

# Introduction to Artificial Intelligence

Inteligencia Artificial en los Sistemas de Control Autónomo  
Máster Universitario en Ingeniería Industrial

Departamento de Automática

## Objectives

1. Think over the meaning of intelligence
2. Understand Artificial Intelligence (AI) as a Computer Science discipline
3. Describe the historical roots of AI
4. Elemental AI terminology
5. Introduce some AI applications

## Objectives

Russell, S., Norvig, P. (1995). Artificial Intelligence: A modern approach. Prentice-Hall.

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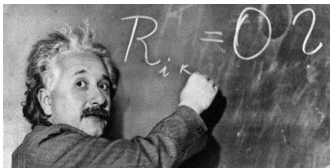
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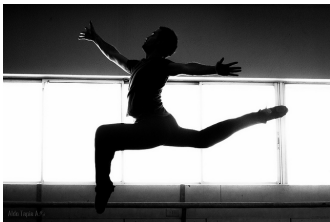
## 4. AI applications

- Disciplines and techniques
- Application domains

What is intelligence?



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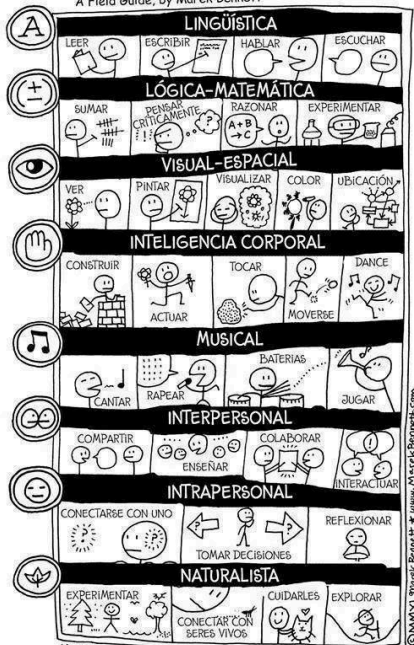


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# INTELIGENCIAS MÚLTIPLES

A Field Guide, by Marek Bennett



After Thomas Armstrong, MULTIPLE INTELLIGENCES IN THE CLASSROOM

# Introduction

## Intelligence (I)

### Definition of intelligence

*“A very general mental capability that, among other things, includes the ability to reason, pose, solve problems, think abstractly, understand complex ideas, learn quickly and learn from experience”*

Gottfredson, 1997

Not only from books, limited academic ability, or make good tests

- It reflects a broader and deeper capacity

# Introduction

## Intelligence (II)

Alternative definition: Capacity to **learn** and **solve** problems (Websters dictionary)

- The ability to solve novel problems



# Introduction

## Artificial Intelligence (I)

### Definition of AI

Build machines that perform tasks that were previously performed by human beings

- People process information slowly but in parallel
- Computers are incredibly fast but essentially linear
- It reflects a broader and deeper capacity
- Intelligence requires knowledge: **Learning**

# Introduction

## Artificial Intelligence (II)

Alternative definition: **Understand** and **build** intelligent entities

- Understand: Use computers to study intelligence (Science)
- Build: Solve real problems using knowledge and reasoning (Engineering)
- Intelligent entity = **agent**

AI deals with **algorithms** and **knowledge representation**

- AI is not restricted to any programming language

# Introduction

## Approaches to Artificial Intelligence (I)

Two goals: Humanity and rationality

- Human: Like human beings
- Rational: Doing the right thing
- The right thing: What is expected to maximize goal achievement, given the available information

Two dimensions: Processes (thinking) and result (acting)

Thinking humanly	Thinking rationally
Theories about internal activities of the brain $\Rightarrow$ Neuroscience	What are correct arguments? $\Rightarrow$ Logics
Acting humanly	Acting rationally
Can machines think?	Rational agents

# Introduction

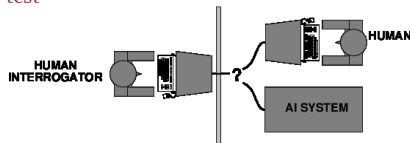
## Approaches to Artificial Intelligence (II)

### Thinking humanly

- Scientific theory of internal activities of the brain
- How to validate?
  - Predicting behavior of humans (**Cognitive science**)
  - Identification of neurological data (**Neuroscience**)

### Acting humanly

Can machines think? Test needed: **Turing test**



Proposed by Alan Turing (yes, that Turing!)

