

COMPUTATIONAL INTELLIGENCE

# Computational Intelligence?

Giovanni Squillero

squillero@polito.it



©2022 GIOVANNI SQUILLERO — FREE FOR PERSONAL OR CLASSROOM USE (SEE LICENSE FOR DETAILS)  
<https://github.com/squillero/computational-intelligence>



## Artificial Intelligence

- Artificial → Not natural, made as *a copy* of something natural
- Intelligence → ???  
... but related to the ability to acquire, understand, and use knowledge
- Note: Humans are not intelligent because they solve problems, they solve problems because they are intelligent
- Intelligence requires **thinking** → AI requires *a copy* of thinking?

The question of  
whether a computer  
can think is no more  
interesting than the  
question of whether a  
submarine can swim

— Edsger Wybe Dijkstra (1930-2002)



## Artificial Intelligence ≠ Artificial + Intelligence

- AI is a **non-compositional compound**  
(or “non-compositional phraseme” or “idiom”)
- The meaning is not the predictable sum of the meanings of the component
- Other examples of NCC
  - “red herring”: something that distracts from a relevant question
  - “bull session”: an informal group discussion

squillero@polito.it

What is Computational Intelligence

5

<b>Artificial Intelligence</b>	
	
<b>THINKING HUMANLY</b>	<b>THINKING RATIONALLY</b>
<b>ACTING HUMANLY</b>	<b>ACTING RATIONALLY</b>
	

# Artificial Intelligence



**cognitivism**

## THINKING HUMANLY

"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)

"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning" (Bellman, 1978)



## THINKING RATIONALLY

**Act** "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)



# Computational Intelligence




THINKING HUMANLY
THINKING RATIONALLY

ACTING HUMANLY
ACTING RATIONALLY

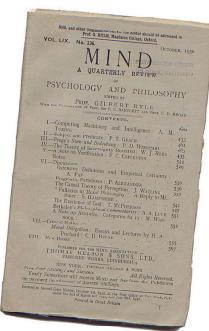






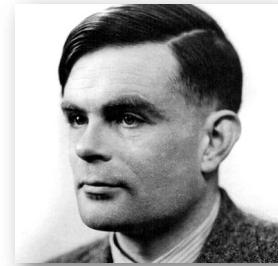
## Acting Humanly

- “The study of how to make computers do things at which, at the moment, people are better” (Rich and Knight, 1991)
- “The art of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990)
- Turing Test

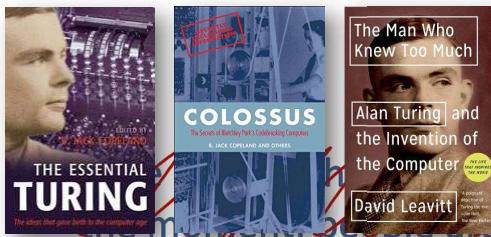


squillero@polito.it

“Computing Machinery and Intelligence”  
A. M. Turing (1950), *Mind* 49: 433-460.

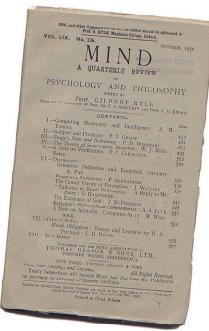


9



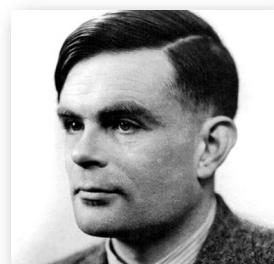
## ing Humanly

- “The art of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990)
- Turing Test



squillero@polito.it

“Computing Machinery and Intelligence”  
A. M. Turing (1950), *Mind* 49: 433-460.



