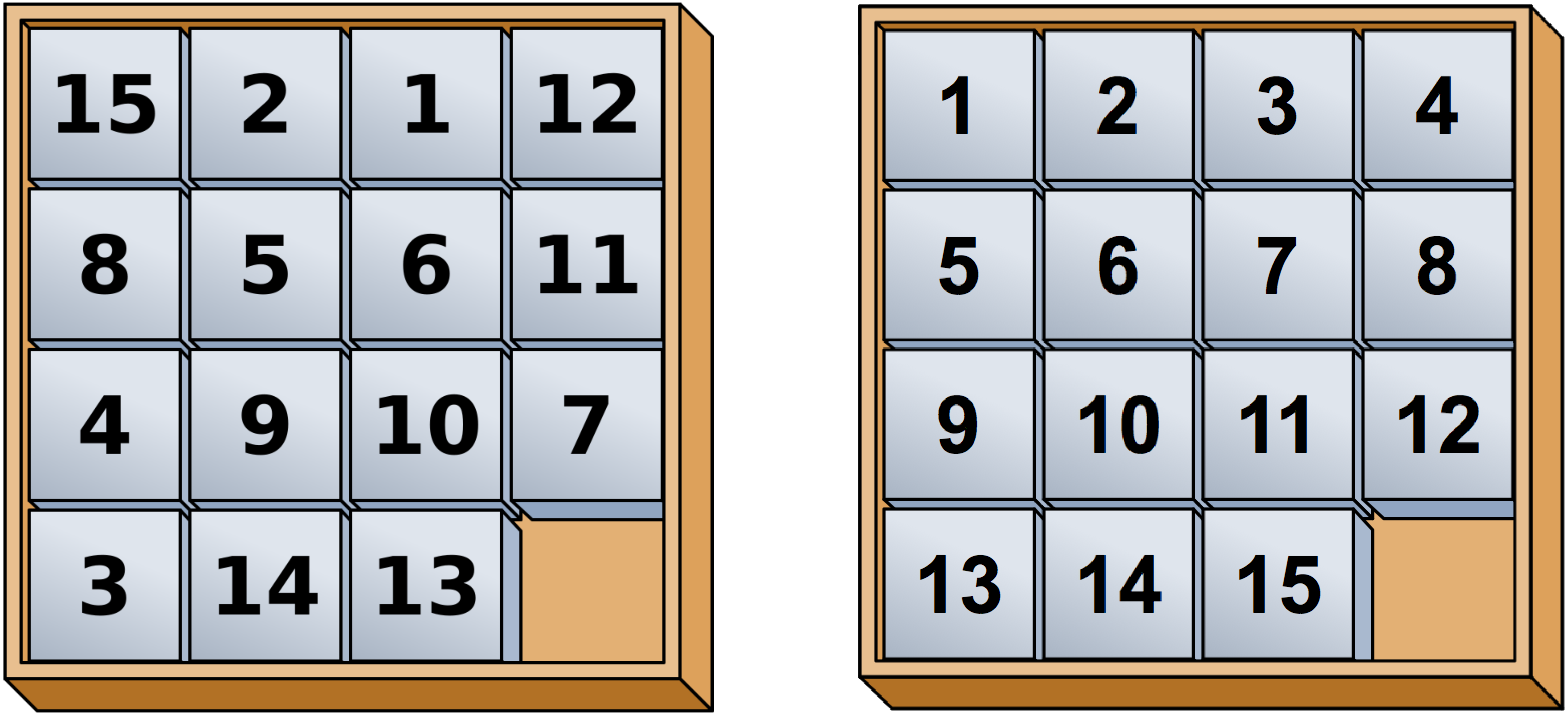
x cm	XS (0–100)	S (100–125)	M (125–150)	L (150–175)	XL (175–200)	XXL (200-∞)	Σ
$P(x\|\text{male})$	0.05	0.15	0.2	0.25	0.3	0.05	**1**
$P(x\|\text{female})$	0.05	0.1	0.3	0.3	0.25	0.0	**1**