# Introduction

## Approaches to Artificial Intelligence (III)

### Real Turing test at the Royal Society (2014)

#### Chat 1

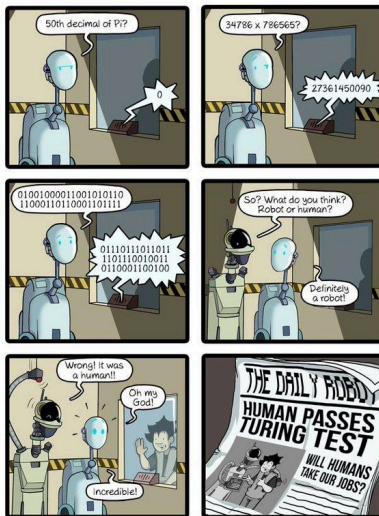
```
[16:28:55] Judge: how tall are you
[16:29:18] Entity: almost 6 feet tall
[16:29:46] Judge: how heavy are you
[16:30:12] Entity: just over ten stone
[16:30:47] Judge: what is your gender
[16:30:59] Entity: male
[16:31:45] Judge: what is your bmi
[16:31:54] Entity: i have no clue
^^I^^
```

#### Chat 2

```
[16:29:04] Judge: how tall are you
[16:29:10] Entity: My height is about 160 cm - it's 5 feet 4 inches.
[16:29:37] Judge: how heavy are you
[16:29:59] Entity: My grandfather taught me not to disclose non-solicited information about myself. Like on the question 'Do you have watch' - never tell time, but answer 'Yes' or 'No'. I always follow his advice. And I forgot to ask you where you are from ...
[16:31:09] Judge: what is your gender
[16:31:17] Entity: I'm a young boy, if you care to know. And not very ugly, by the way!
^^I^^
```

# Introduction

## Approaches to Artificial Intelligence (IV)



# Introduction

## Approaches to Artificial Intelligence (IV)

### Thinking rationally

- “Laws of thought”
- Aristotle: What are correct arguments?  $\Rightarrow$  **Logic**
- Connects Philosophy, Mathematics and AI
- Problems
  - Not all intelligent behavior is deliberative
  - What is the purpose of thinking?

### Acting rationally

**Agent:** Entity that perceives and acts

- A robot may be seen as an physical agent
- Amazon recommender system
- Spam filter

Computational constraints: Design the best program with available resources

# Introduction

## Related fields

Philosophy	Logic, methods of reasoning, mind as physical system, foundations of learning, language, rationality
Mathematics	Formal representation, proof algorithms, computation, (un)decidability, (in)tractability, probability
Probability	Modeling uncertainty, learning from data
Economics	Utility, decision theory, rational economic agents
Neuroscience	Neurons as information processing units
Psychology	How do people behave, process cognitive information, represent knowledge
Computer Engineering	Build fast computers
Control theory	Optimization
Linguistics	Knowledge representation, grammars



# History

## Timeline (I)

- 1943 Early beginnings
  - McCulloch & Pitts Boolean circuit model of brain
- 1950 Turing
  - Turing's "Computing Machinery and Intelligence"
- 1952 Look, Ma, no hands!
- 1956 Birth of AI
  - Dartmouth meeting: "Artificial Intelligence" adopted

# History

## Timeline (II)

### 1950s Early AI programs

- Samuel's checkers program
- Newell & Simon's Logic Theorist

### 1955-65 Great enthusiasm

- Newell and Simon: GPS, general problem solver
- McCarthy: Invention of LISP

### 1966-73 Reality dawns

- AI discovers computational complexity
- Limitations of existing neural networks methods identified
- Neural network research almost disappears

