Mathematical machines and thinking — elementary problems and definitions of artificial intelligence

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1 Examples of problems within AI

2 Can machines think?

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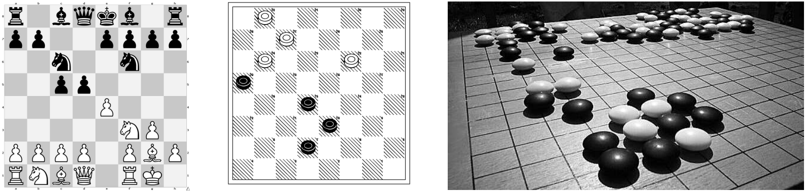
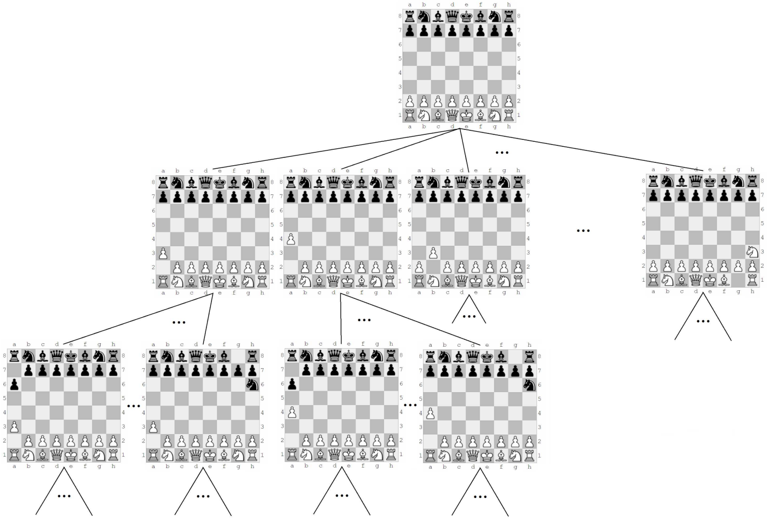
Games

- Commonly, two-person games are considered: chess, checkers, GO, . . .



- Game — a situation of conflict, where players have contradictory goals, and where clear rules are defined.
- **Problem of searching game tree:**
  Given a game position (in particular, an initial position), the task is to provide ***quantitative evaluations (scores)*** for particular ***moves*** at current player's disposal. An evaluation should represent exact or approximate ***payoff*** for the player if he chooses a given move, assuming the optimal counter-play by opponent.

Games — initial chess tree fragment

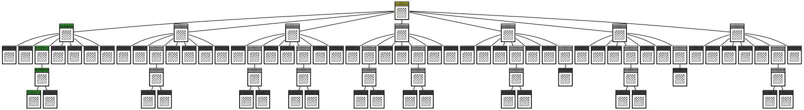


Games

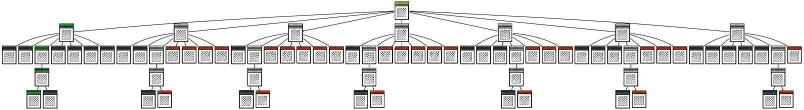
- **Algorithms:** ***min-max***, *α-β* ***pruning***, ***Scout***, ...
- **Refinements:** ***Quiescence***, ***transposition table***, ***refutation table***, ***killer heuristic***, . . .
- **Challenges:**
  - combinatorial (geometric) explosion of game tree,
  - computational and memory complexity,
  - design of position evaluation functions (heuristics),
  - horizon effect,
  - games with random elements,
  - games of imperfect information.

Games — initial tree fragments for checkers

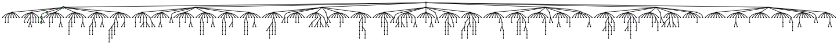
- ***min-max + Quiescence***, depth (for quiet positions): 1.0, states: 86



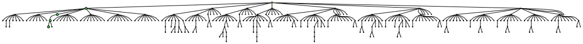
- α-β ***pruning + Quiescence***, depth (for quiet positions): 1.0, states: 78



- ***min-max + Quiescence***, depth (for quiet positions): 1.5, states: 693



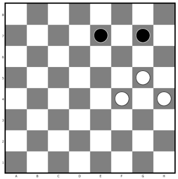
- α-β ***pruning + Quiescence***, depth (for quiet positions): 1.5, states: 323



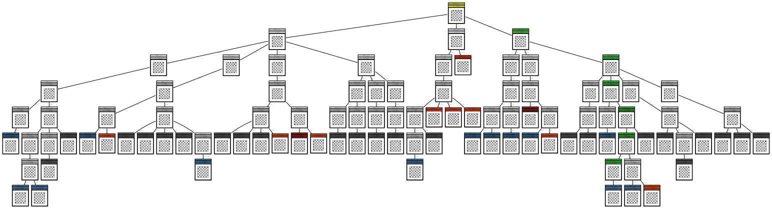
[Results generated by *SaC* library: `https://pklesk.github.io/sac`, illustrations owing to: *Graphviz* `https://www.graphviz.org`.]