10

The Man Who Knew Too Much

ROOM 1

QUESTION →

ANSWER ←

ANSWER ←

QUESTION →

ROOM 2

ROOM 3

A. M. Turing (1950), *Mind* 49: 433-460.

What is Computational Intelligence

squillero@polito.it

11

## Acting Humanly

- “~~The study of how to make computers do things at which, at the moment, people are better~~” (Rich and Knight, 1991)
- “The art of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990)

Deep Blue 1996	Watson 2011	AlphaGo 2016

squillero@polito.it

What is Computational Intelligence

12

## Acting Rationally

- Norvig's *rational agents*
- “Computational Intelligence is the study of the design of intelligent agents” (Poole et al., 1998)
- Multi-agent systems



squillero@polito.it

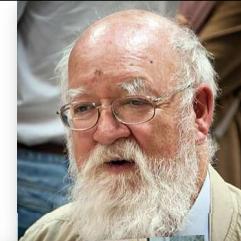
What is Computational Intelligence

13

## Strong AI

VS.

**Weak AI**  
**Narrow AI**



squillero@polito.it

What is Computational Intelligence

# Computational Intelligence

- Solve problems by **searching**
  - Machine Learning
- **Human** Learning
  - Trial & Error
  - Evolution



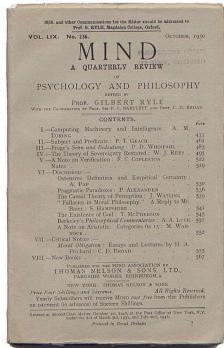
squillero@polito.it

What is Computational Intelligence

15

# Learning & Evolution

- **Heredity** material → **Structure** of the child machine
- **Mutation** → **Changes** of the child machine
- Natural **selection** → **Judgment** of the experimenter



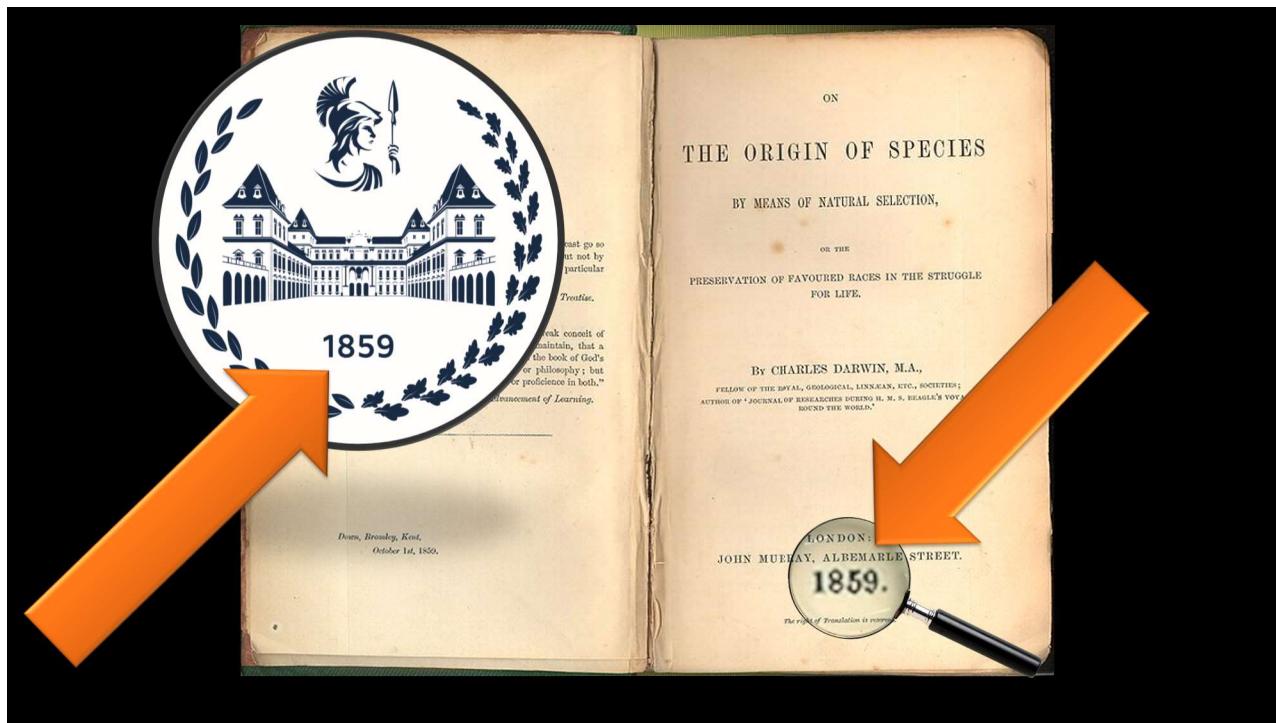
"Computing Machinery and Intelligence"  
A. M. Turing (1950), *Mind* 49: 433-460.

