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
6. Applications of AI in space

Objectives

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

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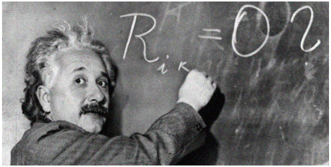
What is intelligence?



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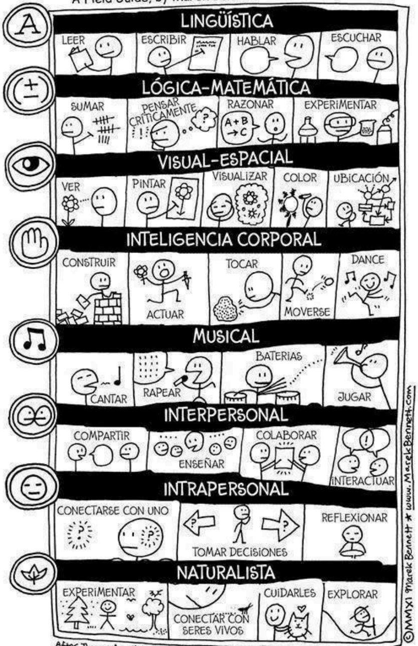
INTELIGENCIAS MÚLTIPLES

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 $\Rightarrow$ Neuscience	What are correct arguments? $\Rightarrow$ Logics
Acting humanly	**Acting rationally**
Can machines think?	Rational agents

Introduction

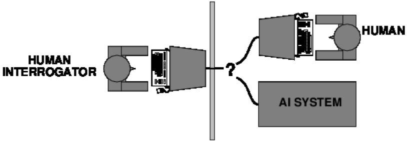
Approaches to Artificial Intelligence (II)

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

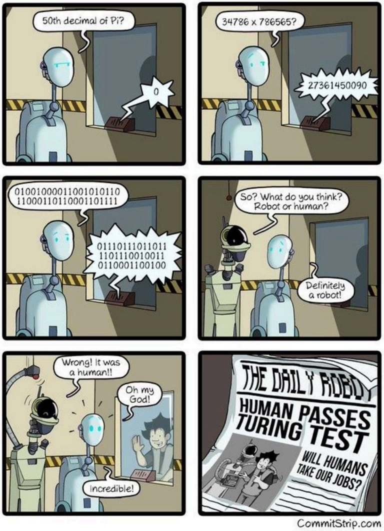
```
[16:28:55] Judge: how tall are you
[16:29:18] Entity: almost 6 feet tall
[16:29:46] Judge: how heavy are you
[16:30:12] Entity: just over ten stone
[16:30:47] Judge: what is your gender
[16:30:59] Entity: male
[16:31:45] Judge: what is your bmi
[16:31:54] Entity: i have no clue
^^I^^I
```

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

Approaches to Artificial Intelligence (IV)



Introduction

Approaches to Artificial Intelligence (IV)

Thinking rationally

- "Laws of thought"
- Aristotle: What are correct arguments? ⇒ **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

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

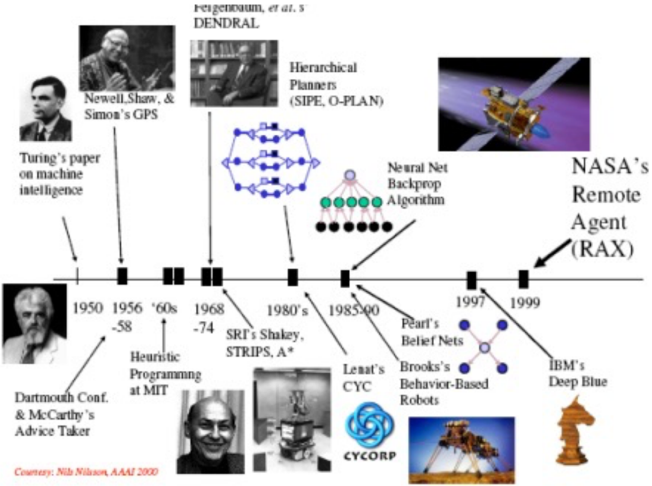
- Integration of learning, reasoning and knowledge representation
- AI used in vision, language, data mining, etc

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

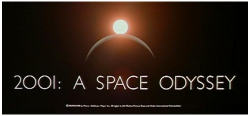
AI applications

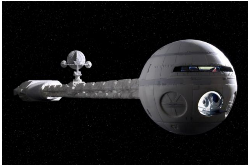
2001: A Space Odyssey (I)

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

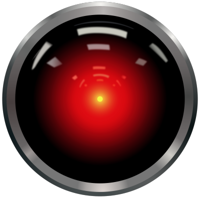
2001: A Space Odyssey (II)

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?