emphasis on problem solving

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

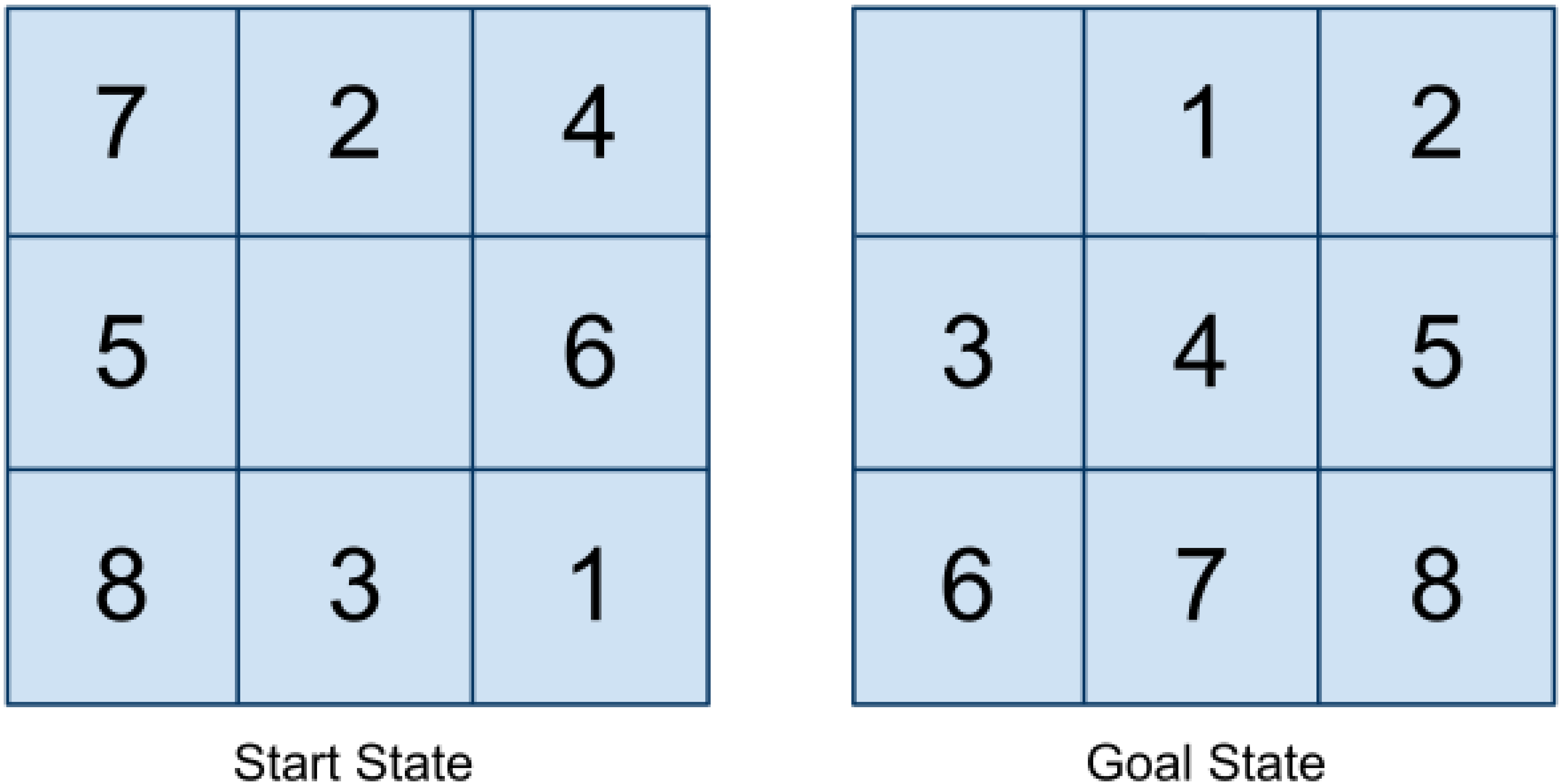


n-1 puzzle