There is an obvious connection between the learning process and evolution



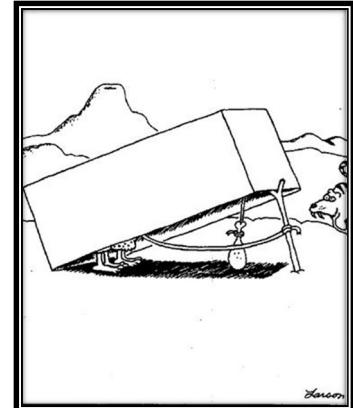
What is Computational Intelligence

## From Biology to Computer Science



## Bio-Inspired & Population-Based Metaheuristics

- Evolution is **not** an **optimization** process
  - Evolution does **not** have a **goal**
  - Evolution does **not** favor **strength**
  - Evolution does **not** favor **intelligence**
- However,
- When all variations are accumulated in **one** specific **direction** the final outcome may look like the product of an **intelligent design**!



squillero@polito.it

What is Computational Intelligence

19

## Computational Intelligence (01URROV)

- Single-State methods
  - E.g., Simulated Annealing
- Population methods
  - E.g., Genetic Algorithms
- Policy optimization
  - E.g., Q-Learning
- Representation problem
  - E.g., Fuzzy logic
- Multi agent systems



squillero@polito.it

What is Computational Intelligence

## Pop Quiz

- Picture yourself running in a street carrying a handful of hamsters
  - What problems do you expect?
  - How would you solve them?
  - Did you ever do it?
  - Did someone tell it to you?



squillero@polito.it

What is Computational Intelligence

21

## Ada Countess of Lovelace (1815–1852)

- Only child of Lord Byron
- First programmer in history

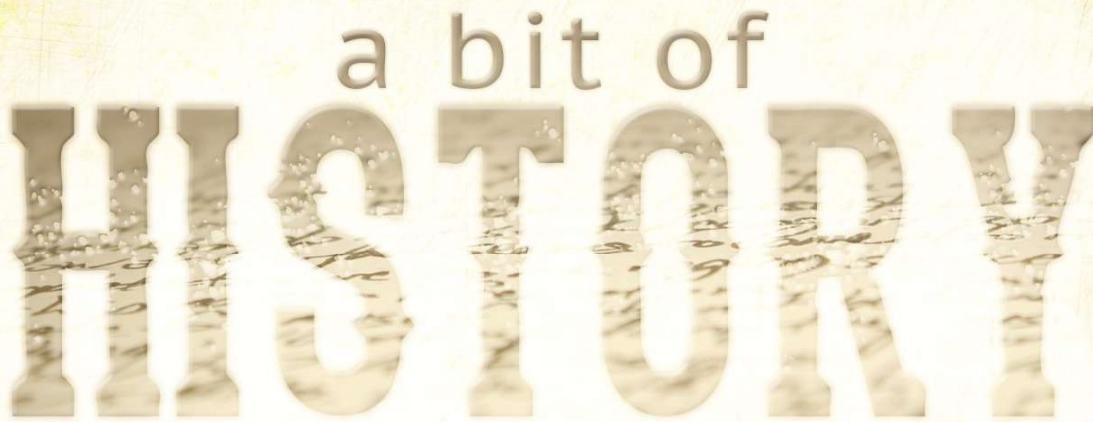
1842

*The “computer” has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform. It can follow analysis; but it has no power of anticipating any analytical relations or truths. Its province is to assist us in making available what we are already acquainted with...*



squillero@polito.it

What is Computational Intelligence

The image features the text "a bit of HISTORY" in a large, serif font. The word "HISTORY" is particularly prominent, with each letter containing a small, faint watermark of a classical building's facade, possibly a temple or a colonnade.