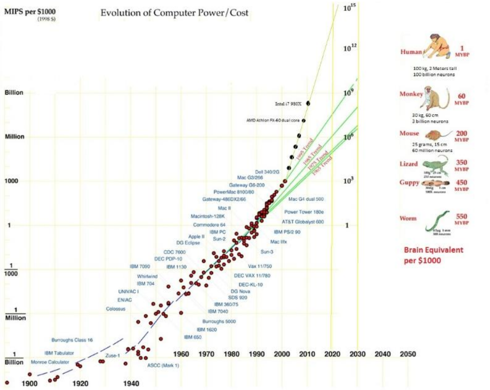
- A neuron is the basic information processing unit
- Arround 10^{12} neurons in a human brain with (10^{14}) synapses
- Processing time: $1ms$

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)



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Conclusion

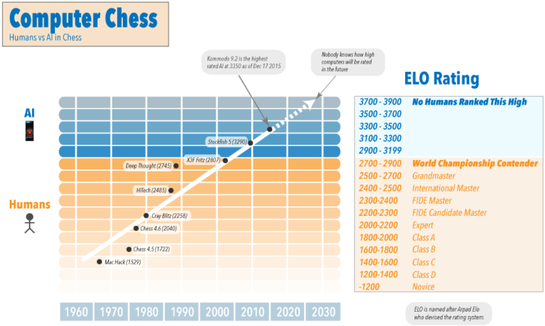
- YES, in a future we will have computers with as many processing units than human brains
  - But, with fewer interconnections, and much faster
- Processing power does not make behave like a brain

AI applications

Building HAL: Chess (I)

Chess is a classic benchmark in AI

- AI techniques: Classic search



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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” ⇒ fik-tish-es
- Generate sound from phonema: ”tish”⇒ 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

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 ambigous ⇒ Different interpretations
- Meaning depends on the context

Example: “Time flies like an arrow”

- What does it mean?

Normal speech is too hard ⇒ Formal representation of knowledge

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

Conclusion: NO

AI applications

Building HAL: Learning (I)

Consider a selft-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

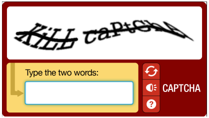
AI applications

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



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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 ...

AI applications

Application domains (IV)

AI in Robotics

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

AI in space

Why is Mars interesting? (I)

Mars is a lot like Earth

- About 1/2 size than Earth
- Martian day slightly under 25 hours
- Avg. temp -63º (-140ºC to 20ºC)

Distant past

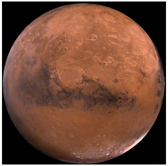
- Evidence of oceans and warm temperatures
- It may have harbored life

Present

- Frozen water and a thin atmosphere of carbon dioxide remain
- It is possible that it harbors life today
- Earth is sending many robotic spacecraft to investigate

Future

- Mars has all of the materials needed to support human civilization
- Several nations interested in sending humans to Mars in the future



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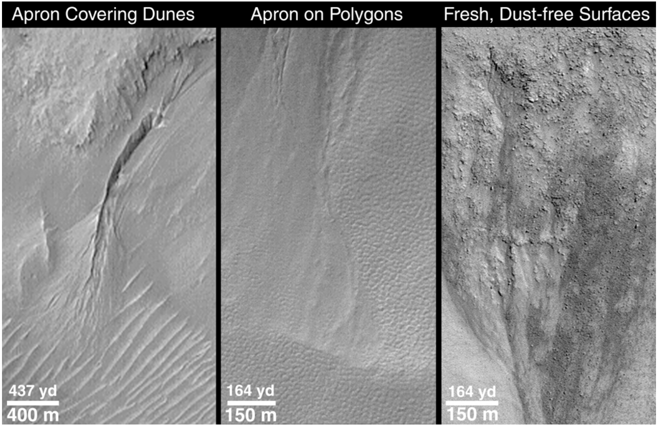
AI in space