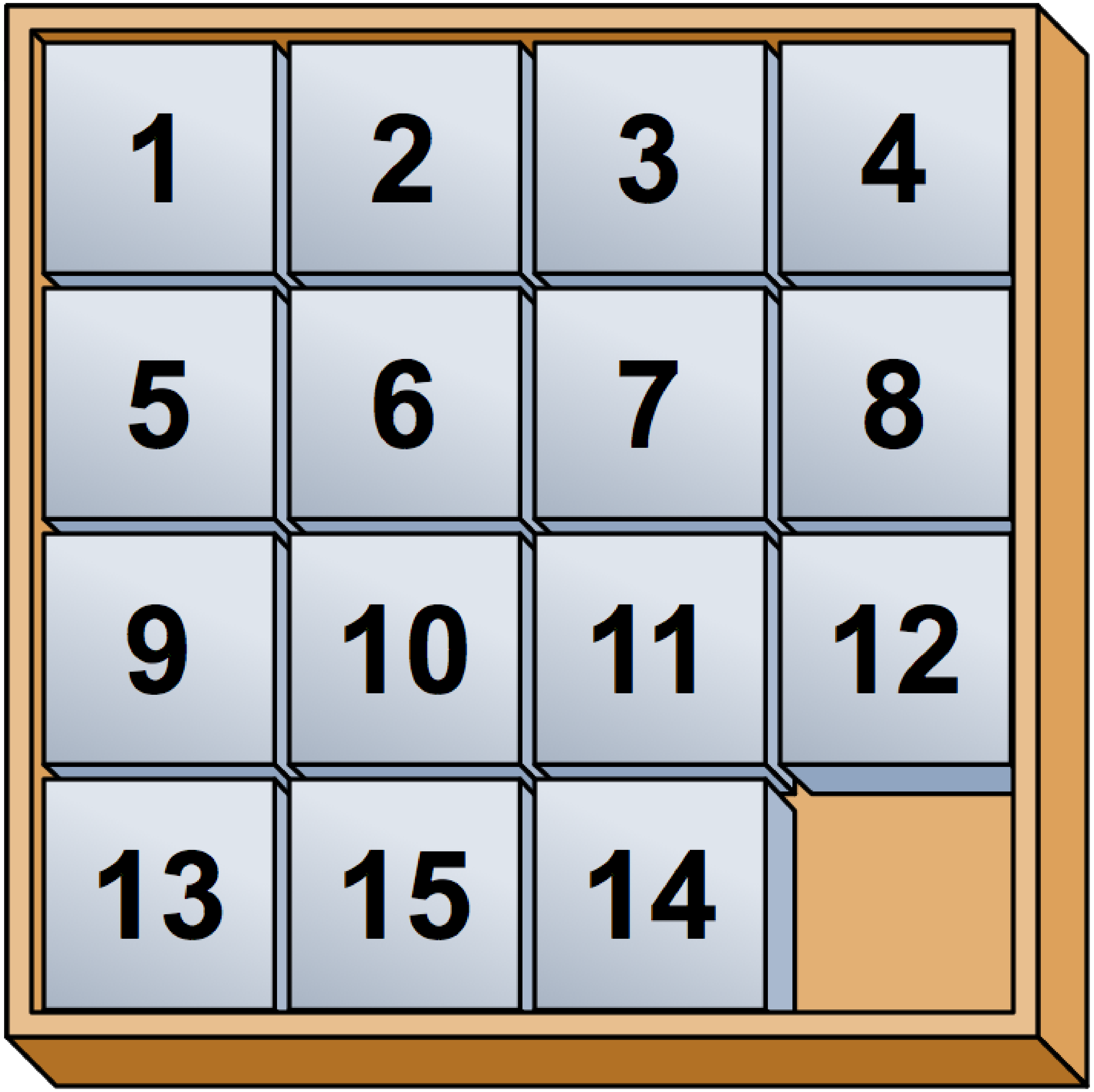
15-puzzle.svg:, Public Domain, https://commons.wikimedia.org/w/index.php?curid=28995093