Games — checkers endgames

- White to start and win in 4 moves:



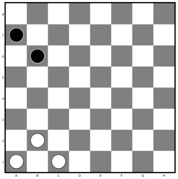
- ***α-β pruning + Quiescence***, depth: 2.5, states: 100



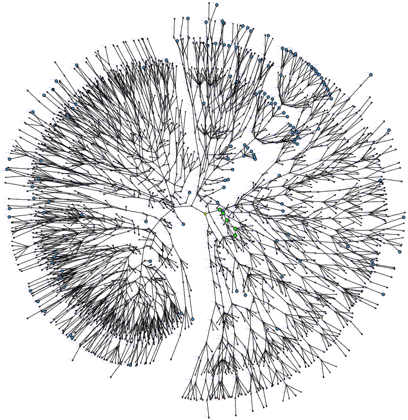
- Principal variation: $(G5 : H6, G7 : F6, F4 : G5, F6 : E5, G5 : F6, E5 : G7, H6 : F8 : D6)$.

Games — checkers endgames

- White to start. Who wins?



- α-β ***pruning + Quiescence***, depth: 5.5, states: 2 845



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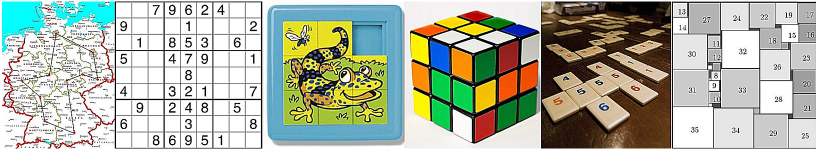
Graphs within AI

- geographical graphs, mazes, navigations . . . but also puzzles, riddles represented as graphs, e.g.: sudoku, sliding puzzle, Rubik's cube, solitaires, Rummikub, packing problems, etc.



		7	9	6	2	4		
9				1				2
	1		8	5	3		6	
5			4	7	9			1
				8				
4			3	2	1			7
	9		2	4	8		5	
6				3				8
		8	6	9	5	1		

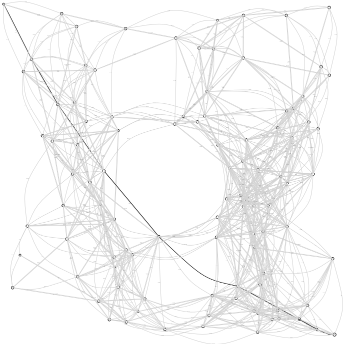
- Nodes (vertices) — states of puzzle, edges — possible moves, manipulations transforming given state into another.
- **Problem of searching graph:**
  Given an initial graph state, the task is to find a path of transitions (if exists) to a goal state. Additionally, if stated in the task, the goal is to find the minimum path.

Graphs within AI

- **Algorithms:** ***Dijkstra's algorithm***, ***Best-first search***, ***A**** , ***IDA****.
- **Challenges:**
  - state representation,
  - generation of descendant states,
  - desing of cost functions (so called: admissible heuristics),
  - graph size unknown in advance,
  - fast data structures.

Geographical graphs — examples

- Synthetic graph: 100 nodes, 10% of possible edges, distances with small perturbations.



- Shortest path $(0, 18, 14, 64, 60, 10, 5, 99)$ with cost ≈ 149.52.
- ***Dijkstra's algorithm:*** for the example above, all states must be visited . . .
  — uninformed search.
- ***A^* algorithm + Euclidean distance:*** closed (visited) states: 18, open states: 38
  — informed search.

Puzzles, riddles, . . .

- Sudoku — level hard:

*	8	9	4	*	6	*	*	*
*	*	*	9	*	*	8	*	*
*	*	7	*	3	*	4	2	*
*	*	3	5	*	*	*	*	*
*	1	*	6	*	*	*	5	2
*	*	*	*	*	*	6	1	*
*	*	*	*	*	9	*	*	1
*	*	4	8	1	5	*	*	7
*	*	*	*	*	*	2	*	8

↓

3	8	9	4	2	6	1	7	5
1	4	2	9	5	7	8	3	6
6	5	7	1	3	8	4	2	9
2	6	3	5	9	1	7	8	4
7	1	8	6	4	3	9	5	2
4	9	5	7	8	2	6	1	3
8	3	6	2	7	9	5	4	1
9	2	4	8	1	5	3	6	7
5	7	1	3	6	4	2	9	8

- ***Best-first search + „empty cells" heuristic***, descendants at „minimum cell", closed states: 222, open states: 18

[time: 46 ms, Intel Xeon CPU E3-1505M v5 2.8 GHz (boost 3.7 GHz)]

Puzzles, riddles, . . .