Why is Mars interesting? (II)

Strong evidence of recent water activity



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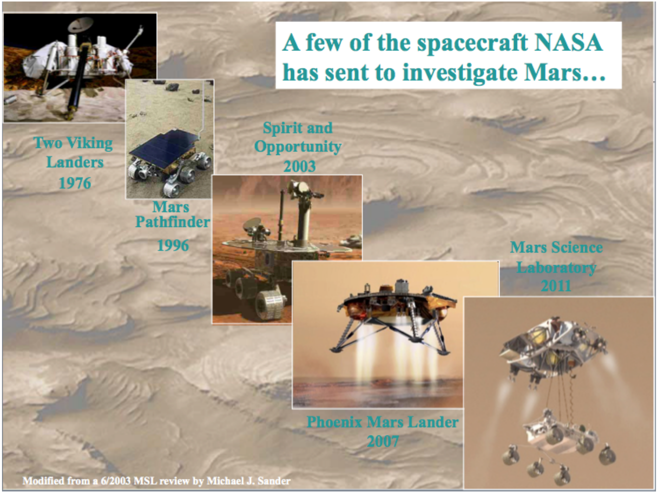
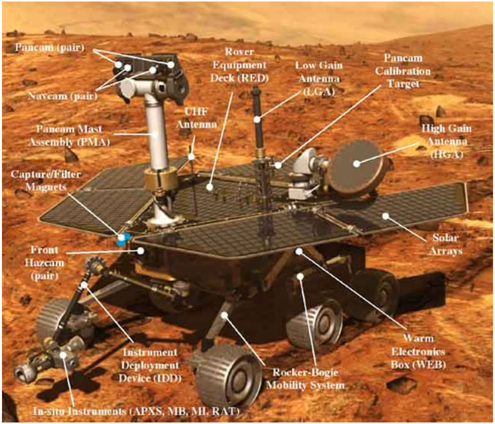
AI in space

Why is Mars interesting? (III)



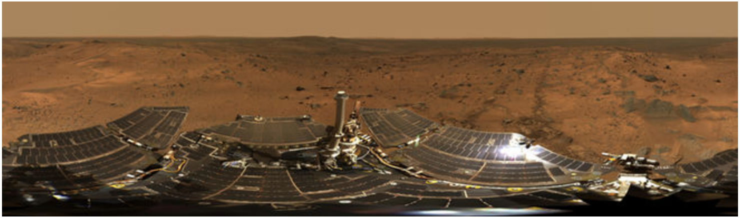
AI in space

Spirit and Opportunity (I)



AI in space

Spirit and Opportunity (II)

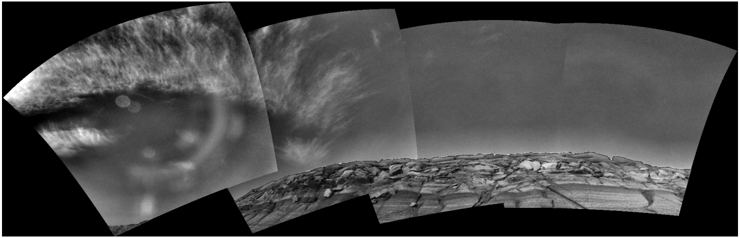


- Some Mars rocks contain minerals that only form in water
- Some sediment layers were formed in standing water
- Mars was covered with standing water in the past
- Mars used to be much warmer and wetter

AI in space

Spirit and Opportunity (III)

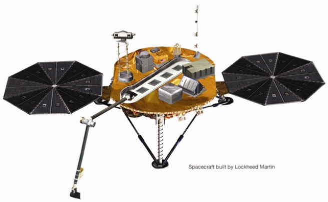
Clouds of water vapor on Mars



(Video Sunset) (Video MER by Steve Squyres)