8-puzzle

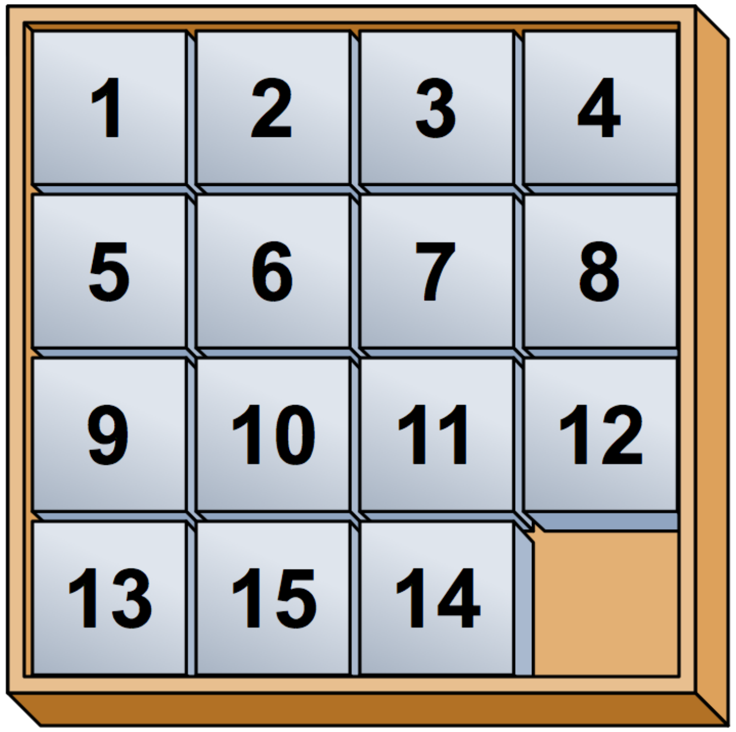


By Haiqiao - Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=14665825

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

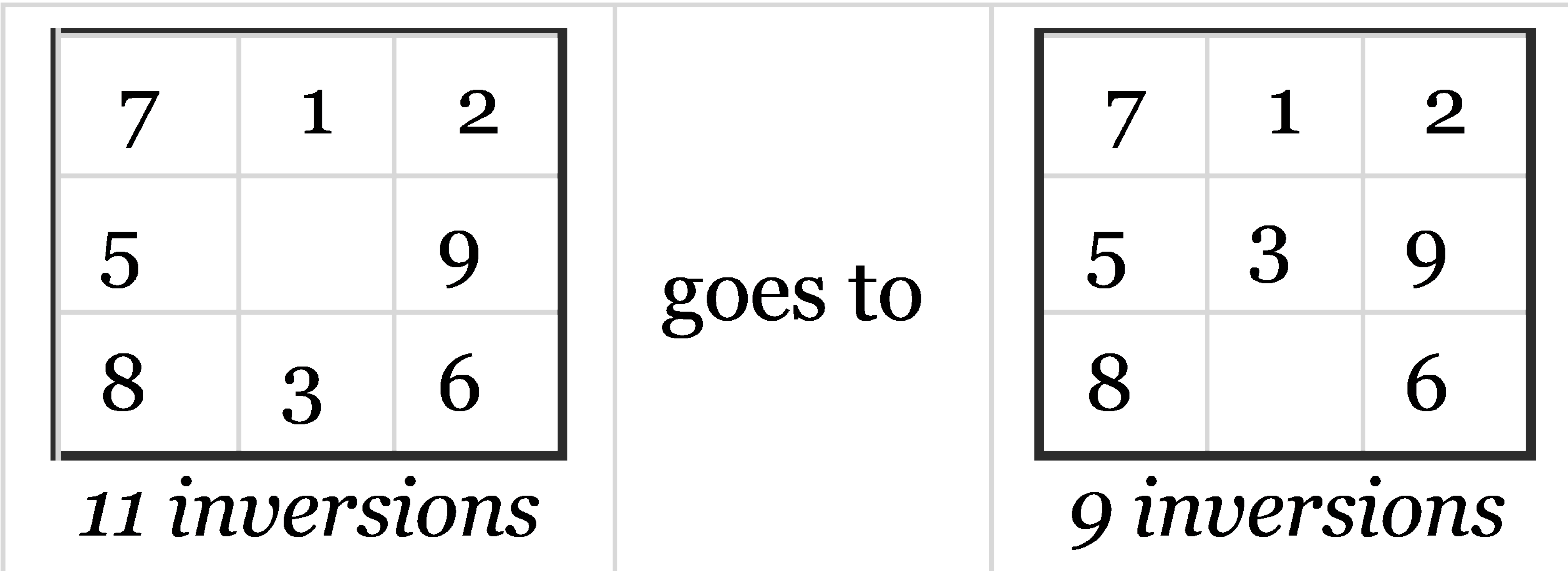
12	1	10	2	7	11	4	14	5		9	15	8	13	6	3

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	goes to	12 1 10 2 7 _ 4 14 5 11 9 15 8 13 6 3
49 inversions blank on even row from bot		*48 inversions blank on odd row from bot*