- *Minimum sudoku:*

*	*	*	8	*	1	*	*	*
*	*	*	*	*	*	4	3	*
5	*	*	*	*	*	*	*	*
*	*	*	*	7	*	8	*	*
*	*	*	*	*	*	1	*	*
*	2	*	*	3	*	*	*	*
6	*	*	*	*	*	*	7	5
*	*	3	4	*	*	*	*	*
*	*	*	2	*	*	6	*	*

↓

3	6	4	8	2	1	7	5	9
2	1	8	7	9	5	4	3	6
5	9	7	3	4	6	2	1	8
9	3	1	5	7	2	8	6	4
4	7	5	6	8	9	1	2	3
8	2	6	1	3	4	5	9	7
6	4	2	9	1	8	3	7	5
1	5	3	4	6	7	9	8	2
7	8	9	2	5	3	6	4	1

- *Best-first search + „sum of remaining possibilities” heuristic*, descendants at „minimum cell”, closed states: 86, open states: 18

[time: 41 ms, Intel Xeon CPU E3-1505M v5 2.8 GHz (boost 3.7 GHz)]

Puzzles, riddles, . . .

- Size of mimum sudoku for 9 × 9 case — **17** — discovered in 2011.
- Researchers: prof. ***Gary McGuire*** and team, University College, Dublin, Ireland.
  [https://maths.ucd.ie/~gmg]
- Their program showed that each sudoku with 16 givens has at least two solutions.
- Not all $\binom{81}{16} \approx 3 \cdot 10^{16}$ initial arrangements had to be checked (due to symmetries, reductions).
- Complete check lasted from January till December ($\approx 7 \cdot 10^{6}$ core-hours).
- Example of minimum sudoku for 4 × 4 case:

*	*	*	*
*	*	1	2
*	*	*	*
4	*	*	3

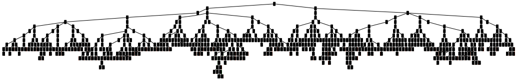
Puzzles, riddles, . . .

- **Sliding puzzle** ($n^2 - 1$ puzzle):
  Given an initial state, by sliding tiles adjacent to the empty cell (no. as 0), the task is to reach the goal state — ordered numbers $\{0, 1, \ldots, n^2 - 1\}$ in successive rows — in as few steps as possible.

$$\begin{array}{ccc}\boxed{0} & 1 & 2\\ 3 & 4 & 5\\ 6 & 7 & 8\end{array}$$

- Search graphs for initial state $(0, 3, 2; 4, 7, 8; 1, 5, 6)$ and different heuristics, shortest path of length 16

A^* + “misplaced tiles”



[states: 672, time: 34 ms, Intel Xeon CPU E3-1505M v5 2.8 GHz (boost 3.7 GHz)]

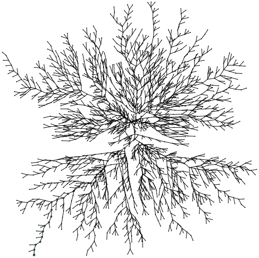
A^* + “Manhattan”

[states: 106, time: 21 ms, Intel Xeon CPU E3-1505M v5 2.8 GHz (boost 3.7 GHz)]

- Shortest path of length 16: $(D, R, D, R, U, L, L, D, R, U, U, L, D, R, U, L)$.

Puzzles, riddles, . . .

- Sliding puzzle for $n = 4$: $(1, 8, 3, 7; 6, 0, 2, 11; 4, 14, 10, 15; 12, 13, 5, 9)$.
  Shortest path of length 28: $(L, D, D, R, R, R, U, U, U, L, D, D, L, D, R, U, U, L, U, L, D, R, D, D, L, U, U, U)$.
- A^* **+ *"Manhattan + linear conflicts"***, states: 2 637.



[time: 47 ms, Intel Xeon CPU E3-1505M v5 2.8 GHz (boost 3.7 GHz)]

- Hard example: $(13, 5, 4, 10; 9, 12, 8, 14; 2, 3, 7, 1; 0, 15, 11, 6)$.
  Shortest of length 55:
  $(R, U, U, L, D, R, D, L, U, U, U, R, D, R, D, L, U, L, D, R, U, U, R, D, D, R, U, U, L, D, D, R, D, L, L, U, U, L, U, R, D, R, R, D, D, L, U, U, R, U, L, L, D, L, U)$.
  States: $4.7 \cdot 10^6$. Time: ≈ 26 s.

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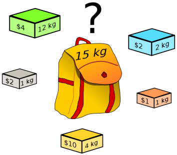
Discrete knapsack problem

- **Problem:**
Given is a knapsack of capacity $C > 0$ and a set of items $I = \{(v_1, c_1), (v_2, c_2), \ldots (v_n, c_n)\}$, where v_i is item's value and c_i its capacity. The task is to find such subset I_* of I that maximizes the sum of values and does not exceed knapsack capacity, i.e.:

$$\sum_{\substack{i \\ (v_i,c_i)\in I_*}} v_i \longrightarrow \max \qquad \text{and} \qquad \sum_{\substack{i \\ (v_i,c_i)\in I_*}} c_i \leqslant C.$$

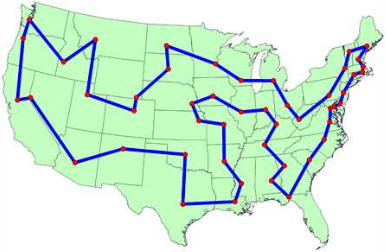


[https://en.wikipedia.org/wiki/Knapsack_problem]

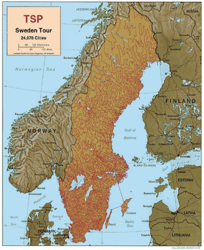
- Computational complexity? Discrete vs. continuous problem version.
- Applications: material cutting — wastes minimization, choice of investments wallet, securitization, key generation for ciphers.
- **Algorithms:** *dynamic programming*, *genetic algorithms*, ...