## 1943–1956: The Inception of AI

- Warren McCulloch and Walter Pitts
- Propositional logic (Russell & Whitehead)
- First network structures able to learn (Donald Hebb)
- Marvin Minsky & Dean Edmonds build a NN computer in 1950
- Alan Turing publish “Computing Machinery and Intelligence” in 1950
- 1956: Cited for coining the term Artificial Intelligence
- 1956: Conference on AI at in Hanover in 1956
  - McCarthy, Minsky, Shannon, Rochester, Newell, Simon, Samuel, Solomonoff, Selfridge...

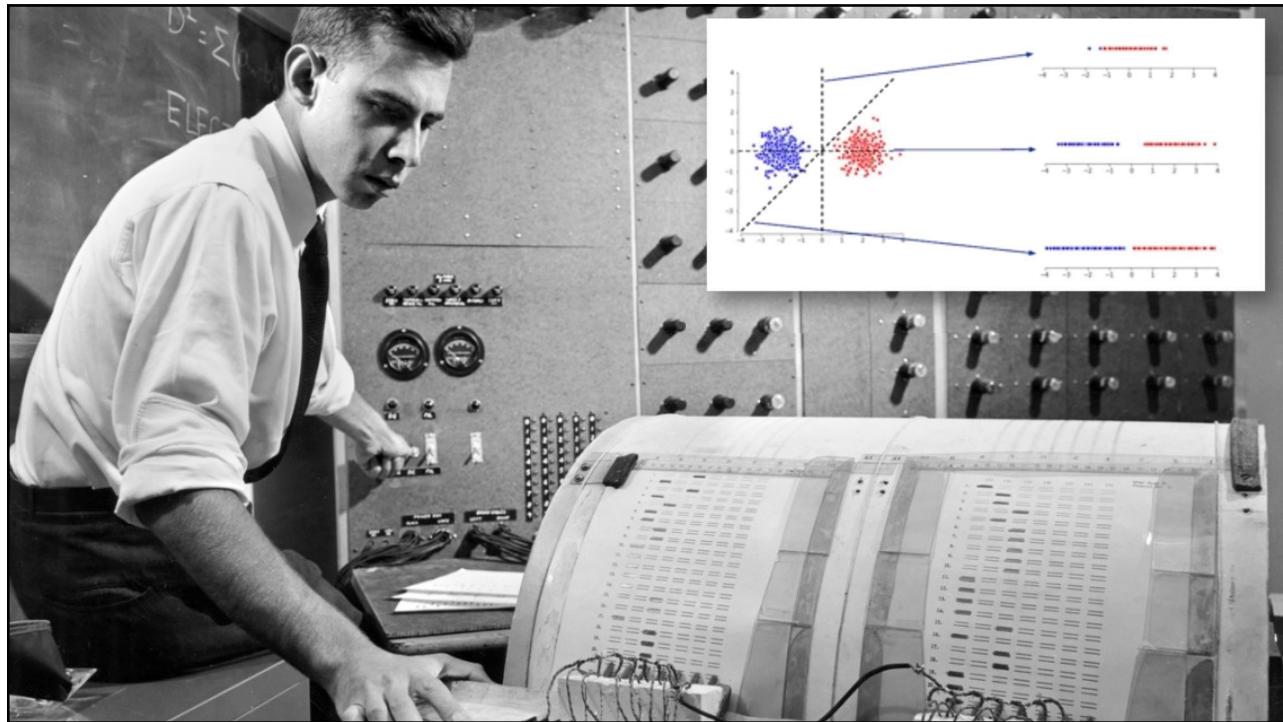
## 1952–1959: Early Enthusiasm

- Focus on tasks that would require intelligence in humans (games, puzzles, IQ tests)
  - The “Look, Ma, no hands!” era (John McCarthy)
- Newell & Simon’s
  - Logic Theorist: Theorem-proving system
  - General Problem Solver (GPS): Solver for a limited class of puzzles, but Credited for coining the term Machine Learning (1959)
- Arthur Samuel’s checkers in 1956
  - Embryonic RL
- Herbert Gelernter’s theorem prover in 1959

