Introduction to Artificial Intelligence

Inteligencia Artificial en los Sistemas de Control Autónomo
Máster en Ciencia y Tecnología desde el Espacio
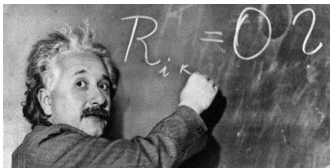
Departamento de Automática

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
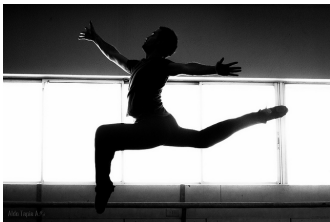5. Introduce some AI applications

Objectives

Russell, S., Norvig, P. (1995). *Artificial Intelligence: A modern approach.* Prentice-Hall.
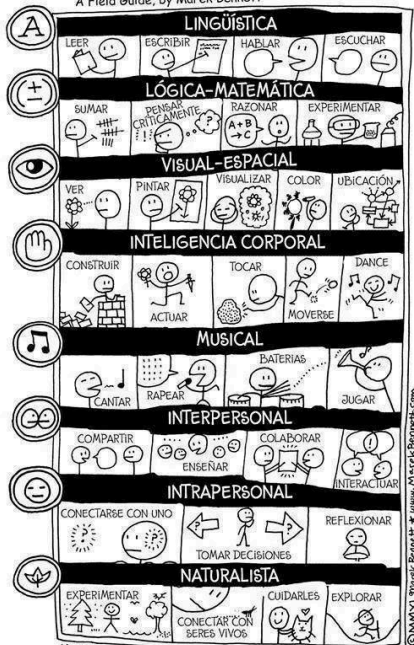
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What is intelligence?

INTELIGENCIAS MÚLTIPLES

A Field Guide, by Marek Bennett

LINGÜÍSTICA

LEER · ESCRIBIR · HABLAR · ESCUCHAR

LÓGICA-MATEMÁTICA

SUMAR · PENSAR CRÍTICAMENTE · RAZONAR · EXPERIMENTAR

VISUAL-ESPACIAL

VER · PINTAR · VISUALIZAR · COLOR · UBICACIÓN

INTELIGENCIA CORPORAL

CONSTRUIR · ACTUAR · TOCAR · MOVERSE · DANCE

MUSICAL

CANTAR · RAPEAR · BATERIAS · JUGAR

INTERPERSONAL

COMPARTIR · ENSEÑAR · COLABORAR · INTERACTUAR

INTRAPERSONAL

CONECTARSE CON UNO · TOMAR DECISIONES · REFLEXIONAR

NATURALISTA

EXPERIMENTAR · CONECTAR CON SERES VIVOS · CUIDARLES · EXPLORAR

After Thomas Armstrong, MULTIPLE INTELLIGENCES IN THE CLASSROOM

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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

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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 $\Rightarrow$ Neuscience	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
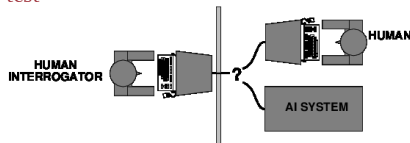
Proposed by Alan Turing (yes, that Turing!)

Introduction

Approaches to Artificial Intelligence (III)

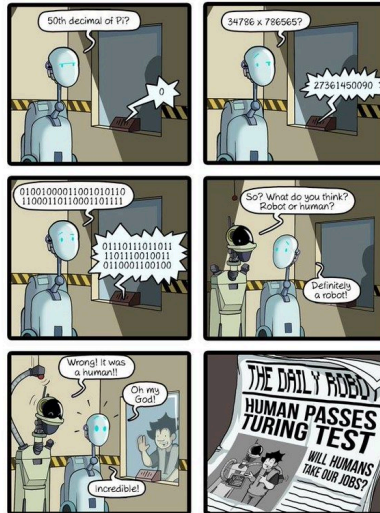### Real Turing test at the Royal Society (2014)