Traveling Salesman Problem (TSP)

- **Problem:**
  Given is a set of n cities. Starting from a fixed city, the task is to travel through all the cities (exactly once) and come back to the city of origin using the shortest (cheapest) path.



[https://optimization.mccormick.northwestern.edu/...]

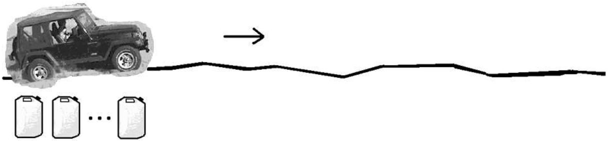


[http://www.math.uwaterloo.ca/tsp/sweden/index.html]

- Computational complexity?
- Applications: routing, logistics, DNA sequencing, ...
- **Algorithms:** *A^* + minimum spanning tree*, *branch-and-bound*, *integer programming*, *LKH (Lin-Kernighan heuristic)*, *approximation algorithms (Christofides, 2-opt, greedy, . . .)*.

Jeep problem

- **Problem:**
  A jeep at a desert has n containers of fuel at disposal, with 1 unit of fuel each. Fuel consuption is 1 : 1, i.e. 1 unit of fuel per 1 unit of distance. The goal is to maximize the distance D_n, the jeep can travel from the base into the desert, satisfying the following rules. At any time the jeep can tank up at most 1 unit of fuel and must not take any additional fuel with it. The jeep can set off from the base, leave some fuel along the way, and go back to the base using the fuel remaining in the tank. At the base, the jeep can tank up using another container and set off once again. When coming across the fuel left along the way, the jeep can fill up the tank.



- Solutions for small caes: D_1 =?, D_2 =?, D_3 =? and their move sequences.
- Can one travel arbitrarily far when unlimited n?
- **Approximation algorithms:** *genetic algorithms*, *reinfocement learning*, . . .

Jeep problem

- Solution:

$$D_n = 1 + \frac{1}{3} + \frac{1}{5} + \cdots + \frac{1}{2n-1} = \sum_{k=1}^{n} \frac{1}{2k-1} = H_{2n-1} - \frac{1}{2} H_{n-1}.$$

- Harmonic number:

$$H_n = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}.$$

- Euler–Mascheroni constant:

$$\gamma = \lim_{n\to\infty} (H_n - \ln n) = 0.5772156649015328\ldots \tag{1}$$

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Prisonner's dilemma

- **Problem:** The police have arrested two suspects of a crime. They remain kept in separate cells. The police do not have sufficient evidence and tries to convince each suspect to confess and betray his partner in exchange for lighter penalty. The police explicitly offer the following table of payoffs to each suspect. What should a player in this game (a suspect) do — stay quiet or betray?

	A stays quiet	A betrays
B stays quiet	A and B sentenced to 1 year	A free to go B senteced to 5 years
B betrays	A sentected to 5 years B free to go	A and B sentenced to 4 years

- **Iterated prisonner's dilemma:** What strategy should a player undertake in a sequence of many prisonner's dilemma games in order to minimize the total penalty? After each round the players get to know the result.
- Can the number of games be known in advance?

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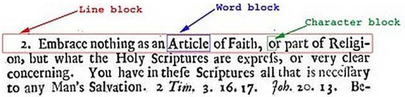
Pattern recognition — examples

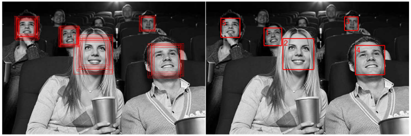
- OCR.



2. Embrace nothing as an Article of Faith, or part of Religion, but what the Holy Scriptures are expreſs, or very clear concerning. You have in theſe Scriptures all that is neceſſary to any Man's Salvation. 2 *Tim.* 3. 16. 17. *Joh.* 20. 13. Be-

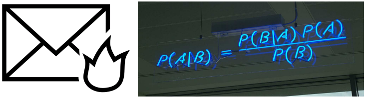
[http://simon-tanner.blogspot.com/2015/06/text-capture-and-optical...]

- Object detection (faces, pedestrians, vehicles, road signs, ...).



[https://www.researchgate.net/project/Constructions-of-sets-of-integral-...]

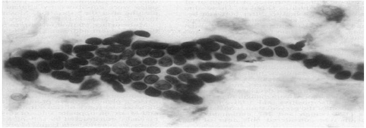
- Anti-spam filters.



[https://en.wikipedia.org/wiki/Naive_Bayes_spam_filtering]

[https://pythonmachinelearning.pro/text-classification-tutorial-...]