# History

## Timeline (III)

1969-79 Adding domain knowledge

- Early development of knowledge-based systems

1986- Raise of Machine Learning

- Neural Networks return to popularity
- Major advances in Machine Learning and its applications

1990- Role of uncertainty

- Bayesian networks for knowledge representation

1995- AI becomes a science

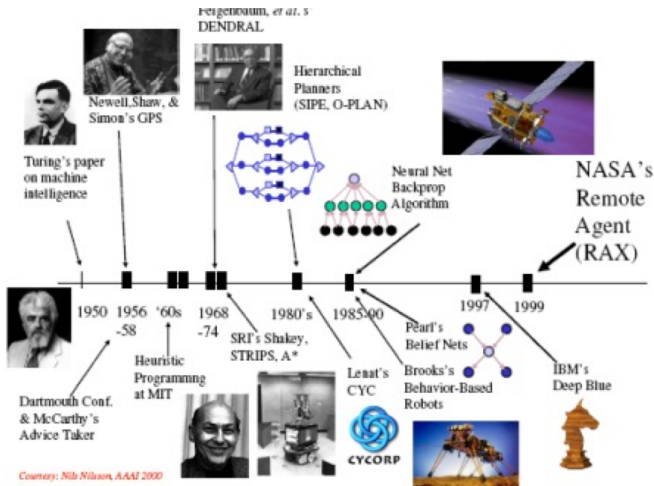
- Integration of learning, reasoning and knowledge representation
- AI used in vision, language, data mining, etc

2000- Popularity of Soft Computing / Bioinspired algorithms

2010- Machine Learning meets large databases: Big Data

# History

## Timeline (IV)



# History

## Success milestones

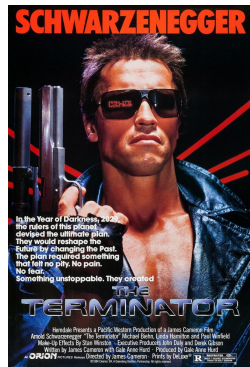
- Deep Blue defeated Garry Kasparov in 1997
- Proved the Robbins conjecture, unsolved for decades
- No hands across America
- During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people
- NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft
- Proverb solves crossword puzzles better than most humans
- Robot driving: DARPA grand challenge 2003-2007
- 2006: Face recognition software available in consumer cameras
- 2011: IBM Watson defeats human players in Jeopardy!
- 2016: First AI to defeat a Go human champion

# Building Terminator (I)

## Terminator

- Come on, do you really do not know what Terminator is?
- Classical action movie filmed in 1984
- Relates a robot from 2029 chasing Sarah Connor
- ... and self-aware AI named Skynet that leads the raise of the machines

(Video trailer)



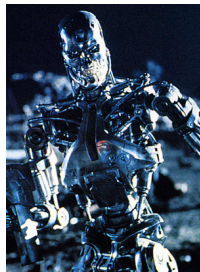
# Building Terminator (II)

The main character is a T-800 robot, terminator

- T-800 is a robot model designed to exterminate humans

T-800 displays very advanced features

- Plan how to exterminate Sarah Connor
- Speak easily with humans
- Recognize human faces
- Navigate vehicles
- Diagnose on-board problems
- Make life-and-death decisions
- Understand human emotions



Terminator was sci-fi in 1984 ... Is it still sci-fi?

# Building Terminator (III)

Imagine we want to build T-800 ... What would we need?

- Fast hardware?
- Chess-playing at grandmaster level?
- Speech interaction?
- Learning?
- Image recognition and understanding?
- Planning and decision-making?