squillero@polito.it

What is Computational Intelligence

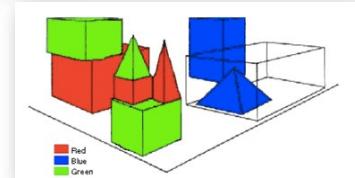
25



## 1952–1959: Early Enthusiasm

- John McCarthy created Lisp in 1958
  - Try Scheme on Replit!
- McCarthy vs. Minsky
- Minsky's "microworld" (e.g., blocks world)

```
1 (display "Hello World")
2 (newline)
```



## 1960–1973: Back to Reality

**The Spirit is willing  
but the Flesh is weak**



**The Vodka is good  
but meat is rotten**

## 1960–1973: Back to Reality

- Minsky publishes “Steps toward artificial intelligence” in 1961
- Failure to solve practical tasks
- Failure to tackle the “combinatorial explosion”
- XOR problem (“Evolutionary Computation” book “Perceptrons”, 1969)
- Birth of “Machine Evolution”

## 1969–1986: Expert Systems

- General-purpose vs. “Weak” methods
- Bruce Buchanan and friend’s DENDRAL in 1969
  - Able to infer molecular structures from mass spectra
  - Not simple brute force, first *knowledge-intensive* system
- Minsky’s frames (1975)

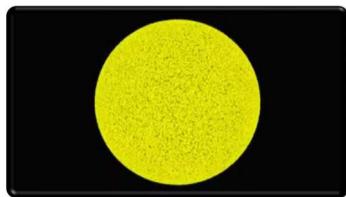
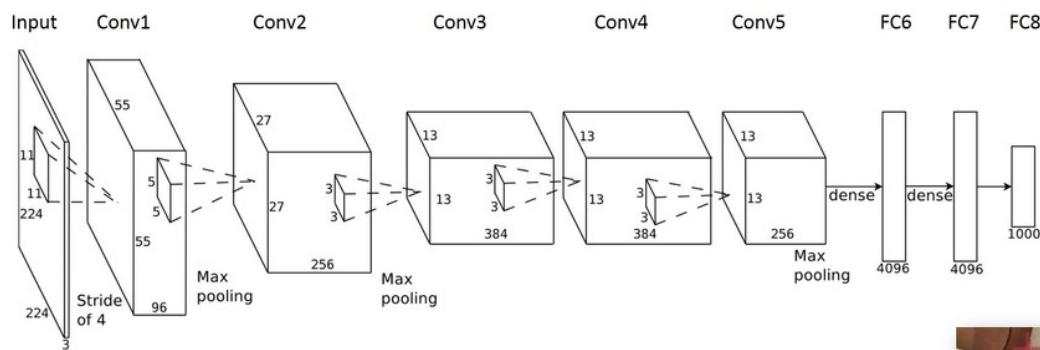
## 1986–now: The Return of NN

- The re-invention of back-propagation (Leibniz, 1676; Kelley, 1960; Bryson, 1961; Dreyfus, 1962; Linnainmaa, 1970)
- Big data (since 2001?)
- Deep Learning (since 201?)

squillero@polito.it

What is Computational Intelligence

31



squillero@polito.it

What is Computational Intelligence



## ?–now: Probabilistic Reasoning

- Mostly ML's topics
- Lotfi Zadeh's Fuzzy Logic in 1965
- Leonard Baum's Hidden Markov Models in late 1960s
- Judea Pearl coined the term “Bayesian Networks” in 1985