- Computer-Aided Diagnosis (CADx).



[https://archive.ics.uci.edu/ml/datasets/Breast+Cancer...]

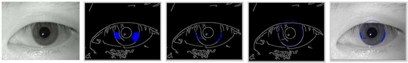
[https://www.nature.com/articles/srep24454]

Pattern recognition — examples

- Face recognition.

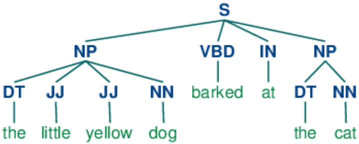
[http://scikit-learn.org/stable/auto_examples/...]

- Iris recognition.



[http://www.cs.princeton.edu/ andyz/irisrecognition]

- Part-of-speech/sentence recognition.



[https://en.wikipedia.org/wiki/Part-of-speech_tagging]

- Speech recognition.

[https://en.wikipedia.org/wiki/Speech_recognition]

Pattern recognition

- **Algorithms:**
  - *naive Bayes classifier*,
  - *decision trees (CART, ID3, C4.5)*,
  - *distance-based classifiers (k-NN)*,
  - *artificial neural networks (MLP, RBF)*,
  - *support vector machines (SVM)*,
  - *ensemble classifiers (AdaBoost, RealBoost, Random Forest)*,
  - *logistic regression*,
  - *convolutional neural networks (CNN)*,
  - *hidden Markov models (HMM)*,
  - *...*
- **Related issues:** feature extraction, overfitting, model complexity selection, regularization, accuracy testing, . . .

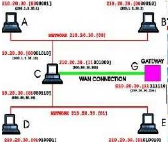
Spis treści

Data mining — examples

- Association rules in shopping transactions.

if DIAPERS then BEER

- Behavioral rules of social networks users.
- Rules in bioinformatics (gene expression).
- User preference rules (searches, products).
- Rules in sport events, market events, . . .
- **Algorithms:** *Apriori* and variations.



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Regulation and control

- **Examples**:
    - reversed pendulums,
    - house heating controllers,
    - automatic gantry (e.g. for ship loading/unloading),
    - automatic medication feeders,
    - image stabilizers in digital cameras,
    - self-driving cars, ...
- **Algorithms:** ***PID controllers***, ***fuzzy sets — Mamdani–Zadeh controller***, ***Kalman filter***, ***reinforcement learning (Q-learning)***, ...

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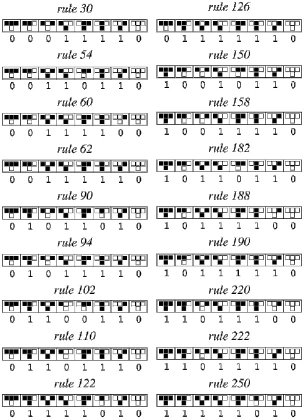
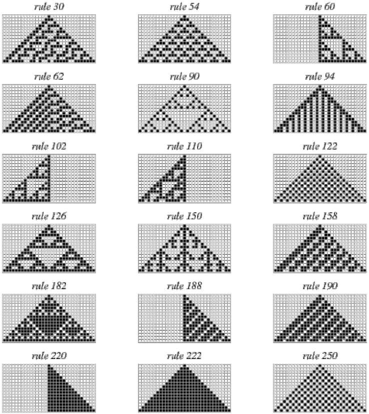
Artificial life

- Cellular automata
  — Stephen Wolfram (1980s; thorough analysis of one-dimensional cellular automata).
- "The Game of Life"
  — John Horton Conway (1970; two-dimensional cellular automata with surprising behaviors).
- Simulations of worlds / ecosystems — populations of individuals with defined senses, motorics, hunger, agression, ...

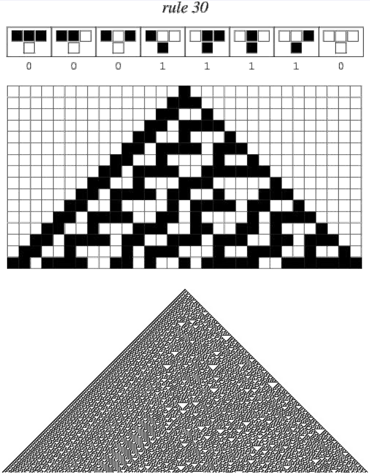
Cellular automata

[http://mathworld.wolfram.com/ElementaryCellularAutomaton.html]



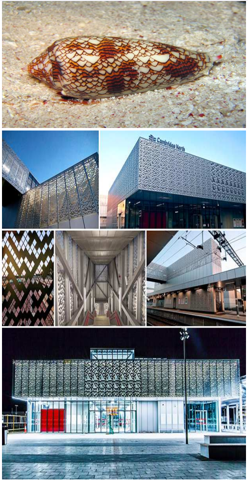


Cellular automata — „rule 30”



[http://mathworld.wolfram.com/Rule30.html]

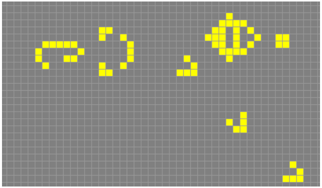
[https://www.youtube.com/watch?v=60P7717-XOQ]



[http://blog.stephenwolfram.com...]