Let's analyze them



# AI applications

## Building Terminator (IV)

HUMAN SKILL	AI FIELD
Motion control	Robotics
Image reconition	Computer vision
Speech understanding	Natural Language Processing
Reasoning	Automatic reasoning
Plan	Planning & Scheduling
Learn	Machine Learning
Drive vehicles	Control
Play chess	Search

And, of course, we need some hardware

# Building Terminator

## Hardware (I)

How complicated is our brain?

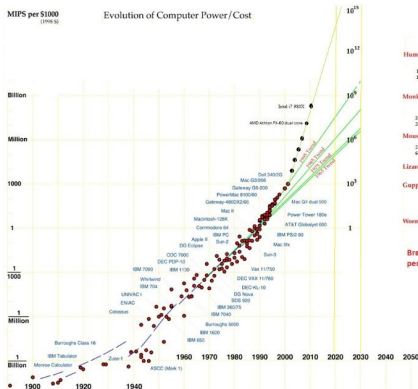
- A neuron is the basic information processing unit
- Around  $10^{12}$  neurons in a human brain with  $(10^{14})$  synapses
- Processing time: 1ms

How complex can we make computers?

- $10^8$  or more transistors per CPU
- Supercomputers with thousands of CPUs
- Processing time:  $10^{-9}$ s

# Building Terminator

## Hardware (II)



(Source)



## Conclusion

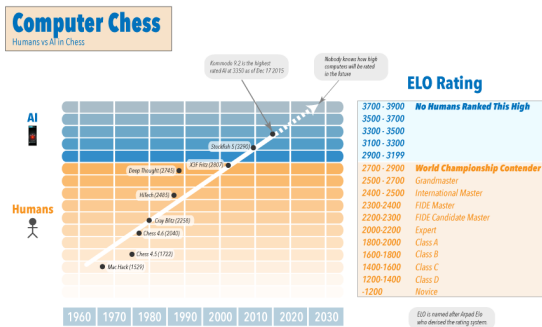
- YES, in a future we will have computers with as many processing units than human brains
- But, with fewer interconnections, and much faster
- Processing power does not make behave like a brain

# Building Terminator

## Chess (I)

Chess is a classic benchmark in AI

- AI techniques: Classic search



Conclusion: YES

(Source)

# Building Terminator

## Chess (II)



In 2015, an AI beats the best human Go player

- Historic mildstone

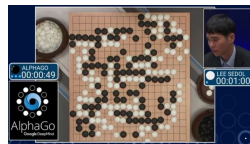
Go is much harder from AI perspective

- Huge branching factor
- Fuzzy heuristics

AI techniques

- Monte-Carlo Search Trees
- Deep neural networks

Next challenge: StarCraft II



# Building Terminator

## Speech synthesis

Three different problems to make computers talk

- (Speech synthesis), speech recognition and speech understanding

Speech synthesis: Generate sound from text

- Translate text to phonemas: “fictitious”  $\Rightarrow$  fik-tish-es
- Generate sound from phonema: “tish”  $\Rightarrow$  Sound

Difficulties

- This approach makes sounds unnatural
- Sounds are not independent (almost solved)
- Show emotions, emphasis, semantic-aware pronunciation

Conclusion

- YES for words
- NO for complete sentences

# Building Terminator

## Speech recognition

Speech recognition: Map sounds into a list of words

- Classic (and difficult) problem in AI
- Techniques: Neural networks, Hidden-Markov Chains, Deep Learning, ...

Recognizing single words from a small vocabulary

- Numbers, city numbers, names, ...
- Highly successfull solutions (99 % accuracy)

Recognizing normal speech is much more difficult

- Large vocabularies
- Continuous sound (detect word boundaries)
- Humans use context to recognize speech
- Background noise, accents, other speakers, ...
- Modern systems with 60 %-70 % accuracy

Conclusion: YES for restricted problems, NO for normal speech

# AI applications

## Building Terminator: Speech understanding

Speech understanding: What is the meaning of the speech?

- Another classic (and difficult) problem in AI
- Same than text mining
- Techniques: Knowledge representation, ontologies, ML, NLP

Very hard problem

- Natural language is ambiguous  $\Rightarrow$  Different interpretations
- Meaning depends on the context

Example: “Time flies like an arrow”

- What does it mean?