AI in space

2007 Phoenix Mars Lander (I)



Launched August 2007

- Operated on Mars May-November 2008

Goals

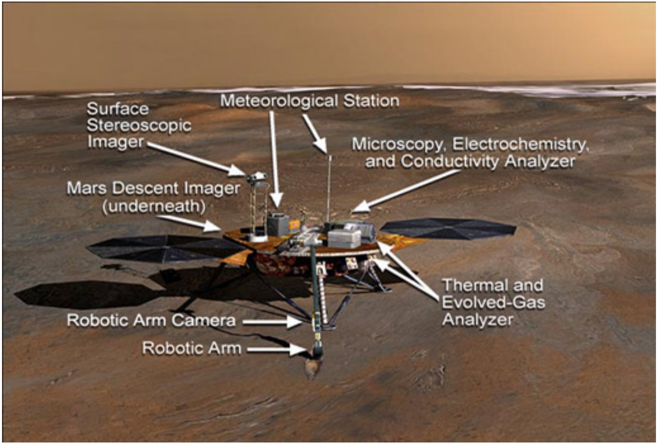
- Study the history of water in the Martian artic
- Search for evidence of a habitable zone and assess biological potential

How?

- Land in the Martian Arctic
- Dig through regolith to water ice
- Analyze ice samples in on-board

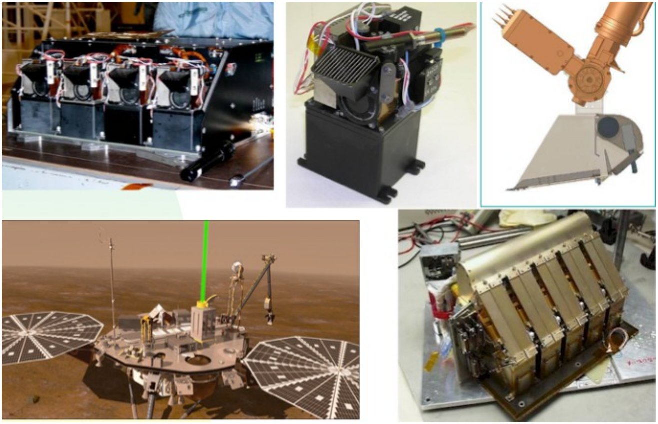
AI in space

2007 Phoenix Mars Lander (II)



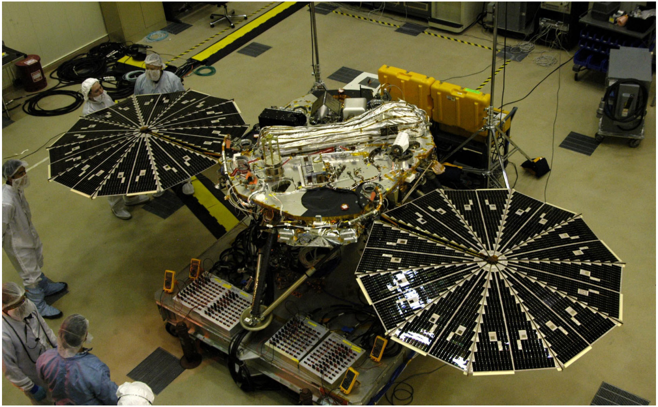
AI in space

2007 Phoenix Mars Lander (III)



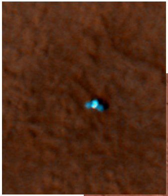
AI in space

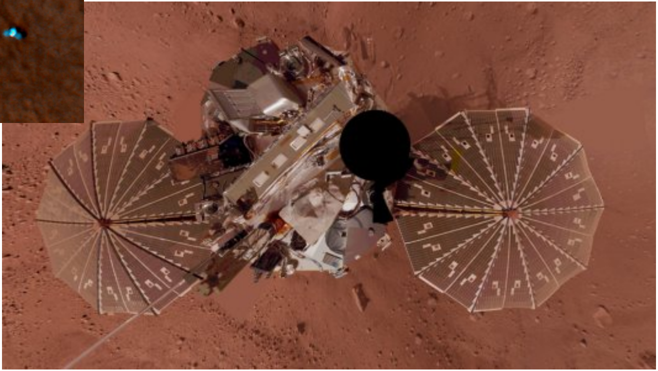
2007 Phoenix Mars Lander (IV)