Conway's "The Game of Life"

- Earlier, similar ideas due to: John von Neumann, Stanisław Ulam (1940s).
- Two-dimensional cellular automata.



[https://bitstorm.org/gameoflife]

- Rules:
  1. if a full cell has 0 or 1 neighbor then it dies (loneliness),
  2. if a full cell has 4 or more neighbors then it dies (crowdedness),
  3. if a full cell has 2 or 3 neighbors then it lasts alive,
  4. if an empty cell has exactly 3 neighbors then it becomes full.

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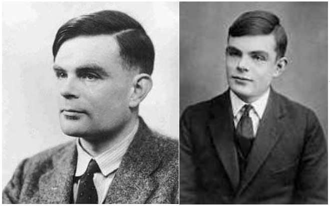
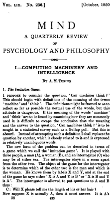
Can machines think?

1. **No**, if *thinking* is defined as a solely human activity. Then, any machine activity of that kind can only be called similar to thinking.
2. **No**, if one assumes that in the very nature of thinking there is something secret, mystical.
3. **Yes**, if one accepts that this question can be **decided via an experiment (!)**, by comparing machine's behavior vs. human behavior for some activity with respect to which the term *thinking* applies naturally.

Can machines think?



Alan Mathison Turing (1912–1954)



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MIND
A QUARTERLY REVIEW
OF
PSYCHOLOGY AND PHILOSOPHY

I.—COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

1. *The Imitation Game.*

I propose to consider the question, 'Can machines think ?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, 'Can machines think ?' is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

The new form of the problem can be described in terms of a game which we call the 'imitation game'. It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart from the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end of the game he says either 'X is A and Y is B' or 'X is B and Y is A'. The interrogator is allowed to put questions to A and B thus:

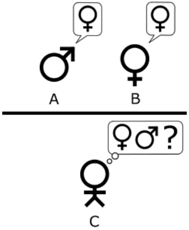
C: Will X please tell me the length of his or her hair ?

Now suppose X is actually A, then A must answer. It is A's

28 433

- **A.M. Turing, "Computing Machinery and Intelligence", *Mind*, 1950.**
  [https://academic.oup.com/mind/article/LIX/236/433/986238]
- Turing proposes to consider the question: *„Can machines think?"*.
- It seems necessary to define: *machine* and *to think*. Definitions should be good enough to represent the everyday intuitive meaning of these words.
- Difficulties: non-strict definitions, ambigous, statistical (if based on surveys) — danger: the response to the posed question would also be only statistical.
- Therefore, Turing replaces the original problem with a less ambiguous one — *the imitaiton game*.

"The Imitation Game"



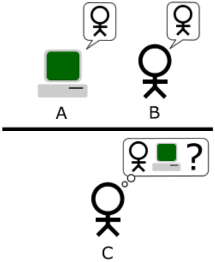
- Man A and woman B remain in a separate room then the interrogator C.
- C obtains answers from players denoted as X and Y, and tries to determine whether $X = A$ and $Y = B$, or $X = B$ and $Y = A$.
- The goal for A is to mislead C, so that C misidentifies A as B.
- Questions posed by a terminal that precludes identificaiton possibilities based on: voice, smell, etc.

“The Imitation Game”

- Interrogator might ask: *„Will X please tell me the length of his or her hair?”*.
- Suppose X is actually A, then A's answer might therefore be:. *„My hair is shingled, and the longest strands are about nine inches long.”*.
- The goal of B is to help interrogator. Probably, the best strategy for her is simply to tell the truth.
- She might add *„I am the woman, don't listen to him!”*, but obviously A can do the same.

"The Imitation Game"

- **Turing:** *What happens if A is replaced by a machine in the game? Will the interrogator be able to make correct identification as frequently as in the case of human players?*



- **Turing:** *Let the questions above replace the original problem: "Can machines think?"*

"The Imitation Game"

Example conversation according to Turing:

Q: *Please write me a sonnet on the subject of the Forth Bridge?*

A: *Count me out on this one. I never could write poetry.*

Q: *Add* 34 957 *to* 70 764.

A: *(After a pause of* 30 s*)* 105 621.

Q: *Do you play chess?*

A: *Yes.*

Q: *I have K at my K1, and no other pieces. You have only K at K6 and R at R1. It is your move. What do you play?*

A: *(After a pause of* 15 s*) R-R8 mate.*

"The Imitation Game"

Critique by Turing himself:

1. + *Strong separation between body and intellect. Artificial skin (if existed) does not make a machine dressed in it more human.*
2. − *Odds are weighted too heavily against the machine. Think of an opposite game, where human tries to pretend to be a machine, and immediately is given away by slowness and inaccuracy in arithmetics.*
3. − *May not machines carry out something which ought to be described as thinking but which is very different from what a man does? (strong objection). Obviously, yes. Strong drawback in case of the negative result from the imitation game.*
4. + *Nevertheless, if a machine can be constructed to play the imitation game satisfactorily, we need not be troubled by the above objection.*

Turing predicted that in 50 years computers shall have a memory of order $\approx 10^9$ bits, and be able to mislead about 30% of interrogators.