Normal speech is too hard  $\Rightarrow$  Formal representation of knowledge

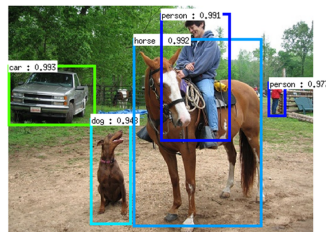
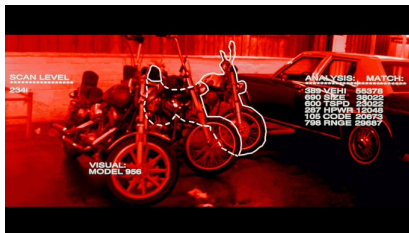
- Semantic Web, ontologies, deep neural networks (recently), etc

Conclusion: NO



# Building Terminator

## Image recognition



(Source)

Several tasks:

- Segmentation, object recognition, (image synthesis), etc

Technology

- Deep neural networks

Conclusion: NO for general recognition, YES for restricted domains

# Building Terminator

## Learning (I)

Consider a self-driving car, we could ...

- ... program a huge number of rules
- ... or we could drive and let the computer learn



(Source)

## Machine Learning

- Allows computers to do things without explicit programming
- Many techniques: Neural networks, decision trees, bayesian networks, ...
- Huge number of applications
- Hot topic nowadays (and job opportunities!)

# Building Terminator

## Learning (II)

Another discipline: Expert systems

- It maintains a knowledge base, facts base and inference engine
- Expert systems can learn

Other approaches: Case Based Reasoning, Reinforcement Learning, probabilistic learning, Deep Learning, ...

- (Video)

Conclusion: YES

# Building Terminator

## Plan and make decisions

Intelligence involves solving problems, making decisions and plans

- Plan: Sequence of actions to achieve a goal
- Techniques: Search

Example: You want to plan a trip to Caribe

- Decide on dates, flights, airport transport, hotel, fit timetables, ...

It is a hard problem

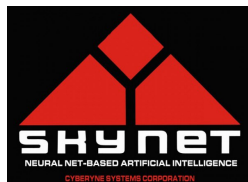
- World is not predecible (flights can be delayed)
- Huge number of details, common sense constrains decisions

Life-and-death decisions: (Video)

Conclusion: NO for real-world planning, YES for restricted domains

# Building Terminator

## Artificial General Intelligence



State-of-the art AI is competitive in very restricted domains

- How AI generalizes to broad domains?
- **Artificial General Intelligence**
- State-of-the-art uses Deep Reinforcement Learning (neural networks)

General AI is a controversial field

- Eventually, we could develop an intelligence explosion ...
- ... and a superintelligence ...
- ... or even a strong AI

# AI applications

## Disciplines and techniques

### AI disciplines techniques

#### Disciplines

- Automatic reasoning
- Planning
- Agents
- Expert systems
- Computer vision
- Evolutionary Computation
- Natural Language Processing
- Machine Learning
- Knowledge representation
- ...

#### Techniques

- Neural networks
- Search algorithms
- Genetic Algorithms
- Case Based Reasoning
- Logic
- Fuzzy logic
- Web mining
- Ontologies
- ...

# AI applications

## Application domains (I)

### Genetic Algorithms

- Optimization of production chains
- Optimization of airline planes and crews
- Antenna design

### Expert Systems

- Decision making in financial markets
- Fraud detection
- Medical diagnosis systems

### Neural networks

- Face recognition
- Robot control
- OCR

# AI applications

## Application domains (II)

- Handwriting recognition (reading service postcodes USA)
- Search engines on the Web and Semantic Web
- Bio(logical) computing
- Anti-spam email
- Proof of theorems automatically
  - Using new methods of inference to prove new theorems



## Collorary

AI addresses the automatic problems  
resolution