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^^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^^I
```

Introduction

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 phisical agent
- Amazon recommender system
- Spam filter

Computational constrains: 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

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
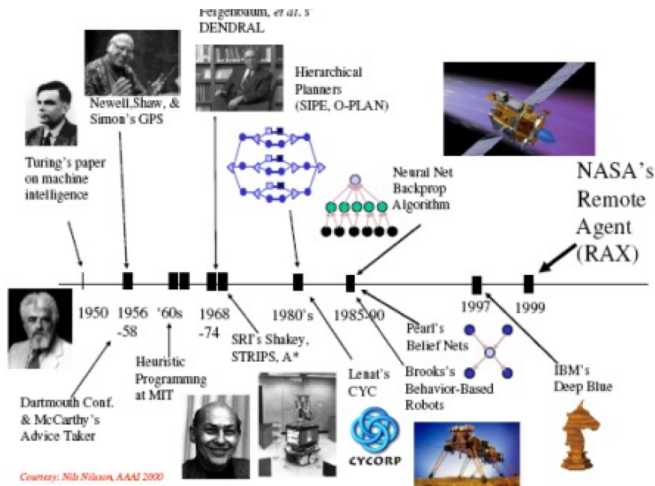
1995-   AI becomes a science
- Integration of learning, reasoning and knowledge representation
- AI used in vision, language, data mining, etc

2000-   Popularity of Soft Computing / Bioinspired algorithms

2010-   Machine Learning meets large databases: Big Data

History
Timeline (IV)

Turing's paper on machine intelligence

Newell, Shaw, & Simon's GPS

Feigenbaum, et al.'s DENDRAL

Hierarchical Planners (SIPE, O-PLAN)

Neural Net Backprop Algorithm

NASA's Remote Agent (RAX)

1950 1956 -58 '60s 1968 -74 1980's 1985-90 1997 1999

Dartmouth Conf. & McCarthy's Advice Taker

Heuristic Programmng at MIT

SRI's Shakey, STRIPS, A*

Lenat's CYC

Pearl's Belief Nets

Brooks's Behavior-Based Robots

IBM's Deep Blue

Courtesy: Nils Nilsson, AAAI 2000

CYCORP

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!
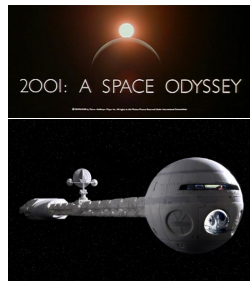- 2016: First AI to defeat a Go human champion

AI applications

2001: Space Odyssey

- Claimed as the best (and most realistic) sci-fi movie ever
- Filmed in 1969 by Stanley Kubrick
- Relates a journey to Jupiter (among many other things)

(Video trailer)
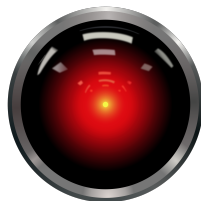
AI applications
2001: A Space Odyssey (II)

The main character is HAL 9000

- HAL is an AI that controls an intelligent spaceship (an agent)

HAL has very advanced features

- Play chess
- Speak easily with the crew
- Understand the emotions of the crew
- Display emotions
- Navigate the ship
- Diagnose on-board problems
- Make life-and-death decisions
- Recognize the crew faces

HAL was sci-fi in 1969 ...
Is it still sci-fi?

AI applications
Building HAL

Imagine we want to build HAL ... 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
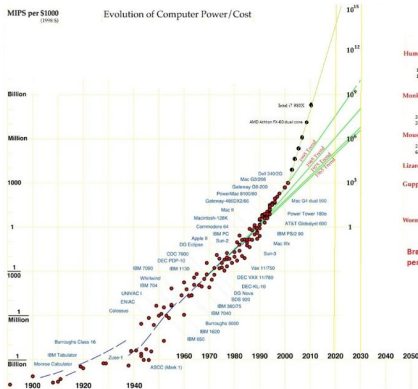
AI applications
Building HAL: Hardware (I)

How complicated is our brain?

- A neuron is the basic information processing unit
- Arround 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

AI applications
Building HAL: 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
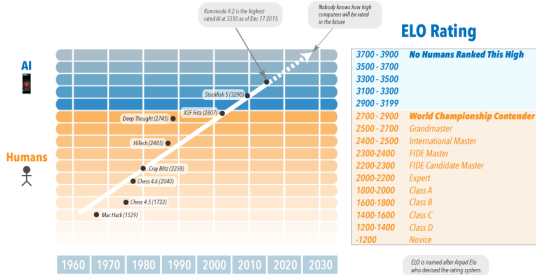- Processing power does not make behave like a brain

AI applications
Building HAL: Chess (I)

Chess is a classic benchmark in AI

- AI techniques: Classic search

(Source)

Conclusion: YES

AI applications
Building HAL: Chess (II)

AlphaGo

In 2015, an AI beats the best human Go player
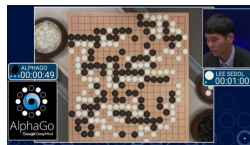
- Historic mildstone

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

AI applications
Building HAL: 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 indepentent (almost solved)
- Show emotions, emphasis, semantic-aware pronuntiation

Conclusion

- YES for words
- NO for complete sentences

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AI applications
Building HAL: 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
- Continous 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 HAL: 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

AI applications
Building HAL: 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 nowdays (and job opportunities!)

AI applications
Building HAL: Learning (II)

Another discipline: Expert systems

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

Other approaches: Case Based Reasoning, Reinforcement Learning, probabilistic learning, Deep Learning, ...
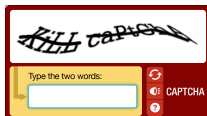
- (Video)

Conclusion: YES

AI applications

Building HAL: Image recognition

Recognition vs. understanding (like speech)

- Applications: Face recognition, object recognition, object tracking, ... (Video)
- Techniques: Computer vision, Machine Learning, Deep Learning, ...

Again, it is a hard problem

(Source)

Conclusion: NO for general recognition, YES for restricted domains

AI applications
Building HAL: 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

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

AI applications
Application domains (III)

- Applied Problems
- Pattern Recognition
- Artificial Creativity
- Machine Vision
- Automatic diagnosis
- Game Theory
- Intelligent games and bots
- Language Processing
- Planning and scheduling
- Nonlinear control
- Learning ...

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AI applications
Application domains (IV)

AI in Robotics

- (Video Athlete)
- (Video Spot)
- (Video Atlas)
- (Video ExoMars)
- (MSL Photos)

Collorary

AI addresses the automatic problems resolution