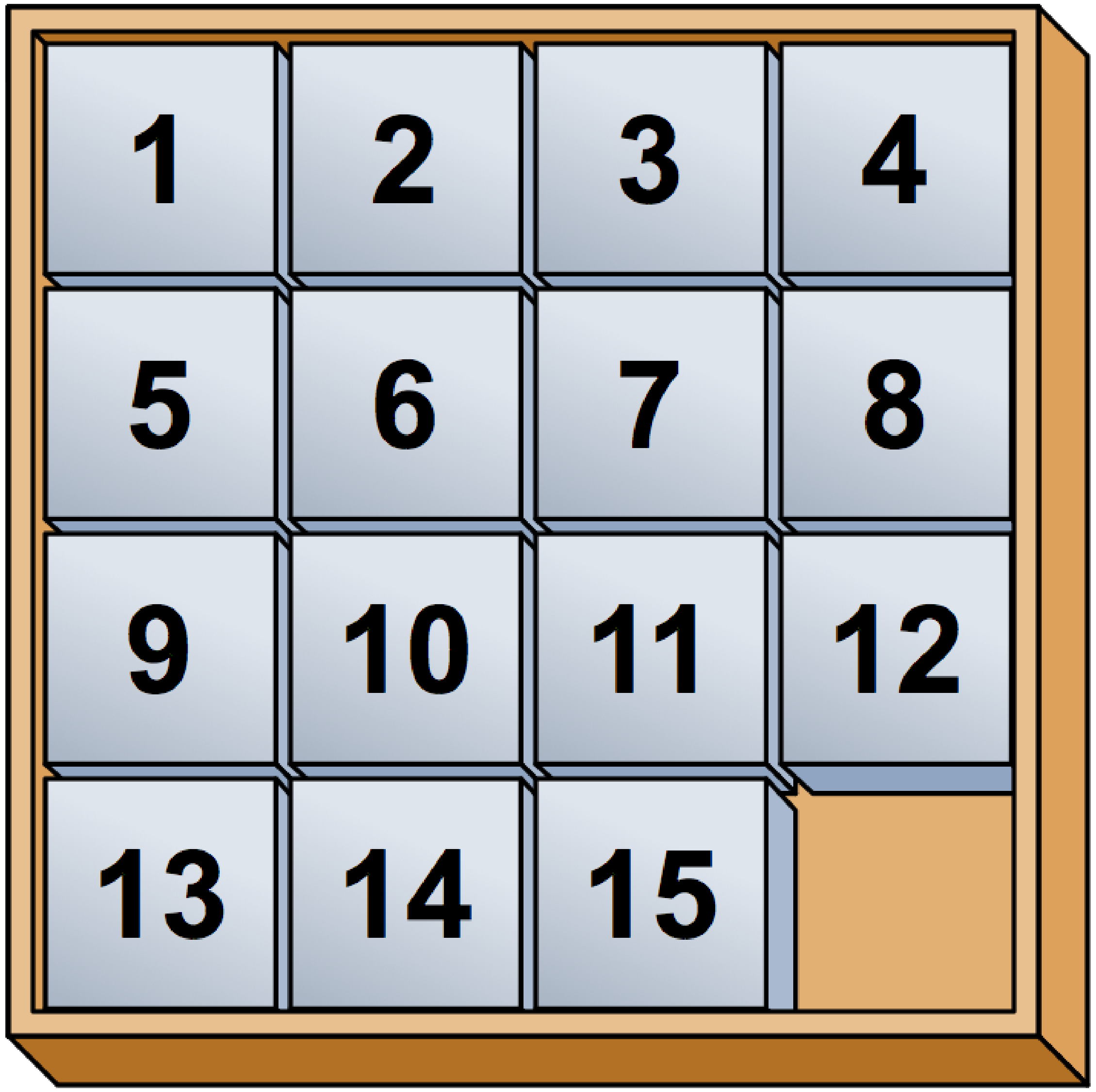
Moving a tile up or down:

- 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:

	1	2
3	4	5
6	7	8



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;