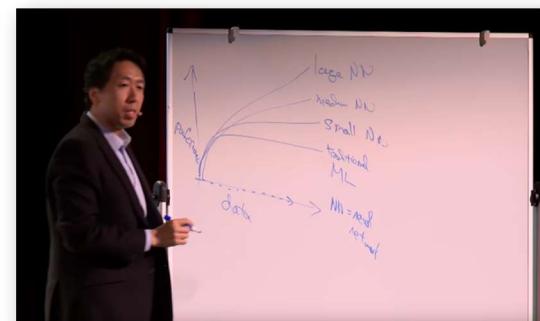
squillero@polito.it

What is Computational Intelligence

33

## 1996–now: Crunching data

- Deep Blue defeated Garry Kasparov in 1996
- “Probably we can now (or we will soon be able to) automate almost everything that a human can do in less than a second of thought”  
— Andrew Ng (2018)



squillero@polito.it

What is Computational Intelligence

34



## Artificial Intelligence

- My programmable alarm clock **understood** that it should wake me up at 6:30 this morning !?



squillero@polito.it

What is Computational Intelligence

37



*Deep Blue was intelligent the way your programmable alarm clock is intelligent.  
Not that losing to a \$10 million alarm clock made me feel any better.*

— Gary Kasparov, *Deep Thinking: Where Machine Intelligence Ends and Human Creativity Begins*, 2017

What is Computational Intelligence

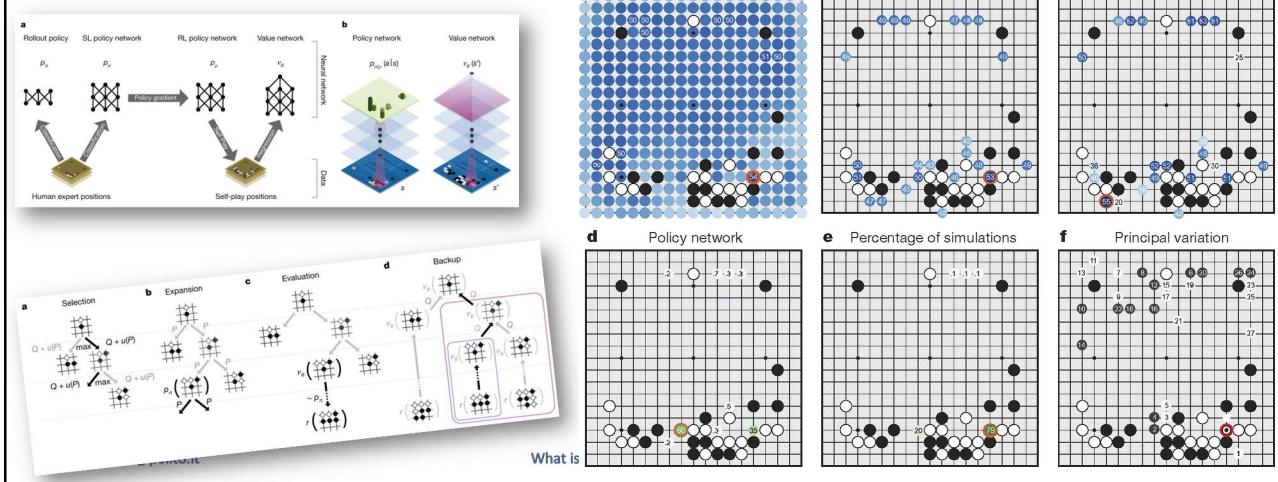


## Mastering the game of Go with deep neural networks and tree search

David Silver , Aja Huang, Chris J. Maddison, Arthur Guez, Laurent Sifre, George van den Driessche, Julian Schrittwieser, Ioannis Antonoglou, Veda Panneershelvam, Marc Lanctot, Sander Dieleman, Dominik Grewe, John Nham, Nal Kalchbrenner, Ilya Sutskever, Timothy Lillicrap, Madeleine Leach, Koray Kavukcuoglu, Thore Graepel & Demis Hassabis

*Nature* 529, 484–489 (2016)

Montecarlo Tree Search  
Reinforcement Learning  
NN  
Q-Learning



## Complex ≠ Intelligent

- **The Game of Life**, created by John Horton Conway (1970)
  - Repeated applications of simple rules may lead to unforeseeable results
  - Complex properties arise from simple laws



squillero@polito.it

What is Computational Intelligence

41

## 2022

- AI winter is coming
- AI is the new electricity



squillero@polito.it

What is Computational Intelligence

42