Objections to Turing’s views

1. Theological objection
2. “Heads in the sand” objection
3. Mathematical objection
4. Argument from consciousness
5. Arguments from various disabilities
6. Lady Lovelace’s objection
7. Argument from extrasensory perception

Objections to Turing's views

Theological objection

Thinking is a function of man's immortal soul. God has given an immortal soul to every man and woman, but not to any other animal or to machines. Hence no animal or machine can think.

- **Turing:** *In scientific sense noone should be bothered by this objection! In theological terms the following remarks can be given.*
- **Turing:** *The argument would be more convincing if animals were classed with men, for there is a greater difference between the typical animate and the inanimate than there is between man and the other animals.*
- **Turing:** *Any orthodox view becomes clearer if we consider how it might appear to a member of some other religious community. How do Christians regard the Moslem view that women have no souls? Why did Christians accept Copernican theory at last?*
- **Turing:** *The objection implies a serious restriction of the omnipotence of the Almighty. There are certain things that He cannot do such as making one equal to two, but should we not believe that He has freedom to confer a soul on an elephant if He sees fit? All these turn out to be dogmatical speculations . . . .*

Objections to Turing's views

"Heads in the sand" objection

The consequences of machines thinking would be too dreadful. Let us hope and believe that they cannot do so.

- **Turing:** *Also scientifically ridiculous.*
- **Turing:** *Connected to the theological objection — we like to believe that Man is in some subtle way superior to the rest of creation.*
- **Turing:** *It is best if he can be shown to be necessarily superior, for then there is no danger of him losing his commanding position.*
- **Turing:** *It is likely to be quite strong in intellectual people, since they value the power of thinking more highly than others, and are more inclined to base their belief in the superiority of Man on this power.*

Objections to Turing’s views

Mathematical objection

Basing on certain results from mathematical logic there exist limits to possibilities of discrete states machines. One of such results is Gödel’s theorem (1931): In any logical system, one can construct statements which cannot be assigned true or false value (cannot be proved or disproved within the system). E.g.: „The statement I am saying now is false.”

- **Turing:** *Questions which cannot be answered by one machine may be satisfactorily answered by another (in other formal system).*
- **Turing:** *Although limits of all machines has been proved, it is often claimed (without proof) that no such limits apply to human.*
- **Turing:** *Anytime a Gödel-like question is posed to machine, the given answer must be wrong. This gives us an illusionary feeling of superiority. People do make mistakes in answering many more trivial questions.*
- **Turing:** *Those who hold to the mathematical argument would mostly be willing to accept the imitation game as a basis for discussion. Those who believe in the two previous objections would probably not be interested in any criteria.*

Objections to Turing's views

Argument from consciousness

Prof. Jefferson (1949): „*(. . .)Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain-that is, not only write it but know that it had written it. No mechanism could feel (and not merely artificially signal, an easy contrivance) pleasure at its successes, grief when its valves fuse, be warmed by flattery, be made miserable by its mistakes, be charmed by sex, be angry or depressed when it cannot get what it want.*"

- **Turing:** *According to the most extreme form of this view the only way by which one could be sure that machine thinks is to* ***be*** *the machine and to feel oneself thinking. One could then describe these feelings to the world, but of course no one would be justified in taking any notice.*
- **Turing:** *Likewise according to this view the only way to know that a man thinks is to be that particular man. It is in fact the solipsist point of view. It may be the most logical view to hold but it makes communication of ideas difficult. A is liable to believe "A thinks but B does not" whilst B believes "B thinks but A does not"; instead of arguing over it is usual to have the polite convention that everyone thinks.*
- **Turing:** *Prof. Jefferson would probably be willing to accept the imitation game as a test rather than an extreme argument above.*

Objections to Turing's views

Arguments from various disabilities

"I grant you that you can make machines do all the things you have mentioned but you will never be able to make one to do X."
Numerous features X are suggested: be kind, resourceful, beautiful, friendly, have initiative, have a sense of humour, tell right from wrong, make mistakes, fall in love, enjoy strawberries and cream, make some one fall in love with it, learn from experience, use words properly, be the subject of its own thought, have as much diversity of behaviour as a man, do something really new.

- **Turing:** *No support is usually offered for these statements and comes from a false induction. A man has seen thousands of machines in his lifetime. From what he sees he draws a number of general conclusions. Machines are ugly, each is designed for a very limited purpose, when required for a different purpose they are useless.*
- **Turing:** *Many of these limitations are associated with the very small storage capacity (memory) of most machines.*
- **Turing:** *Other are a disguised version of objection from consciousness.*
- **Turing:** *The "impossibility of making mistakes" is clearly false. A machine playing the imitation game must make mistakes (planned and random) in order to be misidentified.*

Objections to Turing's views

Lady Lovelace's objection

Lady Lovelace (1842): „*(. . .)The Analytical Engine has no pretensions to originate anything. It can do whatever we know how to order it to perform(. . .)*".