AI in space

2007 Phoenix Mars Lander (V)

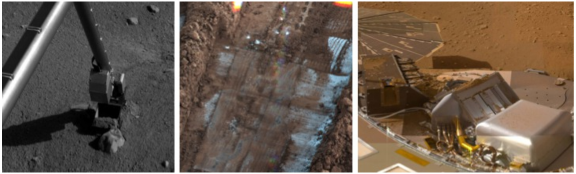




AI in space

2007 Phoenix Mars Lander (VI)

Phoenix achievements



- Observed and sampled water ice in the Martian arctic
- Studied the water cycle
  - Sublimation of ice, precipitation of ice crystals (snow)
  - Evidence that a liquid water film can form in the soil
- Studied chemical makeup of the soil
  - Salts that typically form in presence of liquid water
  - Perchlorates that could be an energy source for life

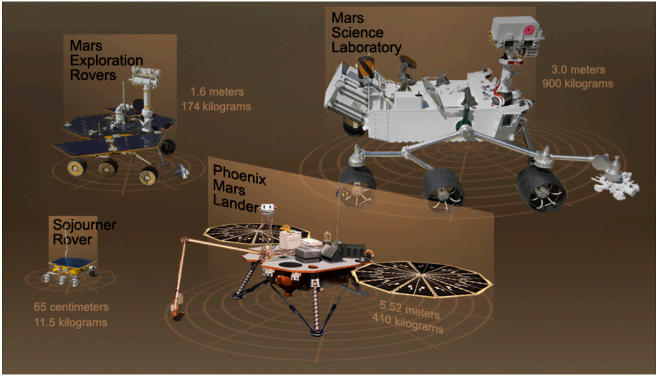
AI in space

2007 Phoenix Mars Lander (VII)

(Video)

AI in space

MSL (I)



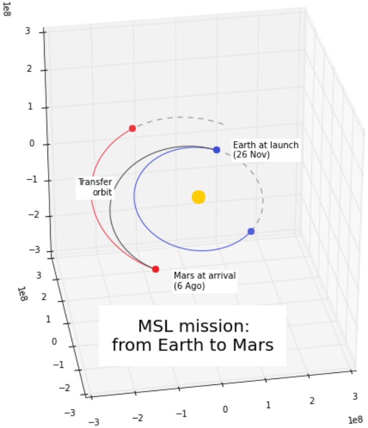
AI in space

MSL (II)

- Launch: Nov. 26, 2011
  - Inside Atlas V rocket
  - Cape Canaveral Air Force Station in Florida
- The spacecraft arrived at Mars in August 2012

AI in space

MSL (III)



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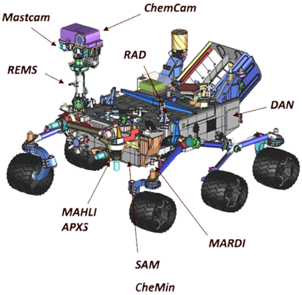
AI in space

MSL (IV)



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- Mast Camera (Mastcam)
- Chemistry & Camera (ChemCam)
- Alpha Particle X-ray Spectrometer (APXS)
- Mars Hand Lens Imager (MAHLI)
- Chemistry & Mineralogy (CheMin)
- Sample Analysis at Mars (SAM)
- Radiation Assessment Detector (RAD)
- Rover Environmental Monitoring Station (REMS)
- Dynamic Albedo of Neutrons (DAN)
- Mars Descent Imager (MARDI5)

AI in space

MSL (V)

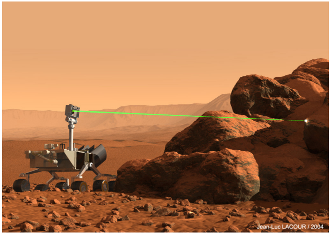
MSL goals (Primary mission 687 days)

- Assess potential habitat for life, past or present
- Assess biological potential...
- Characterize the geology of the landing region ...
- Investigate processes relevant to past habitability...
- Characterize surface radiation...

Instruments include

- Chemcam
- Variety of spectrometers
- Subsurface water detection

(Video MSL) (Video Landing Process MSL)



Collorary

AI addresses the automatic problems resolution