- Additional meaning of this objection is that a designer of an intelligent system must be capable to predict all the consequences of such system. The machine cannot surprise us.
- **Turing:** *Assertion that machines can only do what they are designed to is clearly right. But it is not the reason for drawing false conclusions out of it.*
- **Turing:** *Human can create, compose, learn because a biological program he is equipped with has functions like: adaption, ability to change itself (the program) e.g. as a result of observational interaction with the environment.*
- **Turing:** *It is clearly false, that a designer is able to predict all the consequences of a programme, even the most remote ones (e.g. after billions of operations) by means of a device under his skull.*
- Examples: artificial life, Conway's game of life, chaos theory programmes, chess programmes surprising the grand masters designing them.

Objections to Turing's views

The argument from extrasensory perception

If one acknowledges (statistically confirmed) existence of telepathy, then one may consider the following scenario: let us play the imitation game having as players a machine and a human having strong telepathy skills. Interrogator could then ask e.g. "what color is the card I am holding?". And a human would answer right more frequently than machine.

- **Turing:** *strong argument. Telepathy, in general, produces difficulties in many scientific approaches.*
- **Turing:** *One solution is to strengthen the imitation game by a restriction which makes room „telepathy-proof" (in a similar sense as sound-proof rooms). This is compliant with Turing's postulate about strong body-mind separation in the experiment.*

Turing’s chess test

- **Version 1:**
  A human plays a chess game against an unknown opponent, and has to decide wether it is a man or a machine.
- **Version 2:**
  A human looks at a finished chess game played by to opponents and has to identify each of them as: human or machine.
- Garri Kasparov passes Turing’s chess test in version two with success ratio of over 80%.

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Towards AI

8 PROCEEDINGS OF THE IRE January

Steps Toward Artificial Intelligence*

MARVIN MINSKY†, MEMBER, IRE

Marvin Lee Minsky (1927–2016)

- **M. Minsky, "Steps Toward Artificial Intelligence", *Proceedings of IRE*, 1961.**

  [http://ieeexplore.ieee.org/document/4066245]
- Minsky agrees with Turing's views.
- There exist no unified and generally acceptable theory of intelligence.
- Five main areas can be named within AI: search, image recognition, learning, planning and induction.

Minsky's remarks

On search problems:

- **Minsky:** *If for a given problem we know the way to check the correctness of a candidate solution, then we are always able to browse through multiple candidate solutions.*
- **Minsky:** *From a certain point of view all search problems may seem trivial. E.g. think of chess game tree. It is for sure finite! Each terminal node (leaf) is either a win for white or black or a draw. By propagating it upwards (min-max procedur) the initial node is also assigned with one of these three values. In this sense chess is similarly non-interesting as tic-tac-toe.*

Minsky's remarks

On search problems:

- **Minsky:** *Usually, it is not difficult to program an exhaustive search procedure, but for every complex problem it is too inefficient to be practically applied.* ***What good comes from the fact that we have a programme which will not finish the computation within our lifetime or even our civilization lifetime?***
- Samuel (1959) estimates: checkers approx. 10^{40} states, chess approx. 10^{120} states. Let us assign generously $1\mu s$ for each tree node to be analyzed by computer and let us estimate the number of centuries needed to analyze the whole game tree for checkers:

$$\frac{10^{40}}{\underbrace{10^9 \cdot 60 \cdot 60 \cdot 24 \cdot 365.25 \cdot 100}_{\text{liczba ns in 1 century}}} \geqslant \frac{10^{40}}{10^9 \cdot 10^2 \cdot 10^2 \cdot 10^2 \cdot 10^3 \cdot 10^2} = \frac{10^{40}}{10^{20}} = 10^{20} \text{ [centuries]}$$

Minsky's remarks

On search problems:

- **Minsky:** *Technological improvements of computers does not lead to solution of all problems.*
- **Minsky:** *Wise algorithms are more needed, that would be directed to searching more promising states in first order and discarding less promising ones.*
- **Minsky:** *Every technique (or a heuristic) which can potentially reduce the search is valuable.*

Minsky's remarks

Generally on the development of AI as a domain:

- **Minsky:** *We should believe, that sooner or later* ***we shall be able to create complex programmes, equipped with combinations of heuristics, recurrences, image processing techniques, etc.***
- **Minsky:** ***One should not try to see true intelligence in them. It is rather a matter of esthetics than science.***
- **Minsky:** ***Every machine capable of ideal*** 100% ***introspection (self-awareness) must conclude it is only a machine.***
- **Minsky:** *Introduction of a body/mind duality on the grounds of psychology, sociology etc. is actually only implied by the fact that our currently known mechanical model of the brain is not complete.*
- **Minsky:** *At the low mechanical level (or digital-like level) all we have is simple rules: „if . . . then . . . " — it is hard to be excited by this. Similarly in mathematics, as soon as the proof for a theorem becomes understood, the contents of the theorem seems trivial.*